

Timed 360° Turn Test Following Anterior Cruciate Ligament Reconstruction: A Cross-Sectional Reliability and Validity Study

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Cite this article as:

Kocaman H, Canlı M, Alkan H, Yıldırım H, Yıldız NT. Timed 360° Turn Test Following Anterior Cruciate Ligament Reconstruction: A Cross-Sectional Reliability and Validity Study. J Clin Pract Res 2024; 46(1): 58–66.

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Submitted: 26.10.2023

Revised: 17.01.2024

Accepted: 07.02.2024

Available Online: 19.02.2024

Erciyes University Faculty of Medicine Publications -
Available online at www.jcpres.com



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ABSTRACT

Objective: This study aims to evaluate the validity and reliability of the Timed 360° Turn Test (360°-TTT) in measuring dynamic balance in patients who have undergone anterior cruciate ligament reconstruction (ACL-R) surgery.

Materials and Methods: Forty patients who underwent ACL-R surgery were included in this study. The reliability analysis involved evaluating the inter-rater and test-retest reliability of the test duration and number of steps of the 360°-TTT by calculating intraclass correlation coefficients (ICCs). To assess the concurrent validity of the 360°-TTT, correlations between the test duration and number of steps of the 360°-TTT and the Berg Balance Scale (BBS) and Time Up and Go (TUG) test were examined. Additionally, standard error of measurement₉₅ (SEM₉₅) and minimal detectable change₉₅ (MDC₉₅) values were computed for the test duration and number of steps of the 360°-TTT.

Results: The inter-rater and test-retest reliability for both the test duration and the number of steps within the 360°-TTT demonstrated excellence, with ICCs of 0.83, 0.91, 0.88, and 0.87, respectively. A statistically significant correlation was observed between the 360°-TTT and both the BBS and the TUG ($p < 0.001$). The inter-rater and test-retest reliability of the raters was visually confirmed using Bland-Altman plots, further affirming the consistency of outcomes. The SEM₉₅ and MDC₉₅ values for the test duration and number of steps of the 360°-TTT were 0.09, 0.24, 0.18, and 0.49, respectively.

Conclusion: The 360°-TTT is a reliable and valid method for evaluating dynamic balance in patients undergoing ACL-R surgery.

Keywords: Timed 360° Turn Test, anterior cruciate ligament, reconstruction, dynamic balance, reliability.

INTRODUCTION

Turning is a crucial yet complex aspect of mobility that requires recalibration and synchronization of axial segments to navigate changes in direction while concurrently maintaining dynamic stability.¹ Individuals routinely engage in rotational movements, with the proportion of daily steps attributed to turning varying between 8% and 50%, depending on the nature of the activity and environmental context.² The anterior cruciate ligament (ACL) is the most commonly damaged ligament in the knee and is the most frequent site for surgical reconstruction following injuries.³ Non-contact injuries account for about 80% of cases. The most common mechanisms of injury include the cutting maneuver, which involves a change in direction or deceleration, landing on the ground with knee extension after a jump, or rotation while the foot remains fixed on the ground and the knee is extended.⁴ ACL reconstruction (ACL-R) is often employed to restore stability to the knee joint after an injury.⁵

The rate of return to the previous activity level in patients undergoing ACL-R surgery is approximately 63%.⁶ In these patients, loss of knee extension strength,⁷ balance disorders,⁸ and risk of re-injury are frequently observed. After an ACL injury, individuals' activity levels and motor coordination are adversely affected due to the disruption of afferent information flow from the ligament's mechanoreceptors.⁹ Moreover, knee pain and inefficient lower extremity loading accompanying the trauma disrupt the body's biomechanics, making it difficult for individuals to maintain balance.¹⁰ Primarily due to knee instability, ACL tears cause a significant imbalance in the body. ACL-R reduces but does not eliminate this instability.^{11,12} Therefore, evaluating balance after ACL-R is critical. For instance, Grueva-Pancheva et al.¹³ stated that after ACL-R, dynamic and static balance were impaired not only in the operated extremities but also in the non-operated extremities of patients.

When examining the literature, the number of tests evaluating balance performance is quite limited. The single-leg stance test is one of the most commonly used tests to assess postural balance after ACL-R, but it evaluates overall balance.^{14–16} A performance-based test designed to assess dynamic balance is the Timed 360° Turn Test (360°-TTT). Although originally developed for assessing balance in older individuals, the 360°-TTT has recently been found to be a reliable and valid method for evaluating dynamic balance in patients with Multiple Sclerosis,¹⁷ those with knee osteoarthritis,¹⁸ and patients with Parkinson's disease.¹⁹

Rotational movement is one of the crucial predisposing factors in the mechanism of ACL injury. Assessing dynamic balance during rotational activity, especially through tests

like the 360°-TTT, is essential for preventing re-injury in the postoperative phase for patients undergoing ACL-R.²⁰ In this context, establishing the validity and reliability of the 360°-TTT test in this patient population is significant for developing assessment and treatment programs in clinical practice. With this in mind, the aim of this study was to evaluate the reliability and validity of the 360°-TTT in patients undergoing ACL-R.

MATERIALS AND METHODS

Study Design and Participants

This cross-sectional research received approval from the Mus Alparslan University Ethics Committee (date: 10.03.2023, no: 03-2023/34). Conducted in accordance with the Declaration of Helsinki, the study required participants to sign a written consent form beforehand. Forty male patients who had undergone ACL-R and visited the Orthopedics and Traumatology Polyclinic for routine control between April and August 2023, and who volunteered to participate in the study, were included. The inclusion criteria were being aged between 18 and 35 years, having at least six months post-ACL-R, and having isokinetic knee extension strength on the operated side of at least 80% of the strength of the uninjured side. Those with concurrent posterolateral corner injuries, multiple ligament injuries, ACL-associated meniscal injuries, and concomitant neuromuscular disorders were excluded.

In the post-hoc power analysis process, concerning the correlational design, the smallest intraclass correlation coefficient (ICC) score from the test duration of the Timed 360° Turn Test measurements between evaluators was used as a reference. The effect size was determined to be 2.22 (corresponding to ICC=0.83), based on data from 40 individuals at a $\alpha=0.05$ significance level. It was observed that the power value was approximately 0.99, due to the high effect size. This value indicates that the power level is more than sufficient, demonstrating that the effect investigated in this study can be easily detected with the current sample size.

Procedures

Demographic characteristics (age, body mass index) of patients who underwent ACL-R surgery using a hamstring tendon graft were recorded. Additionally, the duration post-surgery, injured knee side, and dominant side were documented. The Biodex isokinetic dynamometer (Biodex, Corp., Shirley, NY) was employed to ensure that the isokinetic knee extension strength of the operated side was at least 80% that of the uninjured side. Given the associations between static and dynamic balance and the 360°-TTT,¹⁸ it was hypothesized that correlations between the 360°-TTT, the Berg Balance Scale (BBS), and the Time Up and Go (TUG) test

would be observed in this study. The BBS and TUG tests were administered to all participants to test this hypothesis and confirm the concurrent validity of the 360°-TTT. A 5-minute rest interval was provided to each participant to prevent fatigue between the BBS and TUG tests. Subsequently, the inter-rater and test-retest reliabilities of the 360°-TTT were examined. For the inter-rater reliability assessment, two specialist physiotherapists experienced in orthopedic rehabilitation administered the 360°-TTT to participants one hour apart. To assess the test-retest reliability of the 360°-TTT, the same physiotherapists administered the 360°-TTT to all participants five days later. Detailed information was provided before the tests, followed by a trial test to ensure participants understood the procedures.

Outcome Measures

Timed 360° Turn Test

In this study, the dynamic balance and turning ability of the patients were evaluated using the 360°-TTT. The 360°-TTT was developed by Gill et al.²¹ to assess dynamic balance. At the designated starting point, participants assumed a comfortable standing position and performed one full turn in both directions (right and left). The timing started when the rater said “go” and ended when the participant returned to the starting position (Fig. 1). The time taken for each participant to complete the 360°-TTT, along with the number of steps for each rotation in both directions, was averaged and recorded. A two-minute rest interval was provided between two consecutive tests to minimize potential fatigue effects.²¹

Berg Balance Scale

The Turkish version of the BBS was used to assess the participants’ balance.²² The BBS evaluates the ability to maintain balance in various positions and assesses changes in posture and movement. The scale comprises 14 items, each scored between 0 and 4 points (0: unable to do it, 4: normal). A total score is calculated from the scale, ranging from 0 (dependent on functional ambulation) to 56 (independent functional ambulation). The Turkish version of the BBS has been reported to have high test-retest reliability (ICC=0.98) and internal consistency (Chronbach’s $\alpha=0.98$).²²

Time Up and Go Test

The TUG is a reliable test for evaluating dynamic balance and gait speed. Participants were instructed to sit in a standard chair, stand up from the chair, walk a distance of 3 meters, turn around a target, and sit back down in the chair (Fig. 2). The elapsed time between the participant standing up from the chair and sitting back down was recorded in seconds.²³



Figure 1. Timed 360° Turn Test procedure.

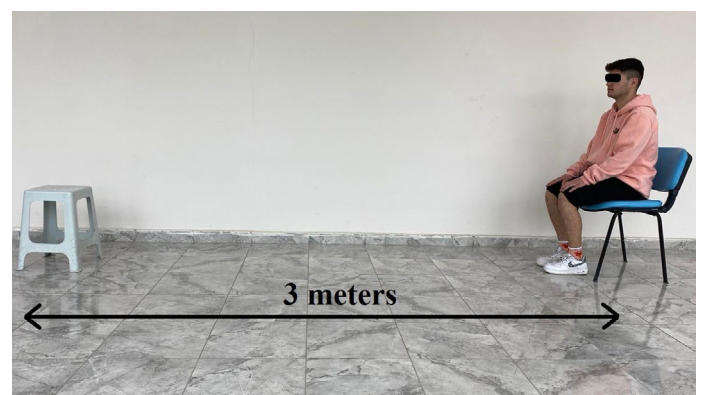


Figure 2. Time Up and Go Test procedure.

Table 1. Descriptive characteristics and clinical measurement results of ACL-R patients (n=40)

	Mean	SD	Min	Max
Age (years)	26.2	4.93	19.00	35.00
BMI (kg/m ²)	25.45	3.21	21.73	28.30
Post-surgery duration (months)	8.15	1.82	6.00	12.00
TUG test (seconds)	7.46	0.85	6.05	9.15
BBS score	48.75	4.78	39.00	56.00
Test duration of the 360°-TTT (Rater 1) (seconds)				
Test	3.04	0.51	2.19	4.01
Retest	2.95	0.56	2.21	3.96
Test duration of the 360°-TTT (Rater 2) (second)				
Test	3.07	0.53	2.09	4.12
Retest	3.14	0.62	2.1	4.20
Number of steps of the 360°-TTT (Rater 1)				
Test	3.85	0.98	3	6
Retest	3.96	0.78	3	5
Number of steps of the 360°-TTT (Rater 2)				
Test	4.15	0.87	3	6
Retest	4.25	1.06	3	6
Injured extremity, n (%)				
Right		32		80
Left		8		20
Dominant lower extremity, n (%)				
Right		35		87.5
Left		5		12.5

BBS: Berg balance scale; BMI: Body mass index; Max: Maximum; Min: Minimum; SD: Standard deviation; TUG: Time up and go test; 360°-TTT: Timed 360° Turn Test.

Statistical Analysis

All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 24 (SPSS Inc., Chicago, Illinois). To evaluate the normal distribution of variables, both visual methods and analytical techniques were applied. The reliability of the 360°-TTT was assessed using the ICC. Additionally, Bland-Altman plots facilitated the visual examination of inter-rater and test-retest reliability. ICC values were categorized as follows: poor (less than 0.40), fair (between 0.40 and 0.59), good (between 0.60 and 0.79), and excellent (greater than 0.80).¹⁹ Pearson correlation analysis was performed to determine the concurrent validity of the 360°-TTT through its relationship with secondary measurements, with correlation coefficients considered poor (less than 0.30), moderate (between 0.30 and 0.60), and strong (greater than 0.60).²⁴ The standard error of measurement₉₅ (SEM₉₅) for the 360°-TTT scores was calculated using the formula: $SEM_{95} = \text{Standard deviation} \times \sqrt{(1-ICC)}$. The minimal detectable change at a 95% confidence interval (MDC₉₅)

was determined using the formula: $MDC_{95} = 1.96 \times SEM_{95} \times \sqrt{2}$.²⁵ The established level of statistical significance was set at $p < 0.05$.

RESULTS

In this study, 48 patients were contacted. Eight of them did not meet the inclusion criteria or chose not to participate, resulting in a final cohort of 40 patients. Table 1 displays the clinical measurement values and descriptive characteristics of the ACL-R patients included in the study.

Inter-rater and test-retest reliability results are provided in Table 2. Regarding inter-rater reliability, the ICC values for the first and second raters for test duration and the number of steps in the 360°-TTT were 0.83 and 0.88, respectively, indicating excellent inter-rater agreement between the raters. The ICC values for test duration and the number of steps in the 360°-TTT were 0.91 and 0.87, respectively, indicating excellent test-retest reliability (Table 2).

Table 2. Inter-rater and test-retest reliability of the 360°- TTT (n=40)

	Difference (Mean±SD)	Inter-rater (ICC_{1,2}) (95% CI)	Test-retest (ICC_{1,1}) (95% CI)	SEM₉₅	MDC₉₅
Test duration of the 360°- TTT (seconds)	0.02±0.3	0.83 (0.68-0.91)	0.91 (0.82-0.95)	0.09	0.24
Number of steps of the 360°- TTT	0.05±0.5	0.88 (0.77-0.93)	0.87 (0.76-0.93)	0.18	0.49

CI: Confidence interval; ICC: Intraclass correlation coefficient; MDC₉₅: Minimum detectable change at the 95% confidence interval; SD: Standard deviation; SEM₉₅: Standard error of measurement at the 95% confidence interval; 360°- TTT: Timed 360° Turn Test.

Table 3. Correlations between test duration and number of steps of the 360°-TTT with other tests

		Test duration of the 360°- TT	Number of steps of the 360°- TT
TUG (seconds)	r	0.839	0.766
	p	< 0.001 *	< 0.001 *
BBS score	r	-0.468	-0.426
	p	< 0.001 *	< 0.001 *

BBS: Berg Balance Scale; TUG: Time up and go test; 360°- TTT: Timed 360° Turn Test; *: P<0.001.

Bland-Altman plots were generated separately for both the test duration and the number of steps of the 360°-TTT measurements and are shown in Figure 3 and Figure 4, respectively. According to these plots, both the test-retest assessments within raters and the inter-rater assessments fall within the 95% confidence interval limits for almost all values around the mean difference of zero. The overall results indicate that the 360°-TTT is a reliable measure of both test duration and the number of steps in patients with ACL-R, as demonstrated by both analytical (ICC) and visual (Bland-Altman plots) methods.

There was a positive, strong correlation between the test duration (r=0.839) and the number of steps (r=0.766) of the 360°-TTT with the TUG (p<0.001). Additionally, there was a negative, moderate correlation between the test duration (r=-0.468) and the number of steps (r=-0.426) of the 360°-TTT with the BBS (p<0.001) (Table 3).

DISCUSSION

Enhancing neuromuscular control of the knee after ACL-R is crucial for returning to functional activities and preventing or reducing the risk of re-injury.²⁶ Therefore, evaluating neuromuscular control and dynamic balance with valid and reliable tests is essential in the rehabilitation process after ACL-R. This study demonstrates that the 360°-TTT is a valid and reliable test for assessing dynamic balance in patients with ACL-R. Furthermore, our findings reveal significant associations between the BBS and TUG test, which are frequently used in balance assessments, and the 360°-TTT. These findings

strongly support the clinical utility, validity, and reliability of the 360°-TTT as an assessment tool for ACL-R patients.

Proprioceptive deficits and the associated loss of balance in the lower extremity following injury and surgical reconstruction of the ACL have been reported. Hence, measuring the dynamic balance of these patients after ACL-R with specific tests, such as the 360°-TTT, is important to track improvements while restoring neuromuscular control of the lower extremity and improving balance.²⁶

The reliability of the 360°-TTT has previously been the subject of research in various populations. For instance, Tager et al.²⁷ investigated the test-retest reliability of the 360°-TTT in geriatric individuals reporting an ICC of 0.92. Similarly, Cardoso et al.²⁸ found an ICC of 0.97 in amputated individuals, Shiu et al.²⁹ reported an ICC of 0.94 in stroke patients, Soke et al.¹⁷ observed an ICC of 0.94 in patients with multiple sclerosis, and Yarar et al.¹⁸ reported an ICC of 0.93 in patients with knee osteoarthritis, all indicating excellent test-retest reliability. In the current study, the inter-rater and test-retest reliability of the test duration and number of steps of the 360°-TTT were assessed in patients with ACL-R. Consistent with the findings of previous studies, this study demonstrated excellent inter-rater and test-retest reliability for the test duration and number of steps (ICC=0.83, ICC=0.88, ICC=0.91, and ICC=0.87, respectively).

The 360°-TTT was initially developed to evaluate dynamic balance in the geriatric population.²¹ To date, the TUG test and the BBS have been extensively utilized to examine

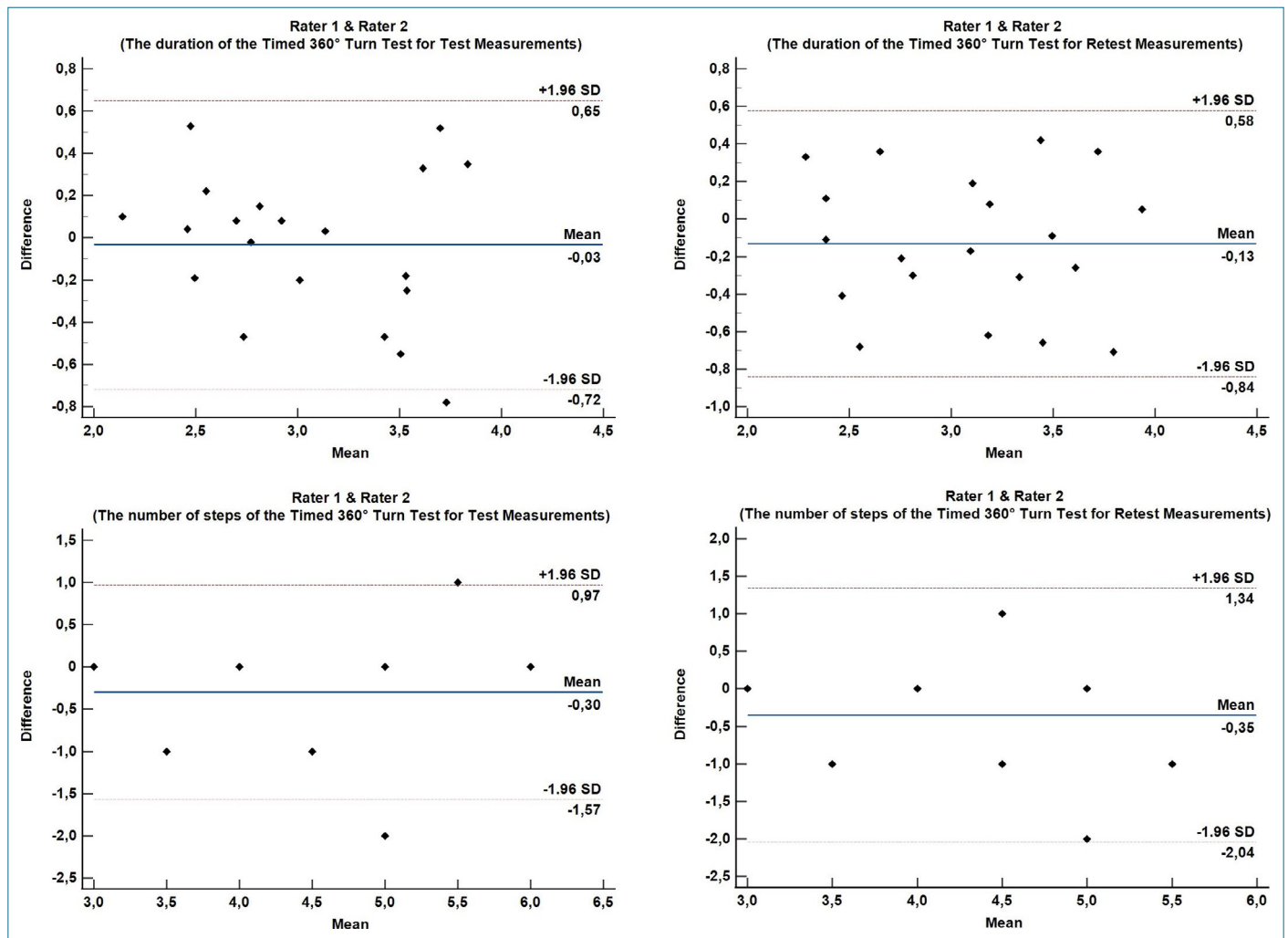


Figure 3. Bland-Altman plots for inter-rater reliability of test duration and number of steps in the Timed 360° Turn Test.

the concurrent validity of the 360°-TTT across various conditions, revealing significant associations between the 360°-TTT, BBS, and TUG test.^{18,19} Yazar et al.¹⁸ evaluated the concurrent validity of the 360°-TTT with the TUG test in patients with knee osteoarthritis. Their study found significant associations between the test duration and the number of steps of the 360°-TTT and the TUG test, with Pearson correlation coefficients ranging from 0.388 to 0.700. In another study examining the validity and reliability of the 360°-TTT in patients with Parkinson's disease, high correlations were reported between the 360°-TTT and both the BBS and TUG test.¹⁹ Soke et al.¹⁷ investigated the validity and reliability of the 360°-TTT in patients with multiple sclerosis and found high correlations between the 360°-TTT and the BBS and TUG test. They also stated that the 360°-TTT is a valid test. In the present study, similar to other studies, we analyzed the potential correlations

between the test duration and number of steps of the 360°-TTT and the BBS and TUG test to evaluate the 360°-TTT's concurrent validity. Our findings revealed positive high correlations between the TUG test and both the test duration and number of steps of the 360°-TTT. Additionally, negative moderate correlations were found between the BBS and both the test duration and number of steps of the 360°-TTT. These findings are consistent with the results in the existing literature.

Given that the SEM₉₅ for clinical measurement tests indicates the potential error level in measurements, clinicians should consider this value when interpreting results from the relevant tests. Therefore, it is crucial to include the SEM₉₅ values of clinical tests in literature reporting.³⁰ In our study, we observed a minimal margin of error in the test duration of the 360°-TTT for ACL-R patients, with an SEM₉₅ value of 0.09.

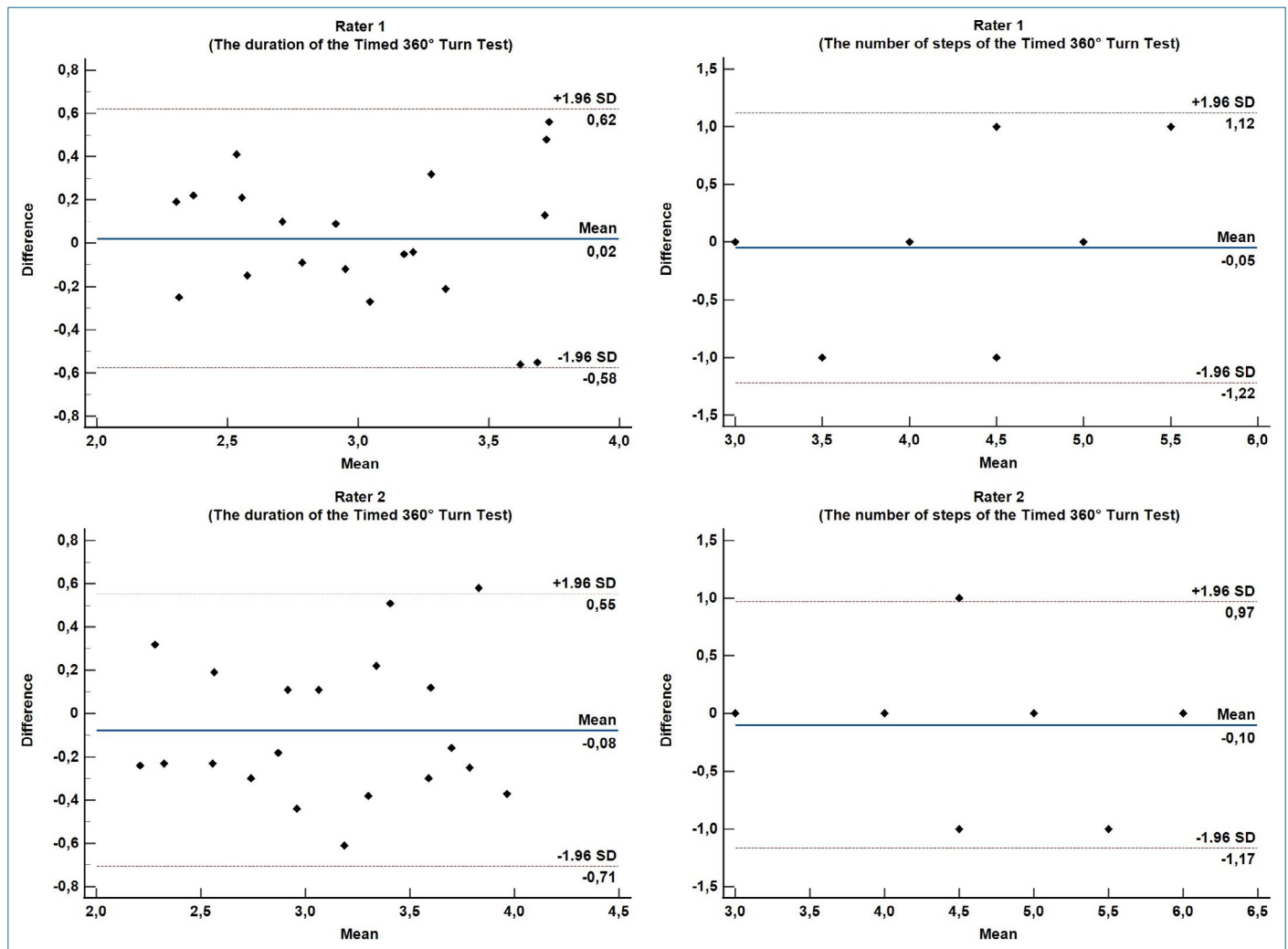


Figure 4. Bland-Altman plots for test-retest reliability of test duration and number of steps in the Timed 360° Turn Test.

Similarly, the number of steps component of the 360°-TTT exhibited a very low margin of error, as indicated by an SEM_{95} value of 0.18 in ACL-R patients. Based on these findings, accurate results with approximately a 95% confidence interval (CI) can be achieved in both components of the 360°-TTT for patients with ACL-R. In line with our findings, Yarar et al.¹⁸ achieved a minimal margin of error in patients with osteoarthritis, reporting SEM_{95} values of 0.091 for the test duration component and 0.156 for the number of steps component of the 360°-TTT.

The MDC_{95} value in clinical measurement tests represents the minimum detectable change between measurements, playing a crucial role in evaluating improvements or deterioration in the measured parameter during routine patient follow-up. A lack of awareness of the MDC_{95} value could lead to the risk of making inaccurate judgments

regarding the clinical significance of changes in the measured parameter.³⁰ In a previous study, the MDC_{95} value for the 360°-TTT was documented as 0.253 for the test time component and 0.432 for the step count component in patients with osteoarthritis.¹⁸ A study involving Parkinson's patients reported an MDC_{95} value of 1.98 for the test time component in the dominant lower extremity and 1.48 for the non-dominant lower extremity.¹⁹ Furthermore, in a study involving patients with multiple sclerosis (MS), the MDC_{95} value for the test duration component was reported as 1.49 for the dominant lower extremity and 1.53 for the non-dominant lower extremity.¹⁷ In our study, the analysis of the MDC_{95} value for the test duration component of the 360°-TTT revealed high sensitivity in ACL-R patients, consistent with findings in the existing literature, with an MDC_{95} value of 0.24. Similarly, the MDC_{95} value for the number of steps component of the 360°-

TTT demonstrated high sensitivity in ACL-R patients, with an MDC_{95} value of 0.49. These findings imply that the 360°-TTT exhibits high sensitivity, enabling the detection of subtle changes in lower limb function among ACL-R patients. This sensitivity can empower clinicians to make more informed decisions regarding patient management and treatment.

Study Limitation

In this study, only patients who have undergone ACL-R with a hamstring tendon graft were included, while those who underwent ACL-R with a patellar tendon graft were excluded. The technique using a patellar tendon graft may cause anterior knee pain and weakness in the knee extensor mechanism, whereas the technique using a hamstring tendon graft may result in ligament laxity and a decrease in knee flexion strength. These effects may lead to different levels of deficits in muscle strength, endurance, and balance, depending on the type of graft used. In future studies, it may be useful to investigate the 360°-TTT in patients who have undergone ACL-R with a patellar tendon graft, and, if possible, to evaluate and compare the 360°-TTT outcomes in patients using these different techniques.

CONCLUSION

In conclusion, the 360°-TTT is a valid and reliable method for assessing dynamic balance in patients who have undergone ACL-R. It provides a practical and effective means of evaluating dynamic balance during rotational movements in the postoperative period for these patients. This assessment can serve as a reference for designing appropriate interventions to restore dynamic balance to optimal levels and may help prevent re-injury.

Ethics Committee Approval: The Mus Alparslan University Clinical Research Ethics Committee granted approval for this study (date: 10.03.2023, number: 03-2023/34).

Author Contributions: Concept – HK, MC, HA; Design – MC, HY; Supervision – MC, HY; Resource – NTY, HA; Materials – HK, MC; Data Collection and/or Processing – HK, MC; Analysis and/or Interpretation – HA, HY; Literature Search – HY, MC; Writing – NK, NTY; Critical Reviews – NTY.

Conflict of Interest: The authors have no conflict of interest to declare.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Use of AI for Writing Assistance: Not declared.

Financial Disclosure: The authors declared that this study has received no financial support.

Peer-review: Externally peer-reviewed.

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