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# Optimal cut-off scores of performance-based tests of physical function to discriminate disease severity in patients with knee osteoarthritis

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ABSTRACT

*Background:* A set of physical tests representing typical activities relevant to persons with knee osteoarthritis (KOA) is recommended by the Osteoarthritis Research Society International (OARSI). The objective of this study was to designate the cut-off values for OARSI-recommended performance-based tests to better discriminate disease severity in patients with KOA.
*Methods:* As recommended by the OARSI, we conducted the 30-s chair stand test (30-s CST), 40-m fast-paced walk test (40-m FPWT), stair climb test (SCT), 6-min walk test (6MWT), and timed up and go test (TUG). To investigate the discriminative power of the performance test scores using the Kellgren–Lawrence (K-L) grading system, receiver operating characteristic (ROC) curve analysis was performed. Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was used to assess self-administered health status.
*Results:* Forty-eight patients with bilateral KOA were included this study. The area under the curves for four of the five performance tests (30-s CST, six-step SCT, 40-m FPWT, and TUG) had acceptable discrimination (0.753–0.793), while the 6MWT had excellent discrimination (0.860). The stepwise multiple regression analysis demonstrated that 6MWT and 30-s CST were significant and independent determinants of WOMAC score, explaining 48% of the variance ($P < 0.001$).
*Conclusion:* The OARSI performance tests can discriminate disease severity in individuals with KOA. The 6MWT has the highest level of discriminative validity among all. In addition, despite the correlation between all five tests and the WOMAC score, 6MWT and 30-s CST are independent and significant determinants of the WOMAC.

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## 1. Introduction

Osteoarthritis (OA) is the fourth leading factor contributing to disability [1]. As a common degenerative condition, knee osteoarthritis (KOA) targets the articular cartilage of the knee with symptoms such as swelling, pain, and functional loss [2]. Being one of the most debilitating conditions, KOA is most commonly linked to reduced ability to walk and climb stairs [3]. Patients exhibit deteriorated gait patterns, resulting in a general decline in function and quality of life [4]. All these elements work together to create a vicious cycle leading to poor physical performance [5].

The availability of a standardized set of performance-based tests has made it easier to compare treatment results across studies [6]. A set of physical tests representing typical activities relevant to persons with KOA is recommended by the Osteoarthritis Research Society International (OARSI). These tests include the 30-s chair stand test (30-s CST), 40-m fast-paced walk test (40-m FPWT), stair climb test (SCT), 6-min walk test (6MWT), and timed up and go test (TUG). The first three are recommended as the minimum required set of outcome measures in OA both in clinical and research settings [7]. The physical tests included in the set recommended by OARSI have been shown to be effective in a variety of conditions ranging from early- up to severe-stage KOA [5,7]. In addition, the recommended core set can discriminate between controls and individuals with Kellgren–Lawrence (K-L) grade 0–II KOA [5]. Previous studies have demonstrated that pain severity, muscle strength, and physical activity levels significantly impact performance-based functional tests in patients with KOA [8–10]. It has been reported that lower quadriceps and hamstring strength is strongly correlated with poorer performance in the 6MWT, TUG, and 30-s CST [10]. Additionally, it is indicated that higher physical activity levels are associated with better performance in gait speed and balance tests, reinforcing the importance of functional assessments in clinical settings [8]. It has been shown that tests such as TUG, and Step Test can effectively differentiate KOA severity levels, aiding in diagnosis and treatment planning [11].

Despite the importance of the tests recommended by the OARSI in patients with KOA, we lack evidence on the cut-off scores for these tests to discriminate disease severity. Therefore, there is a need to determine cut-off scores of the OARSI-recommended physical tests. By establishing the cut-off scores for these functional tests, clinicians can enhance diagnostic accuracy, improve patient stratification for treatment, and optimize rehabilitation programmes tailored to specific severity levels. In this respect, the primary objective of this study was to designate the cut-off values for OARSI-recommended physical tests to better discriminate disease severity in patients with KOA. Secondarily, we aimed to specify physical predictors of disease severity in KOA.

## 2. Materials & methods

### 2.1. Study design and the participants

To participate in our cross-sectional study, we included individuals who were: (1) above 50 years of age; (2) diagnosed with bilateral KOA according to radiological and clinical criteria of the American College of Rheumatology (ACR); (3) independent community dwellers without any walking aids. Patients with (1) central or peripheral nervous system involvement, (2) previous knee surgery within the past 6 months, (3) neurological or musculoskeletal disorders that would limit their performance on the tests, and (4) history of systemic arthritic conditions were excluded.

Participants were recruited based on predefined inclusion and exclusion criteria, ensuring that only individuals diagnosed with KOA were considered for the study. All patients were evaluated by an experienced orthopaedic surgeon, who confirmed the diagnosis and classified disease severity using the K-L grading system, which is widely used for radiographic assessment. Each participant underwent a comprehensive clinical and radiological evaluation by same experienced orthopaedic surgeon to confirm the diagnosis, assess joint stability, and determine disease severity.

Approved by Selcuk University Faculty of Health Sciences Ethics Committee (Report number: 2023/60), the study protocol was prepared according to the guidelines of the Declaration of Helsinki. Informed consent was signed by all participants.

### 2.2. Data collection

#### 2.2.1. Demographic and clinic characteristics

Demographic and clinical data of the participants were recorded. Based on recent weight-bearing and bilateral anteroposterior tibiofemoral joint X-rays, an experienced specialist graded the disease according to the K-L grading system [12]. In our analysis, patients were classified based on the K-L grading system into two distinct groups for receiver operating characteristic curve analysis. Specifically, (1) patients with mild-to-moderate KOA (K-L grades I–II) and (2) patients with moderate-to-severe KOA (K-L grades III–IV).

We used the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) to assess self-administered health status. Originally developed for people with OA, the index contains 24 items in three subscales measuring stiffness (two items), pain (five items), and physical function (17 items) [13]. Validity, reliability, and responsiveness of the Turkish version of the index for Turkish patients with knee OA is demonstrated in a previous study [14]. Higher WOMAC scores indicate worsening of the symptoms. To provide a conservative estimate of the potential need for arthroplasty, a WOMAC score of 39 or greater was demonstrated to indicate ‘severe’ arthritis [15].

### 2.2.2. Performance-based tests

As recommended by the OARSI, we conducted five performance-based physical tests. No walking aid was used during the tests. Before and after each test, fatigue and dyspnea (using Borg scale), and haemodynamics (heart rate and $SpO_2$) were evaluated. A 5-min rest (or longer, if needed) was given between the tests for recovery. In our study, participants were given adequate rest periods between tests to minimize the effects of fatigue. To ensure validity, we monitored signs of fatigue and confirmed that participants could perform all tests with optimal effort. Based on these considerations, we chose to maintain a consistent test order rather than randomization, ensuring comparability with existing literature and clinical assessment protocols. All five tests were completed in the following order. (1) TUG test: starting from a sitting position on an armed chair, the participant stood up, walked 3 m in a comfortable and safe manner, crossed the line, turned, and returned to the initial position. The time to complete the task was recorded in seconds [16]. (2) 40-m FPWT: the participants walked as fast as they could on a 10-m walkway, looped around a cone 2 m behind each end, and continued to complete a total of 40 m. The time to complete the task was recorded in seconds [17]. (3) Six-step SCT: although a stair climb test is recommended by the OARSI, the exact number of the stairs is not specified [7]. Studies in the relevant literature use different numbers of stairs [5,18]. We asked our participants to climb up and down six stairs (step height: 18 cm) as quickly and safely as they could. The time to complete the task was recorded in seconds [19]. (4) 30-s CST: starting from a sitting position on straight-backed chair (seat height: 44 cm) without an armrest, the participants were asked to stand up completely and sit back down on the chair. The number of repetitions performed in 30 s was documented [20]. (5) 6MWT: as indicated in the guideline of the American Thoracic Society (ATS), for a period of 6 min the participants walked back and forth along a 30-m flat walkway with two cones at each end. The total walking distance was recorded in meters [21].

## 2.3. Sample size

To determine the minimum required sample size for multiple linear regression analysis we used G*Power software (version 3.1.9.7; Heinrich Heine University, Düsseldorf, Germany). We referred to the results of a previous study, in which discomfort level during the 6MWT was found as a predictor of WOMAC physical function ($R^2$ = 0.17) [22]. According to the results, we needed a minimum of 41 participants for five determinants in the model (a probability level of 0.05, an anticipated effect size of 0.204, and a statistical power level of 80%). Considering 15% dropout rate, we included 48 individuals in the study.

## 2.4. Data analysis

To analyse the data, we used the IBM SPSS Statistics for Windows (version 25.0; IBM Corp., Armonk, NY, USA). Analytical methods (Skewness and Kurtosis tests) and visual (histograms, probability plots) were used to check the normality of data distribution. Categorical variables were expressed as numbers (percentages) and continuous values as mean ± standard deviation.

To investigate the discriminative power of the performance test scores using K-L grading system (cut-off score ≥ 3), receiver operating characteristic (ROC) curve analysis was performed. The ROC curve was then plotted, and area under the curve (AUC) values were derived using the trapezoidal rule, ensuring robustness of the analysis. To further improve interpretability, we also calculated positive and negative likelihood ratios, which provide additional insights into the discriminatory power of each test. The AUC was calculated and interpreted as follows: outstanding discrimination if AUC ≥ 0.9, excellent discrimination if AUC = 0.8–0.9, and acceptable discrimination if AUC = 0.7–0.8 [23]. The optimal cut-off values for each test were determined using Youden's index (Sensitivity + Specificity – 1), maximizing the trade-off between sensitivity and specificity [24]. To further assess the diagnostic accuracy of functional tests, positive likelihood ratio ($LR^+$) and negative likelihood ratio ($LR^-$) values were calculated using the following formulae:

–$LR^+$ = Sensitivity / (1 – Specificity)
–$LR^-$ = (1 – Sensitivity) / Specificity [25].

To study correlations between WOMAC and five performance tests, we applied Pearson product-moment correlation coefficients. Additionally, stepwise multiple linear regression analysis was conducted for the identification of variables that had the largest effect on WOMAC. For the purpose of the study, we also developed a regression equation.

# 3. Results

Forty-eight participants (mean age = 62.29 years) (83.3% females) completed the study tests. We detected no ceiling or floor effects for any of the tests. Table 1 represents the demographics and characteristics of the participants.

The AUCs for four of the five performance tests (30-s CST, 6-step SCT, 40-m FPWT, and TUG) had acceptable discrimination (0.753–0.793), while the 6MWT had excellent discrimination (0.860) (Table 2, Figure 1). The cut-off points of 30-s CST, 6-step SCT, 40-m FPWT, TUG, and 6MWT were 9.5 counts, 11.3 s, 28.0 s, 9.2 s, 375.0 m, respectively, to discriminate disease severity (Table 2, Figure 1). The 6MWT ($LR^+$ = 2.46, $LR^-$ = 0.23) and 30-s CST ($LR^+$ = 2.15, $LR^-$ = 0.13) demonstrated the strongest ability to classify KOA severity, with low $LR^-$ values (<0.2), indicating good accuracy in ruling out severe KOA. The TUG

**Table 1**
Demographic and characteristic features.

| Variables (n = 48) | Value |
|---|---|
| Age (years) | 62.29 ± 8.72 |
| Female, n (%) | 40 (83.3) |
| Body mass index (kg/m$^2$) | 31.80 ± 4.93 |
| Obese ≥ 30 kg/m$^2$, n (%) | 29 (60.4) |
| Overall pain duration ≥ 1 year | 36 (75) |
| WOMAC score | 45.90 ± 22.17 |
| Kellgren–Lawrence classification, n (%) | |
| I | 3 (6.3) |
| II | 10 (20.8) |
| III | 28 (58.3) |
| IV | 7 (14.6) |
| Performance-based tests | |
| 30-s CST (counts) | 9.56 ± 2.46 |
| 6-step SCT (s) | 19.14 ± 9.16 |
| 40-m FPWT (s) | 37.21 ± 11.40 |
| TUG (s) | 11.39 ± 3.56 |
| 6MWT (m) | 373.54 ± 120.13 |

Values are presented as mean ± standard deviation or number (%). 30-s CST, 30-s chair stand test; 40-m FPWT, 40-m fast-paced walk test; 6MWT, 6-min walk test; 6-step SCT, six-step stair climb test; TUG, timed up and go test; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

**Table 2**
Cut-off values of performance-based tests to discriminate disease severity.

| Tests | AUC | 95% CI | *P* | Cut-point | Sensitivity | Specificity | Likelihood ratios (LR$^+$ – LR$^-$) |
|---|---|---|---|---|---|---|---|
| 30-s CST (counts) | 0.793 | 0.661 ~ 0.926 | 0.002 * | 9.5 | 0.923 | 0.571 | 2.15–0.13 |
| 6-step SCT (s) | 0.784 | 0.624 ~ 0.943 | 0.003 * | 11.3 | 0.943 | 0.538 | 2.04–0.11 |
| 40-m FPWT (s) | 0.762 | 0.600 ~ 0.923 | 0.006 * | 28.0 | 0.943 | 0.538 | 2.04–0.11 |
| TUG (s) | 0.753 | 0.608 ~ 0.898 | 0.008 * | 9.2 | 0.771 | 0.615 | 2.00–0.37 |
| 6MWT (m) | 0.860 | 0.741 ~ 0.979 | <0.001 * | 375.0 | 0.846 | 0.657 | 2.46–0.23 |

30-s CST, 30-s chair stand test; 40-m FPWT, 40-m fast-paced walk test; 6MWT, 6-min walk test; 6-step SCT, six-step stair climb test; AUC, area under the curve; CI, confidence interval; TUG, timed up and go test.
* $P < 0.05$.

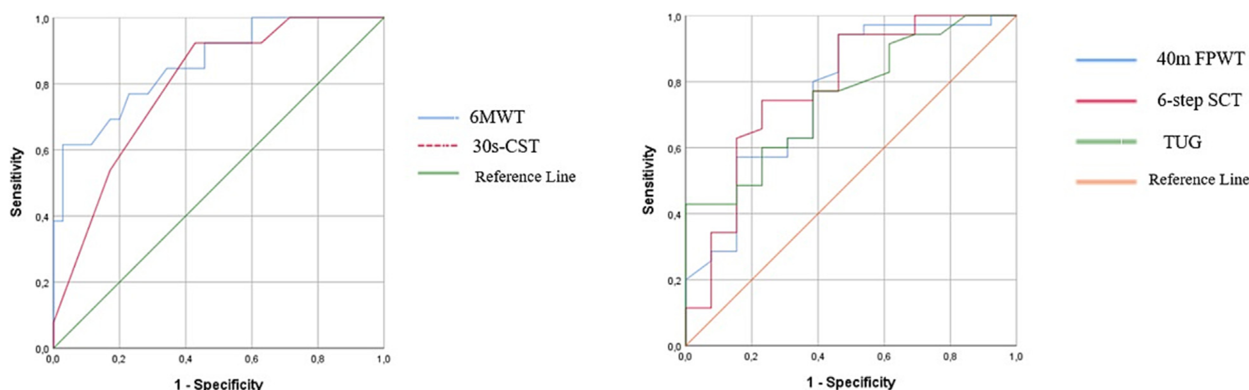


**Figure 1.** Results of the receiver operating curve analysis for performance tests to discriminate disease severity. 30 s-CST, 30-s chair stand test; 40 m FPWT, 40-m fast-paced walk test; 6MWT, 6-min walk test; 6-step SCT, six-step stair climb test; TUG, timed up and go test.

test (LR$^+$ = 2.00, LR$^-$ = 0.37) showed moderate discriminatory power but was less effective in ruling out severe KOA. The 6-step SCT and 40-m FPWT (both LR$^+$ = 2.04, LR$^-$ = 0.11) provided moderate classification accuracy. These results suggest that 6MWT is the most effective tests for differentiating KOA severity (Table 2).

The WOMAC score was significantly correlated with 30-s CST (r = –0.451), 6-step SCT (r = 0.550), 40-m FPWT (r = 0.486), TUG (r = 0.557), and 6MWT (r = -0.653) ($P < 0.05$; Table 3). The stepwise multiple regression analysis demonstrated that

**Table 3**
Correlations between the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score and performance-based tests.

| Variable | r | *P* |
|---|---|---|
| 30-s CST (counts) | –0.451 | **0.001** |
| 6-step SCT (s) | 0.550 | **<0.001** |
| 40-m FPWT (s) | 0.486 | **<0.001** |
| TUG (s) | 0.557 | **<0.001** |
| 6MWT (m) | –0.653 | **<0.001** |

30-s CST, 30-s chair stand test; 40-m FPWT, 40-m fast-paced walk test; 6MWT, 6-min walk test; 6-step SCT, six-step stair climb test; r, Pearson correlation coefficient; TUG, timed up and go test. Significant *P*-values are present in bold.

6MWT and 30-s CST were significant and independent determinants of WOMAC score, explaining 48% of the variance ($P < 0.001$) (Table 4). Below is the regression equation:

$$\text{WOMAC score} = 110.33 + (-0.105 \times \text{6MWT}) + (-2.61 \times \text{30-s CST})$$

## 4. Discussion

The main finding of the study suggests that the OARSI-recommended performance tests can discriminate disease severity in individuals with KOA. Among these tests, the 6MWT had the highest discriminative validity level. Although all five tests were related to the WOMAC score, 6MWT and 30-s CST were independent and significant determinants of the WOMAC.

Through a comprehensive review of the relevant literature and consensus, the OARSI-recommended five performance-based tests to be used both as outcome measures in research, and in clinical settings for decision-making purposes and monitoring functionality over time [7]. We used the K-L grading system to determine disease severity and the OARSI-recommended performance tests to discriminate disease severity. The K-L grading system is a frequently method of classifying the severity of KOA [26].

Performance-based measures provide insight into functional status of individuals with KOA that cannot be captured via self-report tools [27]. Compared with their age-matched healthy counterparts, individuals with KOA report significant physical performance impairments in key activities such as walking, stair climbing, and balance [28]. Mehta et al. demonstrated that functional mobility, gait speed, and physical performance have good discriminant validity in patients with advanced KOA [28]. A previous study demonstrated that the OARSI-recommended tests can highly discriminate between individuals with K-L grade 0–II KOA and healthy controls [5]. We found that this set of tests can discriminate disease severity in patients with KOA. Among all, the 6MWT has the highest level of discriminant validity. According to our results, the cut-off points of 9.5 counts for 30-s CST, 11.3 s for 6-step SCT, 28.0 s for 40-m FPWT, 9.2 s for TUG, and 375.0 m for 6MWT are indicators of severe disease in patients with KOA. A previous study has reported the cut-off scores for the OARSI-recommended tests between patients and controls [5]. Pirayeh et al. [11] demonstrated that the TUG test and other functional measures effectively discriminated between mild and moderate-to-severe KOA based on K-L grading. Similarly, our study classified patients into K-L I–II and K-L III–IV groups and confirmed the discriminative ability of performance-based tests using ROC analysis. While both studies highlight the value of functional measures in assessing OA severity, our study provides additional cut-off values, further supporting their clinical utility. However, a key distinction in our study is the specific inclusion of additional performance-based functional tests and their respective cut-off values for disease severity classification. This comparison supports the notion that functional measures, including the TUG test, play a crucial role in stratifying OA severity levels and aiding clinical decision-making.

It is reported that in patients with total knee arthroplasty objective performance-based physical function is correlated with WOMAC score [29]. Additionally, the WOMAC-Function score has an inverse correlation with stride length and gait

**Table 4**
Stepwise multiple linear regression model of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score.

| Variable | B | SE | Beta | *P* |
|---|---|---|---|---|
| Constant | 110.33 | 10.53 | – | **<0.001** |
| 6MWT (m) | – 0.105 | 0.020 | – 0.571 | **<0.001** |
| 30-s CST (counts) | – 2.61 | 0.98 | – 0.291 | **0.011** |

Summary of model: R = 0.71, $R^2$ = 0.50, adjusted $R^2$ = 0.48 ($P < 0.001$). B, unstandardized regression coefficient; SE, standard error; 6MWT, 6-min walk test; 30-s CST, 30-s chair stand test. Significant *P*-values are represented in bold.

velocity [30]. The 6MWT test is reported to have a correlation with symptoms and functional status in patient with KOA [31]. Similarly, we concluded that all performance tests were related to the WOMAC score. Our results also showed that 6MWT and 30-s CST were significant and independent determinants of the WOMAC. This may suggest that disease severity can be higher in KOA patients with exercise-intolerance and leg muscle weakness.

The results of our study suggest that performance-based functional tests can serve as valuable tools for assessing physical function in patients with KOA and differentiating between disease severity levels. Additionally, our findings reinforce the importance of integrating both self-reported and performance-based assessments in routine clinical practice, as functional limitations assessed objectively may not always align with patient perceptions. This comprehensive approach may improve personalized treatment plans and enhance patient outcomes. By identifying cut-off values for these tests, clinicians can detect early functional decline, allowing for timely intervention with physical therapy or exercise programmes. They can also stratify patients for treatment planning, ensuring appropriate rehabilitation approaches based on severity. Additionally, these tests can aid in surgical decision-making, as functional limitations are key indicators for total knee arthroplasty.

The following limitations need to be considered while interpreting the results of this study. First, although we included more individuals than minimum required, highest concentration of the participants was in K-L grade II and III. Additionally, the sample size was relatively small, which may limit the generalizability of our findings. While previous research has shown that moderate sample sizes can still provide meaningful discriminatory results [32], a larger cohort would enhance statistical power and improve the precision of cut-off scores for functional tests. Lack of a gender- and age-matched healthy control group, which could provide a deeper insight, is the second limitation. Third, as 83% of our participants were women, generalizability of the study findings to men remains in doubt. Potential reasons behind the unequal number of participants per gender could be using a convenience sample, or a reflection of higher risk of KOA in females [33].

## 5. Conclusion

In summary, it can be concluded that the OARSI performance tests can discriminate disease severity in individuals with KOA. The 6MWT has the highest level of discriminative validity among all. In addition, despite the correlation between all five tests and the WOMAC score, 6MWT and 30-s CST are independent and significant determinants of the WOMAC.

## CRediT authorship contribution statement

**Gulsah Ozsoy:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Muhammed Ihsan Kodak:** Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Caner Kararti:** Writing – review & editing, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Fatih Ozyurt:** Writing – original draft, Supervision, Software, Investigation, Funding acquisition, Data curation, Conceptualization. **Seyde Busra Kodak:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Basak Cigdem Karacay:** Writing – original draft, Software, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Ismail Ozsoy:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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