

Article

One-Leg Standing Test as a Practical Indicator of Frailty in Older Male Outpatients with Type 2 Diabetes Mellitus

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Abstract

Frailty is common among older adults with type 2 diabetes mellitus (T2DM). However, simple, objective, equipment-free screening tools for early frailty detection are limited. We evaluated the association between the objective one-leg standing test (OLST) and frailty in older male outpatients with T2DM and defined a clinically relevant OLST cut-off for frailty screening. Males aged ≥ 65 years with T2DM ($n = 335$) were included in this single-center, retrospective, cross-sectional study. Frailty was pre-categorized based on a Kihon Checklist (KCL) score ≥ 8 . The association of OLST time with frailty was assessed by logistic regression. The Youden Index was used to determine the optimal OLST time cut-off. Frailty was observed in 17.3% of the participants. The KCL-frail group exhibited a shorter OLST time than the KCL-non-frail group (median: 12.1 [7.4–30.6] vs. 45.8 [23.2–60.0] s; $p < 0.001$). Shorter OLST time was independently associated with frailty (odds ratio 0.955 per 1 s increase; 95% confidence interval 0.939–0.971; $p < 0.001$). The optimal cut-off for identifying frailty was 34.1 s (area under the curve: 0.768). The OLST is an objective, equipment-free physical performance test that may complement subjective frailty screening to identify frailty in an ambulant male population aged ≥ 65 years with T2DM.

Keywords: ambulant; Kihon Checklist; male; physical performance; routine screening



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1. Introduction

Frailty is a dynamic and potentially reversible clinical syndrome that represents an intermediate state between independence and disability. Frailty is common in the geriatric population (people aged ≥ 65 years) and is a significant predictor of adverse outcomes, including falls, hospitalization, disability, and mortality [1,2]. Individuals with type 2 diabetes mellitus (T2DM) are also a population in which frailty is particularly problematic because it progresses more rapidly as a result of interrelated factors, such as impaired glucose tolerance, insulin resistance or reduced insulin secretion, systemic inflammation, sarcopenia, and peripheral neuropathy [3,4]. A recent study showed that older adults with T2DM experience higher levels of pain and frailty, as well as a greater fear of falling, than those without T2DM [5]. Individuals with frailty and T2DM are more likely to experience complications during T2DM management, such as reduced treatment adherence and

impaired glucose regulation [6]. Therefore, preventing the development and progression of frailty in patients with T2DM may reciprocally improve T2DM management [7].

Early detection of frailty markers in individuals with T2DM is essential for mitigating functional decline and optimizing clinical outcomes [8–10]. According to the 2023 National Health and Nutrition Survey conducted in Japan, the proportion of individuals with T2DM increases with age, with 6.3% of men and 4.6% of women in their 40s, 11.1% of men and 6.2% of women in their 50s, 15.7% of men and 10.1% of women in their 60s, and 26.2% of men and 13.7% of women in their 70s affected [11]. According to these data, the rate of T2DM is notably higher among men than among women in Japan, particularly from their 50s onward. Based on the above evidence, it is clear that a link exists between older age, T2DM, and frailty, and the importance of early detection and intervention for frailty is becoming increasingly recognized in this high-risk population.

Early detection of frailty in older individuals with T2DM necessitates a multidimensional assessment approach that incorporates not only glycemic control but also nutritional status and physical function assessment [12,13]. Several scales and criteria exist for the assessment of frailty, including the Fried Frailty Phenotype [14], Frailty Index [15], Clinical Frailty Scale [16], and the Edmonton Frail Scale [17], among others [18]. However, there is no globally recognized gold standard, with every country having its own scale for national use [19]. The Kihon Checklist (KCL) is widely used in Japan as part of a national initiative for the early detection and prevention of long-term care dependency in community-dwelling older adults [20]. The KCL is a 25-item questionnaire that requires older individuals to answer “yes” or “no” to questions about their daily lives and health conditions. It is a screening tool that is commonly used and familiar in Japanese practice for the early identification of functional decline and helps to identify those at risk of requiring long-term care among community-dwelling older adults [21–23]. The KCL assesses physical, social, psychological, functional, and cognitive domains, which have been shown to predict incident dependency and mortality [24]. The total KCL score has been shown to strongly correlate with other validated frailty assessment tools [25]. However, the KCL relies on subjective responses; therefore, it may not accurately capture emerging deficits in physical function if these are not self-reported by the patients themselves [25]. Therefore, objective measures of physical function may provide a more comprehensive and accurate assessment [26]. Although multidimensional tools such as the KCL remain essential for frailty assessment, objective physical performance tests may provide complementary clinical information and may complement multidimensional frailty assessment by objectively evaluating physical function.

Older patients with T2DM often exhibit reduced muscle strength, reduced endurance, and impaired balance [27–29]—factors that are strongly associated with an increased risk of falls and diminished ability to perform activities of daily living. Moreover, in community-dwelling older adults, an independent relationship exists between leg skeletal muscle mass asymmetry and gait speed, a key indicator of physical function [30]. A study evaluating the physical activity behaviors and performance-based functional ability of community-dwelling older individuals showed that those classified as being at high risk of frailty were more likely to have poor balance, difficulty with mobility, decreased range of motion, poor unimanual dexterity, and difficulty performing activities of daily living than those classified as being at low risk of frailty [31].

Objective tools such as the Short Physical Performance Battery (SPPB) provide validated assessments of strength, gait, and balance [14,32]. However, although the SPPB is a well-established and comprehensive assessment tool, it includes multiple performance tasks, including balance, gait speed, and chair stand assessments. In settings where rapid and simple assessment is required, brief objective measures such as grip strength, one-leg

standing test (OLST), and the 30 s chair stand test (CS-30) may provide complementary clinical information. Therefore, simple objective physical performance tests that can be easily incorporated into routine clinical practice may complement multidimensional frailty assessment, including grip strength, OLST [33], and CS-30 [34].

The primary aim of this study was to investigate the association between multidimensional frailty, pre-categorized using the KCL, and objective measures of physical function (grip strength, OLST, and CS-30) in male patients aged ≥ 65 years with T2DM. As an exploratory secondary objective, we evaluated whether the physical performance measure most strongly associated with KCL-defined frailty could provide a practical screening threshold for identifying individuals who may benefit from further frailty assessment. We focused on older male outpatients with T2DM because T2DM prevalence is higher among older Japanese men than women, and this population represents a clinically relevant group for early frailty identification and intervention.

2. Materials and Methods

2.1. Study Design and Participants

This was a single-center, cross-sectional observational study based on routinely collected clinical assessment data that were extracted from medical records and analyzed. The study included male patients aged ≥ 65 years with T2DM who underwent their first comprehensive frailty assessment during routine outpatient follow-up at the lifestyle-related disease clinic between March 2021 and February 2025. The patients were also screened for comorbidities and medications that could substantially affect physical function, including balance. Of these, 57 patients were excluded because they required support or long-term care ($n = 30$), or had missing data ($n = 27$), resulting in a final analytic sample of 335 patients.

2.2. Ethical Considerations

This study was a non-invasive observational study using routinely collected clinical data obtained during routine outpatient care. Written informed consent for the research use of these clinical data was obtained from all participants at the time of their routine outpatient assessment. The study was approved by the institution's ethics committee (approval number: MJ-080) and was conducted in accordance with the principles outlined in the Declaration of Helsinki. The personal information extracted from the participants' medical records was strictly managed within the scope of the research objectives and was analyzed after anonymization.

2.3. Data Collection

All clinical and physical function assessments were performed on the same day as part of routine outpatient care. The data used in the present study were retrospectively extracted from the medical records for analysis.

2.3.1. Baseline Information

Baseline demographic and clinical information collected from the medical records included age, sex, height, weight, body mass index (BMI), presence of lifestyle-related diseases (ischemic heart disease, hypertension, and dyslipidemia), cohabitation status, and glycated hemoglobin (HbA1c) concentration.

2.3.2. Body Composition

Body composition was assessed using a multi-frequency bioelectrical impedance analyzer (InBody S10; InBody Japan Inc., Tokyo, Japan), which uses frequencies of 1, 5, 50, 250, 500, and 1000 kHz. The participants were seated, and measurements were obtained

using eight contact electrodes placed on the first and third fingers of both hands and the inner and outer sides of both heels. Skeletal muscle mass index (SMI) was calculated by dividing the appendicular skeletal muscle mass by height squared (kg/m^2).

2.3.3. Frailty

The participants were pre-categorized at recruitment as frail or non-frail by the lifestyle diseases clinic rather than as part of the study. The KCL is a binary self-administered questionnaire composed of 25 items covering seven domains: activities of daily living, physical function, nutritional status, oral function, social withdrawal, cognitive function, and depressive mood. The full list of questions is shown in Table S1 [20]. Each item was answered with a “yes” or “no” response, with 1 point assigned to each item indicating a problem. Higher total scores reflect greater functional decline. In this study, the total KCL score was used to categorize frailty [25]. It is important to note that the KCL assesses all aspects of frailty, so the study correlations were made between physical function (based on the OLST, grip strength, and CS-30) and frailty as a whole based on the KCL score, not with the specific KCL score for the physical function domain. Participants with a KCL score of 0–7 were classified into the KCL-non-frail group, while those with a score of ≥ 8 were classified into the KCL-frail group.

2.3.4. Exercise Habits

Exercise habits were assessed using the five-item Stage of Change for Exercise Behavior classification [35], which evaluates individuals’ past and present exercise behaviors and their readiness for behavior change. The participants were classified as having an exercise habit (stages 4 and 5) or no exercise habit (stages 1 to 3).

2.3.5. Self-Administered Questionnaire

The self-administered questionnaire consisted of two questions designed by the investigators to capture participants’ subjective perceptions of their physical fitness and exercise adequacy. To evaluate self-perceived physical fitness, the participants were asked, “Are you confident in your fitness?” with “yes” or “no” response options. To assess whether the participants felt they were getting enough exercise, they were asked, “Do you feel you are getting enough exercise?” with “yes” or “no” response options.

2.3.6. Physical Function

Physical function was assessed using three measures. The participants performed the OLST on a flat, hard floor while wearing shoes. The maximum duration was set to 60 s. The participants were instructed to lift one leg from a stationary standing position, place their hands on their waists, and keep their eyes open. The best of two trials per leg was averaged. The OLST method used in this study was based on that described in the Japan Sports Agency’s “New Physical Fitness Test” implementation guidelines [36].

Grip strength was measured using a grip dynamometer (Baseline[®] Hydraulic Hand Dynamometer; Fabrication Enterprises Inc., NY, USA). The participants were instructed to perform the test while sitting with their elbows flexed and testing each hand twice, totaling four trials. Among the four trials, the maximum value for each hand was identified, and the average of these two values was calculated.

For the CS-30, the participants began seated on a 40 cm-high chair with their legs shoulder-width apart and their arms crossed in front of their chests. The participants were then instructed to stand and sit repeatedly for 30 s with their arms crossed, and the number of complete or partial stands was recorded [37].

2.4. Statistical Methodology

Descriptive statistics for continuous variables are presented as the mean $\pm$ standard deviation when normally distributed or as the median (interquartile range) when non-normally distributed, as determined by the Shapiro–Wilk test. Categorical variables are expressed as frequency and percentage (%). Between-group comparisons were performed using the independent-samples *t*-test or the Mann–Whitney U test for continuous variables and Fisher’s exact test for categorical variables.

Univariable logistic regression analysis was conducted to assess the association between KCL-defined frailty (dependent variable) and each individual explanatory variable. Based on clinical relevance and previous evidence, age, HbA1c, SMI, OLST, grip strength, and CS-30 were selected a priori and entered simultaneously into the multivariable logistic regression model to examine their independent associations with KCL-defined frailty. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. Model performance and goodness-of-fit were evaluated using Nagelkerke R^2 , the omnibus test of model coefficients, and the Hosmer–Lemeshow test.

Receiver operating characteristic (ROC) curve analysis was performed as an exploratory secondary analysis to evaluate the potential clinical applicability of the OLST. A ROC curve was plotted, and the area under the ROC curve (AUC) was calculated. The cut-off value was determined using the Youden Index, which identifies the point that maximizes sensitivity and specificity.

All statistical analyses were performed using IBM SPSS Statistics for Windows, version 27 (IBM Japan, Inc., Tokyo, Japan). Statistical significance was set at $p < 0.05$.

3. Results

Overall, 335 community-dwelling older (aged ≥ 65 years) male outpatients with T2DM were included in the analysis. Of these, 277 (82.7%) were pre-categorized as KCL-non-frail and 58 (17.3%) as KCL-frail. The flowchart of participant selection is shown in Figure 1.

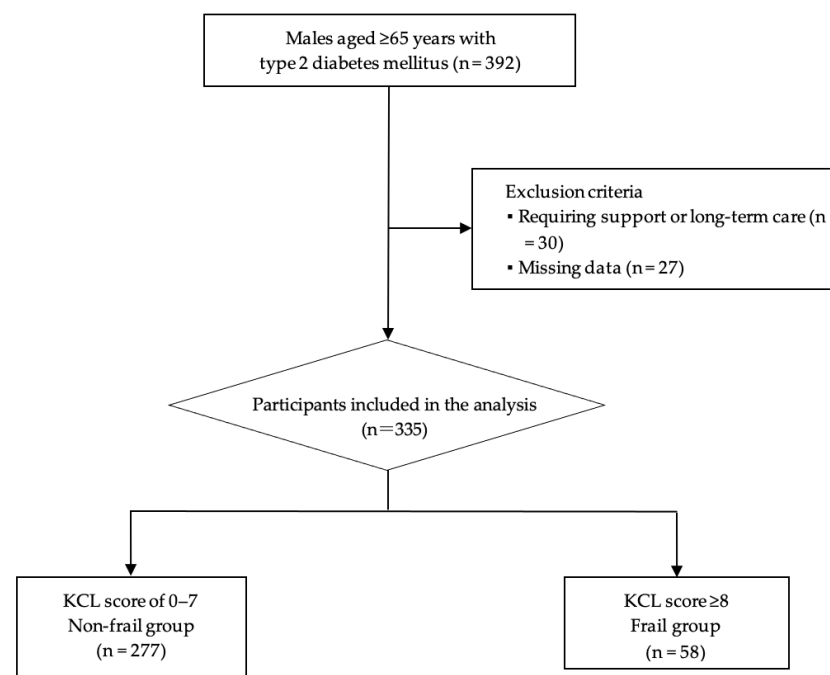


Figure 1. Flowchart of participant selection. KCL, Kihon Checklist.

Table 1 summarizes the baseline characteristics of the participants stratified by KCL-frailty status. Compared with the KCL-non-frail group, the KCL-frail group had significantly lower SMI ($7.3 [6.8\text{--}7.8]$ vs. $7.8 [7.2\text{--}8.3]$ kg/m^2 , $p = 0.002$), OLST time ($12.1 [7.4\text{--}30.6]$ vs. $45.8 [23.2\text{--}60.0]$ s, $p < 0.001$), grip strength (29.9 ± 6.0 vs. 33.6 ± 6.9 kg, $p < 0.001$), and CS-30 score ($15.5 [13.8\text{--}20.2]$ vs. $21.0 [17.0\text{--}25.0]$ repetitions, $p < 0.001$). Additionally, compared with the KCL-non-frail group, the KCL-frail group had a significantly lower proportion of participants with an exercise habit (37.9% vs. 62.5%, $p < 0.001$) and confidence in their physical fitness (32.8% vs. 74.0%, $p < 0.001$), and a higher proportion with an awareness of insufficient physical activity (86.2% vs. 60.3%, $p < 0.001$).

Table 1. Baseline characteristics of the participants stratified by frailty status.

Variables	Total	Non-Frail	Frail	<i>p</i> -Value
Participants	335 (100)	277 (82.7)	58 (17.3)	
Age (years)	75 (70–79)	75 (70–79)	76 (70–82)	0.172
Living alone	38 (11.3)	31 (11.2)	7 (12.1)	0.821
Blood tests				
Random blood glucose (mg/dL)	135 (113–169)	134 (113–166)	140 (112–174)	0.843
HbA1c (%)	7.0 (6.6–7.5)	6.9 (6.6–7.5)	7.0 (6.6–7.9)	0.224
Creatinine (mg/dL)	0.97 (0.83–1.14)	0.94 (0.82–1.13)	1.07 (0.94–1.19)	0.005
Total cholesterol (mg/dL)	180 (157–202)	182 (160–204)	162 (153–189)	0.111
LDL cholesterol (mg/dL)	91 (75–109)	91 (75–109)	87 (73–112)	0.543
HDL cholesterol (mg/dL)	55 (46–66)	56 (47–66)	51 (42–66)	0.223
Triglycerides (mg/dL)	132 (89–179)	133 (91–178)	115 (83–185)	0.483
Body composition				
Height (cm)	165.9 $\pm$ 5.9	165.7 $\pm$ 6.1	166.0 $\pm$ 5.8	0.738
Weight (kg)	66.3 (59.5–73.2)	66.4 (59.9–73.6)	65.3 (58.7–71.8)	0.541
BMI (kg/m^2)	24.2 (22.2–26.2)	24.3 (22.3–26.4)	23.5 (22.2–25.8)	0.495
SMI (kg/m^2)	7.7 (7.1–8.3)	7.8 (7.2–8.3)	7.3 (6.8–7.8)	0.002
Lifestyle-related diseases				
Ischemic heart disease	251 (74.9)	205 (74.0)	46 (79.3)	0.650
Hypertension	206 (61.5)	169 (61.0)	37 (63.8)	0.767
Dyslipidemia	213 (63.6)	174 (62.8)	39 (67.2)	0.522
Questionnaire Items				
Exercise habit	195 (58.2)	173 (62.5)	22 (37.9)	<0.001
Confidence in physical fitness	224 (66.9)	205 (74.0)	19 (32.8)	<0.001
Awareness of insufficient physical activity	210 (62.7)	160 (60.3)	50 (86.2)	<0.001

Table 1. *Cont.*

Variables	Total	Non-Frail	Frail	<i>p</i> -Value
Physical function				
OLST (s)	39.5 (14.9–60.0)	45.8 (23.2–60.0)	12.1 (7.4–30.6)	<0.001
Grip strength (kg)	33.0 ± 7.0	33.6 ± 6.9	29.9 ± 6.0	<0.001
CS-30 (repetitions)	20.0 (16.0–24.0)	21.0 (17.0–25.0)	15.5 (13.8–20.2)	<0.001

Data are presented as the median (interquartile range) or mean ± standard deviation for continuous variables and number (%) for categorical variables. Between-group comparisons were performed using the Mann–Whitney U test for continuous variables and Fisher’s exact test for categorical variables. “Exercise habit” was defined as being in stage 4 or 5 of the Exercise Behavior Change Stage Scale, indicating regular exercise behavior. “Confidence in physical fitness” and “Awareness of insufficient physical activity” were based on self-administered questionnaire items asking, “Are you confident in your fitness?” and “Do you feel you are getting enough exercise?”, respectively. BMI, body mass index; CS-30, 30 s chair stand test; HbA1c, glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; OLST, one-leg standing test; SMI, skeletal muscle mass index.

Univariable logistic regression analysis was performed to assess factors associated with KCL-defined frailty (Table 2). The multivariable logistic regression analysis was performed by simultaneously entering age, HbA1c, SMI, OLST time, handgrip strength, and CS-30 into the model. OLST time (odds ratio [OR] 0.960, 95% confidence interval [CI] 0.941–0.978, $p < 0.001$) and CS-30 (OR 0.922, 95% CI 0.858–0.991, $p = 0.028$) were independently associated with KCL-defined frailty, whereas handgrip strength was not (OR 0.996, 95% CI 0.941–1.054, $p = 0.878$) (Table 3).

Table 2. Univariable logistic regression analysis of the factors associated with frailty.

	β	SE	Wald	<i>p</i> -Value	OR	95% CI
Age	0.032	0.024	1.867	0.172	1.033	0.986–1.082
HbA1c	0.282	0.132	4.525	0.033	1.325	1.022–1.718
SMI	−0.461	0.187	6.084	0.014	0.631	0.438–0.910
Exercise habit	−1.001	0.298	11.314	0.001	0.367	0.205–0.658
Confidence in physical fitness	−1.765	0.312	32.120	<0.001	0.171	0.093–0.315
Awareness of insufficient physical activity	1.526	0.400	14.566	<0.001	4.599	2.101–10.069
OLST	−0.050	0.008	36.621	<0.001	0.952	0.936–0.967
Grip strength	−0.082	0.023	12.686	<0.001	0.922	0.881–0.964
CS-30	−0.157	0.031	25.020	<0.001	0.854	0.803–0.909

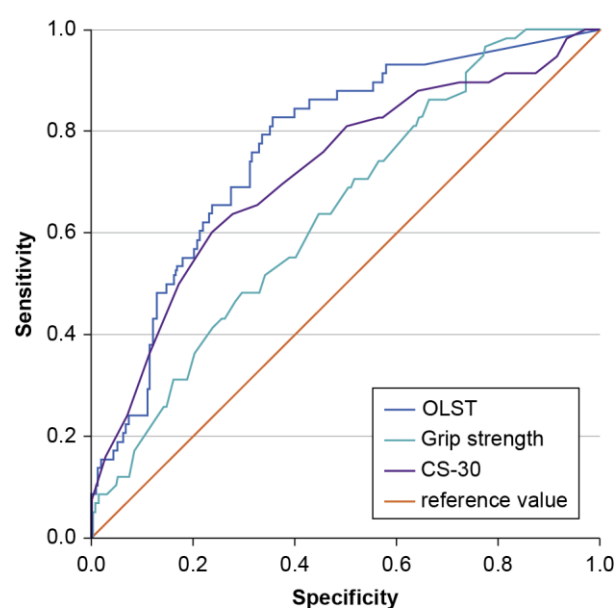
“Exercise habit,” “Confidence in physical fitness,” and “Awareness of insufficient physical activity” were derived from self-administered questionnaires. CI, confidence interval; CS-30, 30 s chair stand test; HbA1c, glycated hemoglobin; OLST, one-leg standing test; OR, odds ratio; SE, standard error; SMI, skeletal muscle mass index.

ROC curve analysis was performed to evaluate the discriminative ability of the OLST to identify KCL-frailty based on the optimal cut-off determined by the Youden Index (Figure 2). The optimal cut-off value was 34.1 s, yielding a sensitivity of 0.828 (95% CI 0.729–0.927) and a specificity of 0.645 (95% CI 0.590–0.702). The AUC was 0.768 (95% CI 0.704–0.833, $p < 0.001$; Table 4).

Table 3. Multivariable logistic regression analysis of the association between physical performance measures and KCL-defined frailty.

	OR	95% CI	p-Value
OLST	0.960	0.941–0.978	<0.001
Handgrip strength	0.996	0.941–1.054	0.878
CS-30	0.922	0.858–0.991	0.028
Age	0.980	0.925–1.039	0.504
HbA1c	1.236	0.920–1.661	0.160
SMI	0.815	0.543–1.224	0.324

The results of the multivariable logistic regression analysis adjusted for clinically relevant covariates are shown. OLST, one-leg standing test; CS-30, 30 s chair stand test; SMI, skeletal muscle index; CI, confidence interval; OR, odds ratio.



Variables	AUC (95% CI)	p-value
OLST	0.768 (0.704–0.833)	<0.001
Grip strength	0.642 (0.568–0.715)	0.001
CS-30	0.719 (0.642–0.795)	<0.001

Figure 2. ROC curves for OLST, grip strength, and CS-30 for identifying frailty. AUC, area under the curve; CI, confidence interval; CS-30, 30 s chair stand test; OLST, one-leg standing test; ROC, receiver operating characteristic.**Table 4.** ROC curve analysis of the OLST for identifying frailty.

	AUC	95% CI	p-Value	Cut-Off	Sensitivity	95% CI	Specificity	95% CI
OLST	0.768	0.704–0.833	<0.001	34.1	0.828	0.729–0.927	0.645	0.590–0.702

ROC curve analysis was conducted to evaluate the discriminative ability of the OLST to identify frailty. The optimal cut-off value was determined using the Youden Index. AUC, area under the curve; CI, confidence interval; OLST, one-leg standing test; ROC, receiver operating characteristic.

4. Discussion

This study examined the association between three simple objective physical performance measures and KCL-defined frailty in older male outpatients with T2DM. Among these measures, OLST was most strongly associated with frailty, and exploratory ROC

curve analysis suggested acceptable discriminative ability for identifying individuals who may warrant further frailty assessment. The OLST is a simple, objective test of balance that can be performed with minimal resource requirements in terms of training, space, and equipment. In a cohort of 335 older male outpatients with T2DM, the OLST time was independently associated with KCL-frailty, supporting its feasibility and potential clinical utility as a screening tool for frailty assessment.

In this study, 17.3% of the male outpatients with T2DM aged ≥ 65 years were pre-categorized as frail at recruitment based on the KCL. This prevalence sits somewhere in the middle of reported figures for the general older Japanese population, ranging from 1.9% among individuals aged 65–69 years to 35.1% among individuals aged ≥ 85 years [38]. Given the participants' demographic characteristics (males with T2DM and a median age of 75 years), this rate of frailty appears consistent with previous findings showing that T2DM increases frailty risk [3].

Physical performance measures, such as grip strength and lower limb function, are widely recognized indicators of frailty [14,39,40], and it has been shown that the response speed to grip strength decreases with frailty [41]. However, in our multivariable analysis, neither grip strength nor CS-30 score (as a measure of lower limb function) was independently associated with KCL-frailty. This may reflect the relatively well-preserved physical performance and strength of the population studied. For instance, the median CS-30 score was 20 repetitions, which exceeds normal values for Japanese adults aged 70–79 years [42]. Furthermore, 58.2% of the participants reported habitual exercise engagement, and HbA1c was well controlled, collectively suggesting well-preserved physical capacity [11].

Among the three simple objective physical performance measures evaluated (grip strength, CS-30, and OLST), OLST remained strongly associated with KCL-defined frailty after adjustment for clinically relevant covariates, although CS-30 was also independently associated, whereas grip strength was not. The OLST reflects balance ability and may provide complementary information regarding early functional decline beyond conventional strength measures [43]. The optimal OLST time cut-off value of 34.1 s was higher than previously reported thresholds in some studies. For instance, one study reported an OLST cut-off of 24–30 s based on the Japanese version of the Cardiovascular Health Study (J-CHS) criteria [33]. The optimal OLST time cut-off value of 34.1 s was higher than reported by some scholars. For instance, one study reported an OLST cut-off of 24–30 s based on the Japanese version of the Cardiovascular Health Study (J-CHS) criteria [33]. Several factors may explain the discrepancy in the findings. First, our study pre-categorized the participants as frail or non-frail at recruitment based on the KCL, a multidimensional tool that assesses physical, social, psychological, functional, and cognitive domains, rather than the J-CHS criteria, which focus more narrowly on physical frailty. The broader scope of the KCL may have meant that the participants in the present study met the criteria for frailty in domains other than the physical frailty domain, explaining their better performance in the OLST than individuals defined as frail based on the J-CHS. Indeed, our sample consisted of ambulant older male outpatients with T2DM and relatively good glycemic control, and their physical function was above average, as indicated by the CS-30 score [43]. The observation that the OLST was significantly associated with KCL-frailty may suggest that even in ambulatory individuals with seemingly good physical function, impairments in balance, as measured by the OLST, may be an early sign of impending physical frailty.

The 34.1 s OLST cut-off was lower than population-based normal values in healthy older adults (e.g., approximately 58–75 s in men aged 70–79 years) reported by other scholars [44], and it provided a meaningful threshold for identifying potential preclinical decline within our population of older males with T2DM. The relatively high sensitivity (0.828) suggests that this cut-off may be useful for identifying individuals who warrant

further frailty assessment; however, the moderate AUC (0.768) and specificity (0.645) indicate that OLST alone may be suitable for triage/screening, but it is not yet sufficient as a standalone diagnostic test, as false-positive results may occur (approximately 35% of KCL-non-frail participants would be classified as screen-positive, necessitating further assessment). Therefore, the 34.1 s OLST cut-off should be interpreted as hypothesis-generating and should be externally validated before clinical implementation. Furthermore, it has been shown that the OLST improves with practice, and standing on one leg is recommended as an exercise skill to improve balance and potentially mitigate fall risk and injury [45–47], adding appeal to its use in preventive care.

Importantly, the OLST may offer physiological advantages over strength-based assessments in the population with T2DM. Diabetic peripheral neuropathy (DPN) is a common complication of T2DM. More than 90% of Japanese patients with T2DM show electrophysiological evidence of DPN, even without symptoms [48]. DPN can impair sensory function and postural control, even before measurable declines in muscle mass or strength [49]. Early-stage DPN impairs postural control through diminished sensory input from the feet and ankles [50], which compromises the use of the ankle in balance control [51]. Balance impairments may therefore emerge earlier than reductions in grip strength and lower limb power or function. Given that the OLST strongly relies on ankle strategy activation [52], it may serve as an indirect marker of subclinical DPN-related imbalance. Furthermore, reduced ankle mobility in individuals with frailty may exacerbate postural instability [53], reinforcing the clinical utility of the OLST for early detection.

Another emerging metabolic marker relevant to frailty is the stress hyperglycemia ratio (SHR), which expresses acute plasma glucose relative to chronic glycemic exposure estimated from HbA1c [54]. Recent work on frail older adults with heart failure with preserved ejection fraction (HFpEF) reported that $\text{SHR} > 1$ was independently associated with poorer physical function, assessed by gait speed, suggesting that stress-related dysglycemia may reflect impaired glycemic resilience, metabolic vulnerability, and frailty severity [55]. Related work has also proposed an immunometabolic pathway linking stress hyperglycemia to cognitive decline in HFpEF through natural killer T-cell activation and inflammation [56]. Although these findings are highly relevant to frailty research, the present study differed in design and population; our cohort consisted of stable older male outpatients with T2DM undergoing routine frailty assessment rather than acutely admitted patients with HFpEF. Therefore, SHR was not included in the analysis. Nonetheless, our findings and the emerging SHR literature are complementary, and future studies should evaluate whether combining SHR with simple physical performance measures, such as the OLST, improves the early identification of frailty progression, falls, hospitalization, or cognitive decline in older adults with T2DM.

Overall, by capturing subtle changes in stability and proprioception, the OLST may serve as a sensitive and clinically relevant indicator of early frailty in patients with T2DM, particularly those with preserved muscle strength with emerging balance deficits. As a practical, quick, low-cost, and widely available test, the OLST may complement multidimensional frailty assessment [57] in older male outpatients with T2DM. Compared with more complex objective assessments, such as the SPPB, the OLST may offer advantages in routine outpatient or community settings, given its minimal spatial and equipment requirements, enabling it to be easily integrated into routine clinical workflows. As a time-efficient and scalable assessment tool, the OLST may facilitate early identification of individuals who would benefit from further multidimensional frailty assessment and timely preventive interventions.

4.1. Strengths

This study has several important strengths. First, the sample size of 335 participants provided adequate statistical power to detect associations between objective physical performance measures and KCL-defined frailty. Moreover, the use of strict participant selection criteria, excluding individuals requiring long-term care or with incomplete data, enhanced the internal validity of the analysis. Second, the study used three established performance-based measures (OLST, grip strength, and CS-30), allowing comprehensive characterization of functional domains, including balance, strength, and endurance, while enabling comparative interpretation of their associations. Third, frailty was pre-categorized according to the KCL, a 25-item instrument widely adopted in Japan for community-based frailty screening [20]. The KCL includes physical, social, psychological, functional, and cognitive domains and is not solely limited to physical frailty; however, it is widely used in Japan as a validated and practical screening tool for overall frailty [58], justifying its use for frailty pre-categorization. Its validity and integration into public health infrastructure enhance the generalizability of the findings within similar aging populations [25]. Although the KCL incorporates several frailty domains, physical decline is often the sentinel marker and clinical entry point to broader multidimensional frailty [59], and several studies have shown that physical performance tests predict multidimensional adverse outcomes in older adults, including falls, hospitalization, and mortality [60–63], justifying the use of physical performance tests, such as the SPPB, grip strength, and the OLST, as objective assessment tools in this study. Fourth, we identified a clinically relevant OLST cut-off. The cut-off value of 34.1 s yielded high sensitivity and moderate specificity, contributing practical value by defining an actionable threshold that can inform screening protocols in this population. Fifth, although previous studies have emphasized grip strength and chair-stand performance as indicators of frailty, this study demonstrated that OLST remained strongly associated with KCL-defined frailty after adjustment for clinically relevant covariates. This distinction is clinically meaningful, particularly in individuals with T2DM, because balance impairment may represent an important component of early functional decline beyond reductions in muscle strength [50]. Finally, the OLST is straightforward, and its scoring is objective, negating intra- and inter-rater variation if performed correctly according to protocol. A study reported optimal reliability (intraclass correlation coefficient > 0.90) with acceptable measurement error (<10%) for common clinical standing balance tests [64]. Moreover, the OLST requires no specialized equipment or time-consuming setup, making it highly feasible for use in routine outpatient care, T2DM management programs, and community health assessments where time and space may be limited. The OLST is positioned as a rapid triage tool, complementing more comprehensive assessment.

4.2. Limitations

This study has several potential limitations that should be acknowledged. First, the KCL was used to pre-categorize patients as frail or non-frail [21–23,58]. Frailty based on the KCL refers to a more global concept of overall frailty, not just physical frailty. Nevertheless, studies have shown that comprehensive multimodal KCL scores correlate with physical frailty [39]. The KCL was simply used as a convenient tool to screen for frailty and enable pre-categorization at recruitment. The study associations were made between the physical tests and frailty, not with KCL scores. However, because the total KCL score includes multiple domains beyond physical function, some misclassification of physical frailty status is possible, which should be considered when interpreting the findings. Second, the high 34.1 s OLST time cut-off suggests a relatively well-functioning cohort. The observation that grip strength was not independently associated with overall frailty, as categorized by the KCL, may suggest that some participants classified as frail

by the KCL had relatively preserved muscle strength but were identified based on other non-physical domains. Even though the population may have appeared physically healthy, balance impairment may represent an important component of early functional decline in this population [49,51,52], supporting the potential utility of the OLST as an early indicator of functional decline. Third, the cross-sectional design means that causal relationships between OLST performance and KCL-frailty status could not be established. Therefore, whether reduced OLST performance contributes to frailty or represents a consequence of frailty remains unclear. Longitudinal studies will be needed to clarify the temporal relationship between OLST performance and frailty progression and to determine whether changes in OLST performance are associated with future frailty-related outcomes, such as falls or hospitalizations. Fourth, the sample consisted exclusively of older male outpatients who were ambulant and physically capable of visiting a lifestyle-related disease clinic. This restricts the generalizability of the findings to the study population and excludes women, younger individuals, individuals with more advanced frailty or T2DM, or those with greater functional impairment. Fifth, the participants exhibited relatively well-controlled glycemic profiles, which may have attenuated the observed associations between metabolic dysfunction and frailty. Moreover, exercise habits and perceived physical fitness were assessed via patient self-reporting, which is subject to recall and response biases. In future research, objective activity monitoring may provide more accurate insights. Sixth, this was a cut-off point analysis rather than a diagnostic test validation. The study aimed to propose a feasible screening threshold rather than establishing diagnostic accuracy. Furthermore, the proposed OLST cut-off was derived and evaluated within the same cohort and has not yet been externally validated. Moreover, internal validation methods, such as bootstrapping, were not performed. Therefore, the generalizability of this threshold should be confirmed in independent cohorts before widespread clinical application. Moreover, we did not explore whether combining the OLST with other simple physical performance measures could improve its discriminative ability because the aim of this study was to evaluate the OLST as a single, simple, and practical objective assessment rather than to develop a battery of physical performance tests. Finally, several factors that may influence balance performance, including visual impairment [65], vestibular dysfunction [66], postural abnormalities [66], lower limb deformities [67], and DPN [27], were not specifically assessed. Therefore, their potential influence on OLST performance cannot be excluded.

4.3. Future Directions

In light of these limitations, future research should aim to validate the diagnostic and prognostic utility of the OLST and determine appropriate population-specific cut-offs in broader T2DM populations, including women, individuals with poorly controlled T2DM, and individuals at different stages of frailty. The identified cut-off in the present population should also be validated in an independent cohort to confirm its robustness. Longitudinal studies are warranted to clarify whether the decline in OLST time precedes frailty progression, falls, or other adverse outcomes. Furthermore, interventional trials targeting balance, particularly among individuals with low OLST time despite preserved muscle strength, are needed to determine whether improving balance can delay or prevent frailty development.

5. Conclusions

This study demonstrated the feasibility of the OLST as a simple, objective, rapid, equipment-free test for the early detection of frailty among older (≥ 65 years) male outpatients with T2DM. The simplicity of the OLST makes it ideal for screening at routine checkups. The OLST may address a critical implementation gap regarding feasible, real-

world objective methods of frailty detection in aging diabetic populations. The OLST outperformed traditional strength-based measures, likely reflecting the early influence of diabetic sensory impairment on balance and postural control. The identification of a clinically actionable cut-off (34.1 s) enhances the translational relevance of the study and supports the integration of the OLST into routine outpatient assessment, particularly in contexts where time and resources are constrained. The ability to use a simple physical performance test to identify frailty in an ambulant older population would be of great value in geriatric health screening, with the view of pre-empting, mitigating, or even reversing it.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/jgg74030026/s1>, Table S1: Kihon Checklist questions.

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Abbreviations

The following abbreviations are used in this manuscript:

AUC	Area under the curve
BMI	Body mass index
CI	Confidence interval
CS-30	30 s chair stand test
DPN	Diabetic peripheral neuropathy
HbA1c	Glycated hemoglobin
HFpEF	Heart failure with preserved ejection fraction
J-CHS	Japanese version of the Cardiovascular Health Study
KCL	Kihon Checklist
OLST	One-leg standing test
OR	Odds ratio
ROC	Receiver operating characteristic
SE	Standard error
SHR	Stress hyperglycemia ratio
SMI	Skeletal muscle mass index
SPPB	Short Physical Performance Battery
T2DM	Type 2 diabetes mellitus

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