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ORIGINAL ARTICLE

A novel upper-extremity-based performance test for sarcopenia: reliability and clinical utility of the elbow performance test

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Abstract

Background Given the limitations of gait speed tests for sarcopenia assessment, this study evaluated the Elbow Performance Test (EPT), a simple upper-extremity alternative.

Aims This study aimed to evaluate the test-retest reliability of the EPT and its ability to distinguish between older adults with sarcopenia and healthy young controls.

Methods This cross-sectional study included 96 male participants: 43 older adults with sarcopenia (≥60 years) and 53 healthy young controls (≤40 years). Assessments covered muscle strength, mass, and physical performance, including 4-meter gait speed, the Short Physical Performance Battery (SPPB), and Timed Up and Go (TUG). The EPT required 30 self-paced elbow flexion-extension repetitions with a 1-kg weight. Test-retest reliability was assessed after 7–10 days using intraclass correlation coefficients (ICCs).

Results All performance test scores differed significantly between the sarcopenia and control groups ($p < 0.01$). The EPT showed excellent test–retest reliability in both the control (ICC = 0.932; 95% CI:0.885–0.960) and sarcopenia (ICC = 0.905; 95% CI:0.831–0.947) groups. In terms of reliability, the EPT outperformed gait speed and SPPB in both groups and was comparable to the TUG test in the sarcopenic group.

Conclusions The EPT demonstrated excellent reliability and effectively distinguished between older adults with sarcopenia and healthy controls. Given its simplicity, high repeatability, and minimal equipment needs, the EPT may serve as a practical tool for assessing upper-extremity muscle performance, particularly in settings where traditional lower-extremity-based tests are less feasible. Further studies are warranted to confirm its broader clinical utility across diverse populations.

Clinical trial registration This trial was retrospectively registered at ClinicalTrials.gov (Identifier: NCT07065448) on July 03, 2025.

Keywords Sarcopenia · Muscle strength · Reproducibility of results · Physical endurance · Aging

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Introduction

Sarcopenia, first defined by Rosenberg in 1988, is a progressive and widespread skeletal muscle disorder characterized by age-related declines in muscle mass and strength [1]. According to the updated definition by the European Working Group on Sarcopenia in Older People (EWGSOP), reduced muscle strength is the key diagnostic criterion, and the condition is associated with increased risks of falls, fractures, disability, and even mortality [2]. Although more prevalent in older adults, sarcopenia can also affect younger individuals. Its reported prevalence varies depending on the diagnostic criteria, ranging from 8% to 36% in adults under 60, and from 10% to 27% in those aged 60 and above [3].

Sarcopenia has been strongly associated with higher morbidity and mortality rates, as it significantly reduces quality of life and imposes substantial economic burdens due to increased hospital admissions and prolonged hospital stays. While the condition may be partially reversible in its early stages, advanced sarcopenia—especially when accompanied by comorbidities—poses greater management challenges. This underscores the critical importance of early diagnosis and timely intervention [4]. Preventive and therapeutic strategies such as promoting physical activity, optimizing nutritional intake, managing body weight, and addressing comorbid conditions are essential for halting or slowing disease progression.

Diagnosis typically follows a stepwise protocol, beginning with the SARC-F questionnaire to identify individuals at risk, followed by objective assessments of muscle strength and mass. Muscle mass is commonly measured using bioelectrical impedance analysis (BIA) or dual-energy X-ray absorptiometry (DXA). To determine disease severity and monitor clinical progression, several physical performance tests are employed, including the 4-meter gait speed test, Short Physical Performance Battery (SPPB), Timed Up and Go (TUG) test, and the 400-meter walk test [2].

These performance tests are central to clinical decision-making in sarcopenia. However, most rely heavily on lower-extremity function and may not adequately account for the impact of common comorbidities in older adults—such as cardiopulmonary disease or degenerative joint conditions—that can confound test outcomes. The 4-meter gait speed test, in particular, though easy to administer, is especially vulnerable to such confounding influences, potentially compromising the reliability of results [5, 6].

To overcome these limitations, performance assessments targeting more localized muscle groups—such as the elbow flexors—may offer a more accurate reflection of sarcopenia-related reductions in muscle endurance, as they are less likely to be affected by systemic comorbidities. Therefore, the development of simple, reliable, and reproducible alternative performance tests is warranted.

The present study aimed to evaluate the test–retest reliability of the Elbow Performance Test (EPT) and to explore its potential advantages over traditional lower-extremity-based assessments in the clinical evaluation of sarcopenia.

Methods

Participants

A total of 96 male participants were enrolled in the study, comprising 43 patients diagnosed with sarcopenia (mean age: 75.3 ± 5.5 years) and 53 healthy young controls (mean age: 28.7 ± 3.8 years), all of whom met the predefined inclusion and exclusion criteria. The main features of both groups are summarized in Table 1. All participants underwent SARC-F screening [7]. The diagnosis of sarcopenia was made in accordance with the EWGSOP2 criteria, which define the condition as the presence of low muscle strength along with either reduced muscle mass or impaired muscle quality.

Inclusion criteria for the sarcopenia group were male sex, age ≥ 60 years, and fulfillment of the EWGSOP2 diagnostic criteria. For the healthy control group, participants were required to be male, aged ≤ 40 years, and to have a SARC-F score of less than 4.

Exclusion criteria for both groups included: inability to provide informed consent or comply with study procedures; acute medical conditions compromising general health; chronic decompensated cardiac, renal, or hepatic failure; diagnosed rheumatologic, psychiatric, or neurological disorders; and current use of performance-enhancing or fatigue-reducing medications.

All study procedures were explained in detail prior to participation, and written informed consent was obtained from each participant in accordance with the Declaration of Helsinki. The study was approved by the institutional ethics committee (Approval No: 2024-49).

Procedures

All participants underwent handgrip strength and muscle mass measurements, along with the standard performance tests endorsed by EWGSOP2, including the 4-meter gait

Table 1 Demographic, anthropometric, muscle strength, and muscle mass data of the groups

	Control group ($n=53$)	Sarcopenia group ($n=43$)	p-value
Age (years)	28.7 ± 3.8	75.3 ± 5.5	0.001[t]
Height (m)	1.8 ± 0.1	1.7 ± 0.1	< 0.001[u]
Weight (kg)	80.8 ± 12.7	70.3 ± 11.4	< 0.001[u]
BMI (kg/m²)	25.4 ± 3.7	24.0 ± 3.5	0.563[t]
Handgrip strength (kgf)	51.2 ± 9.4	21.3 ± 3.3	< 0.001[u]
Total muscle mass (kg)	37.3 ± 4.2	25.8 ± 3.6	< 0.001[u]
Appendicular muscle mass (kg)	29.0 ± 3.1	17.2 ± 2.4	< 0.001[t]
ASM/SMM (%)	77.8 ± 2.6	66.7 ± 4.1	< 0.001[t]
ASM/BMI (kg/m²)	1.2 ± 0.1	0.7 ± 0.2	< 0.001[u]
ASM/Height² (kg/m²)	9.1 ± 0.8	5.9 ± 0.7	< 0.001[u]

Data are presented as mean ± standard deviation

[t]Independent samples t-test; [u]Mann–Whitney U test

ASM: Appendicular Skeletal Muscle; SMM: Skeletal Muscle Mass; BMI: Body Mass Index

speed test, the Short Physical Performance Battery (SPPB), and the Timed Up and Go (TUG) test. In addition, the Elbow Performance Test (EPT), which is the focus of the present study, was also administered. To assess test–retest reliability, all performance tests were repeated within 7 to 10 days following the initial session.

Muscle strength assessment

Muscle strength was evaluated using a digital hand dynamometer (Digital Hand Dynamometer 200 LB, Sammons Preston Rolyan, USA). Participants were seated on a chair with back support, with the elbow flexed at 90°, and the wrist and shoulder in a neutral position. Each participant was instructed to perform three maximum voluntary contractions, each lasting five seconds, with five-second intervals in between. The highest value, measured in kilogram-force (kgf), was recorded. A trial test was conducted beforehand to familiarize participants with the procedure.

Muscle mass assessment

Muscle mass was assessed using a TANITA BC-418 device (Tokyo, Japan) after an overnight fast of at least 8 h. Total appendicular skeletal muscle mass (ASM) and total skeletal muscle mass (SMM) were recorded. These values were normalized to both height squared and body mass index (BMI), and the results were reported in kg/m^2.

Performance tests

For the 4-meter gait speed test, participants wore their usual footwear and were instructed to walk at a comfortable pace along a flat, hard surface over a marked 4-meter path. To account for acceleration and deceleration, an additional 1 m was included before the start line and after the finish line, resulting in a total walking distance of 6 m. The time taken to traverse only the central 4-meter segment was recorded using a stopwatch, and gait speed was calculated in meters per second [8].

The SPPB evaluates standing balance, 4-meter walking speed, and the time required to complete five chair stands. Each subtest is scored from 0 to 4, with a total score ranging from 0 to 12. Higher scores indicate better physical performance [9].

For the TUG test, participants wore their usual footwear and began in a seated position. Upon the therapist's command, they stood up, walked 3 m, turned around, walked back to the chair, and sat down. The total time to complete the task was recorded in seconds using a stopwatch [10].

Elbow performance test

The Elbow Performance Test (EPT) was developed by the authors to assess upper extremity muscle performance and evaluate sarcopenia severity. Participants were seated on a height-adjustable chair, with the dominant-side elbow positioned comfortably on the chair's armrest. To eliminate the contribution of wrist flexor muscles, a 1-kg sandbag was fixed to the distal forearm as a resistance load. The starting position was full elbow flexion. Participants were asked to perform 30 consecutive repetitions of full elbow extension and flexion through the full range of motion at a self-selected pace. The total time to complete all repetitions was recorded using a stopwatch. The fixed load (1 kg) and repetition count (30) were selected to safely assess muscular endurance in older adults.

Statistical analysis

The normality of data distribution was assessed using the Kolmogorov–Smirnov test with Lilliefors correction. Quantitative variables were summarized as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Between-group comparisons were performed using the independent samples t-test for normally distributed data, and the Mann–Whitney U test for non-normally distributed data. A p-value < 0.05 was considered statistically significant.

To evaluate the reliability of the performance tests, intraclass correlation coefficients (ICC) were calculated using a two-way mixed-effects model based on absolute agreement and single measurements. ICC values were reported with 95% confidence intervals and interpreted as follows: <0.5 = poor, 0.5–0.75 = moderate, 0.75–0.90 = good, >0.90 = excellent reliability. Statistical analyses were conducted using PASW Statistics for Windows, Version 18.0 (SPSS Inc., Armonk, NY, USA).

Results

Statistically significant differences were observed between the sarcopenia and control groups in all performance tests (Table 2).

Test–retest reliability analysis in the healthy young adult group demonstrated that the Elbow Performance Test (EPT) had "excellent" reliability, with an ICC of 0.932 (95% CI: 0.885–0.960) (Fig. 1). When considering the confidence intervals, the EPT outperformed the other performance tests in terms of reliability (Table 3).

Table 2 Comparison of performance test results between groups across two separate sessions

	Control group ($n=53$)	Sarcopenia group ($n=43$)	p-value
Elbow Performance Test – Trial 1 (s)	49.36 ± 7.72	53.93 ± 6.33	0.002[t]
Elbow Performance Test – Trial 2 (s)	49.23 ± 7.11	53.73 ± 5.81	0.001[u]
4-meter Gait Speed – Trial 1 (m/s)	1.14 ± 0.13	0.82 ± 0.17	< 0.001[t]
4-meter Gait Speed – Trial 2 (m/s)	1.15 ± 0.14	0.86 ± 0.20	< 0.001[t]
SPPB Score – Trial 1	10.58 ± 1.06	8.35 ± 1.21	< 0.001[u]
SPPB Score – Trial 2	10.72 ± 0.91	8.44 ± 1.05	< 0.001[u]
Timed Up and Go – Trial 1 (s)	8.32 ± 1.15	14.40 ± 2.49	< 0.001[u]
Timed Up and Go – Trial 2 (s)	8.47 ± 1.09	14.27 ± 2.69	< 0.001[u]

Data are presented as mean ± standard deviation

[t]Independent samples t-test; [u]Mann–Whitney U test

Table 3 Intraclass correlation coefficients (ICCs) for performance tests in the control group

Performance test	ICC	95% confidence interval		p-value
		Lower bound	Upper bound	
4-meter Gait Speed	0.370			0.003
SPPB	0.798	0.675	0.878	< 0.001
TUG	0.773	0.637	0.862	< 0.001
EPT	0.932	0.885	0.960	< 0.001

SPPB: Short Physical Performance Battery, TUG: Timed Up and Go, EPT: Elbow Performance Test

Table 4 Intraclass correlation coefficients (ICCs) for performance tests in the sarcopenic group

Performance test	ICC	95% confidence interval		p-value
		Lower bound	Upper bound	
4-meter Gait Speed	0.679	0.477	0.812	< 0.001
SPPB	0.120	-0.190	0.406	0.224
TUG	0.908	0.837	0.949	< 0.001
EPT	0.905	0.831	0.947	< 0.001

SPPB: Short Physical Performance Battery, TUG: Timed Up and Go, EPT: Elbow Performance Test

In the sarcopenic older adult group, the EPT also showed "excellent" reliability, with an ICC of 0.905 (95% CI: 0.831–0.947) (Fig. 1). Based on the confidence intervals, the EPT demonstrated superior reliability compared to the 4-meter gait speed and Short Physical Performance Battery (SPPB), while showing comparable reliability to the Timed Up and Go (TUG) test (Table 4).

Discussion

This study aimed to evaluate the reliability of the Elbow Performance Test (EPT), a novel upper-extremity-focused approach for assessing the severity of sarcopenia, and to compare it with conventional assessment tools. Traditional lower-extremity-based tests (e.g., gait speed, balance) are

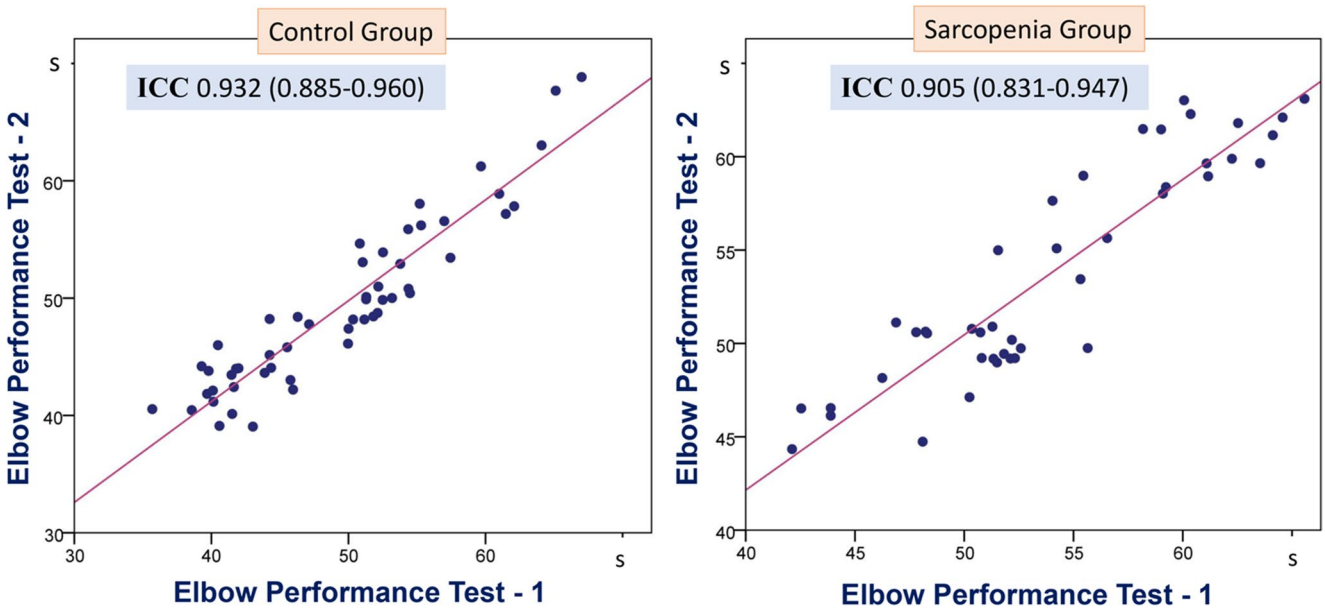

Fig. 1 The correlation between the two Elbow Performance Test trials is shown. The dashed line represents the linear regression line for the data. The individual data points are distributed within a relatively narrow range around the line, indicating strong agreement. Reliability was found to be excellent (> 0.90) in both groups

known to have limitations in older adults with comorbidities due to the involvement of multiple physiological systems [5, 11]. The EPT may offer a more isolated assessment of muscle function and thus holds potential to address some of these limitations. Our findings suggest that the EPT demonstrates high test–retest reliability (ICC≈0.90) and reveals significant performance differences between distinct participant groups (i.e., healthy young adults and individuals with sarcopenia). The relatively low within-subject variability across repeated measurements further supports its utility as a standardized tool that may be less influenced by systemic factors.

Age-related declines in upper extremity muscle volume and strength are likely accompanied by greater responsiveness to physiological changes, indicating that these muscles may be particularly sensitive to the effects of aging. Previous studies have shown significant reductions in upper limb muscle mass and strength among older adults, along with a positive correlation between muscle volume and strength, and a negative association between strength and both motor speed and reaction time [12, 13]. These findings suggest that age-related structural and functional changes in upper extremity musculature can be objectively assessed. The EPT, which is based on isotonic endurance, reflects dynamic movements frequently used in daily life and offers the advantage of assessing muscular endurance in relative isolation from external factors such as cognitive load and balance. In this study, the EPT was found to be safe and feasible across individuals of varying ages and functional capacities. Moreover, the significant differences observed in repetition speed between groups support the potential of the test to capture performance impairments associated with sarcopenia.

Loss of muscle fibers typically begins around the age of 50, reaching approximately 10–20% by the seventh decade and exceeding 20% by the eighth decade of life. This decline is particularly associated with reductions in type II muscle fibers and the number of motor units, leading to marked decreases in muscle strength, contraction speed, and fatigue tolerance [14–17]. Dalton et al. [18]. reported that older adults exhibit more rapid fatigue during isotonic and repetitive tasks compared to younger individuals. The structure of the EPT, which reflects these age-related physiological deteriorations, makes it a potentially sensitive tool for assessing sarcopenia.

One of the comparable tests used to assess upper extremity muscular endurance, the Arm Curl Test, has demonstrated high test–retest reliability in healthy older adults (ICC = 0.88) [19]. In the present study, the EPT similarly showed high reliability across repeated trials (ICC = 0.90). Although the weights recommended for the Arm Curl Test (2.3–3.6 kg) are generally based on healthy populations [20], a fixed 1 kg load was selected in the current study to ensure safe administration, measurement standardization, and comparability in individuals with sarcopenia.

Isotonic muscular endurance is considered a more comprehensive indicator of performance than instantaneous strength, as it reflects the capacity to sustain repeated movements over time. It has been reported that in older adults, the age-related decline in contraction speed becomes particularly evident at higher repetition counts, reaching a measurable level around 30 repetitions [21, 22]. In line with these findings, the EPT aims to objectively assess upper extremity motor endurance and performance tempo by measuring the total duration and repetition speed during 30 consecutive movements performed under a constant load.

Gait speed tests are commonly used to assess the severity of sarcopenia; however, the literature indicates that these tests are associated with several limitations. In particular, short-distance walking tests may be affected by deviations from individuals' natural walking speed, as well as by the disproportionate influence of acceleration and deceleration phases on the measurement. Additionally, their test–retest reliability has been reported to be relatively low (ICC = 0.406) [23–25]. While long-distance walking tests are thought to provide more consistent measurements, their applicability may be limited in older adults and individuals with comorbidities due to concerns such as fatigue, cardiovascular strain, and fall risk [26, 27]. Collectively, these findings suggest that standardizing gait tests is challenging and that they may not be equally applicable to all individuals. In this context, the EPT emerges as a promising alternative, offering advantages such as reduced susceptibility to systemic influences, short administration time, and minimal equipment requirements. In resource-limited outpatient settings or for follow-up assessments in community-dwelling older adults, EPT may offer a feasible alternative, enabling efficient, accessible, and standardized evaluation of muscle performance.

Multicomponent tests such as the TUG and the SPPB involve tasks such as standing up, walking, turning, and sitting down, and therefore may be influenced not only by muscle strength but also by balance, cognitive function, and vestibular system integrity [28, 29]. This multifactorial nature may limit the ability of these tests to accurately and consistently assess sarcopenia-related changes in muscle performance. In our study, although TUG and SPPB demonstrated acceptable levels of test–retest reliability in the healthy young adult control group, the EPT showed excellent reliability, with ICC values exceeding 0.90 in both the healthy young adult group (ICC = 0.932 [0.885–0.960]) and the older sarcopenic group (ICC = 0.905 [0.831–0.947]). These findings highlight the EPT as a more isolated and standardized tool for evaluating muscle performance with minimal influence from other physiological systems in the context of sarcopenia.

This study has several limitations. First, assessments were conducted only on the dominant upper extremity; bilateral testing may provide additional insight into inter-limb differences. Second, the sample consisted exclusively of male participants, which may limit the generalizability of the findings to female populations. Future studies involving female participants and longitudinal validation across clinical populations would be valuable to determine the broader applicability and predictive utility of the EPT across diverse aging populations.

Conclusion

In conclusion, the EPT has the potential to serve as a useful and innovative tool for assessing the severity of sarcopenia. Its brief administration time, reduced susceptibility to systemic influences, and minimal equipment requirements support this potential. As a performance-based assessment tool, the EPT has demonstrated high repeatability and may provide clinically meaningful information in situations where traditional tests fall short. Although further validation is needed, the EPT appears to offer a more consistent means of monitoring sarcopenia-related functional changes and may serve as a valuable tool for tracking treatment responses over time.

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Author contributions All authors reviewed and approved the final manuscript. TYY: Conceptualization, Methodology, Resources, Data Curation, Investigation, Writing - Original Draft; EK: Conceptualization, Methodology, Resources, Writing - Original Draft, Visualization, Validation; TA: Conceptualization, Methodology, Writing - Original Draft; KST, IK: Conceptualization, Methodology, Resources, Formal analysis, Investigation, Writing - Original Draft, Writing – Review & Editing, Supervision.

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Data availability The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethical approval and informed consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. This study was approved by the Ethics Committee of Istanbul Physical Medicine and Rehabilitation Training and Research Hospital (Approval No: 2024-49).

Consent for publication The original article is not under consideration by another publication, and its substance, tables, or figure have not been published previously and will not be published elsewhere.

Consent to participate Informed consent was obtained from all individual participants included in the study.

Conflict of interest The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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