Quantitative Evaluation of Functional Instability Due to Anterior Cruciate Ligament Deficiency

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Background: A safe and simple procedure to evaluate functional instability due to anterior cruciate ligament (ACL) deficiency (ACLD) has not been established. The angle of trunk backward tilting, which is known as a posture at risk for ACL injuries, could be used as a parameter to evaluate functional instability due to ACLD.

Purpose: To measure the backward tilt angle of the trunk with participants standing upright on 1 leg and to investigate its usefulness to quantitatively evaluate functional instability due to ACLD.

Study Design: Cohort study (diagnosis); Level of evidence, 3.

Methods: Our cohort included 50 participants with unilateral ACLD and 40 participants with bilateral healthy knees. The trunk backward tilt (TBT) test was conducted as follows: the participant was asked to maximally tilt the trunk backward in a single-leg standing position, while forward tilt of the index leg was blocked with a custom-made device. The TBT angle was measured using a side-view photograph. Subjective knee instability during the test was recorded using a visual analog scale (VAS). The relative and absolute reliability of the TBT test were verified in a sample of healthy participants and those with ACLD, and comparisons between indicators were performed. Multiple regression analysis was performed with the injured/uninjured side ratio (I/U ratio) of the TBT angle as the dependent variable and the following independent variables: (1) I/U ratio of knee extension muscle strength, (2) I/U ratio of knee flexion muscle strength, (3) side-to-side difference (SSD) of the KT-1000 arthrometer measurement, (4) sex, and (5) SSD of the VAS score.

Results: The TBT test had high reliability among healthy participants and those with ACLD. The TBT angle was significantly smaller and the VAS score was significantly higher on the injured side compared with the uninjured side and with healthy knees ($P < .001$ for all). Among the independent variables, the SSD of the VAS score had a negative influence on the I/U ratio of the TBT angle ($R^2 = 0.59$; $P < .001$).

Conclusion: The TBT test is a simple, safe, and reliable method for quantitatively evaluating functional instability due to ACLD under weightbearing conditions that reflect subjective knee instability. The test will provide an index of treatment outcomes and return to sports through additional objective measurements before and after ACL reconstruction.

Keywords: ACL deficiency; trunk backward tilt test; functional instability; posture control

Anterior cruciate ligament (ACL) injuries, a significant problem among athletes, are caused by actions such as landing from a jump or a sudden change in direction during motion.[25,30,35] If these actions are repeated with an untreated ACL injury, recurrent anterior subluxations of the tibia can not only restrict sports activity but also cause destruction of the index joint.[1,33] An ACL rupture leads to mechanical and functional instability.[34] Mechanical instability due to ACL deficiency (ACLD) is generally assessed objectively using manual instability tests such as the Lachman test and pivot-shift test under nonweightbearing conditions or using devices such as the KT-1000 arthrometer to measure anterior translation of the tibia.[5,16]

In previous studies, functional instability with ACLD has been defined as a feeling of subjective instability caused by impaired neuromuscular function.[3,4,12,22] Symptomatic patients with ACLD have been reported to have reduced proprioception compared with asymptomatic patients.[40] Proprioception is understood to be a component of the complex neuromuscular system that regulates the function of the muscles surrounding the knee and that is impaired to varying degrees after an ACL tear.[3,12,26,51,52]

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Numerous studies have shown that disturbance of the complex function of the knee is not solely caused by an injury of mechanical joint stabilizers but is to a large extent attributable to an impairment of the sensorimotor system.[2,11,20,48]

Objective and subjective knee instability do not necessarily correlate. Patients with ACLD can be classified as either noncopers, those whose sporting activity is restricted as a result of subjective knee instability, and copers, those who can engage in the same level of preinjury sporting activity.[24,42,43,47] Compared with noncopers, copers will increase their hamstring muscle activity, thereby stabilizing the knee joint, and will perform compensatory posture control by controlling the central nervous system through walking, jogging, and dynamic balance activities.[10,12-14,41] Because there is no significant measurable difference between noncopers and copers in terms of joint laxity, a differentiation of these 2 groups is currently not possible,[18,42,47] and thus it is difficult to establish a diagnosis of functional instability in everyday clinical practice. Incorporating relevant findings into effective therapeutic strategies remains a challenge.[44]

Beard et al[3] stated that functional instability can be objectively evaluated by measuring the hamstring reflex when a load is applied from the back to the front of the leg in the standing position so that anterior translation of the tibia is induced. There is evidence that subjectively stable and unstable patients with ACLD can be objectively distinguished by this method,[31] and this method can be used for the clinical diagnosis of functional instability due to ACLD.[44] However, this method requires special equipment and electromyogram analysis in a limited environment and is not widespread in general clinical evaluations. Subjective methods of evaluating knee instability include the Mohtadi Quality of Life Assessment in Anterior Cruciate Ligament Deficiency 2000 and the International Knee Documentation Committee standard evaluation form.[49] However, these questionnaires only determine whether the patient had experienced certain symptoms and/or disabilities and do not allow for the identification or evaluation of functional instability due to ACLD. Therefore, no safe and simple quantitative measure to evaluate functional instability due to ACLD under weightbearing conditions has been established.

Trunk backward tilting is known as a posture at risk for ACL injuries.[8,23,45] We focused on the fact that, clinically, when patients with unilateral ACLD tilt their trunk backward in a single-leg standing position and forward tilt of the index leg is blocked, they complain of knee instability and difficulty in maintaining the backward tilt position. The compressive force applied to the knee under weightbearing conditions has been reported to move the femur backward because of the physiological posterior tibial slope, causing increased anterior shear force on the tibia against the femur.[15,32,50] Moreover, other reports have found that trunk backward tilt (TBT) increases activity in the quadriceps femoris, which is an ACL-antagonist muscle, and relaxes the hamstring, which is the synergist, thereby increasing anterior shear force on the tibia against the femur.[29,46] Boden et al[7,9] stated that forward tilt of the leg under weightbearing conditions acts as a posterior shear force on the tibia against the femur, and the strain on the ACL is reduced.

From these previous studies, we speculated that TBT that blocks forward tilt of the leg can be used as a method of generating anterior shear force on the tibia and provoke a feeling of knee instability. Therefore, we hypothesized that ACLD increases subjective knee instability in TBT that blocks forward tilt of the leg in a single-leg standing position and decreases the angle of TBT compared with the uninjured side. This study aimed to clarify the relationship between subjective knee instability and the TBT angle in an upright, single-leg standing position as well as to investigate the usefulness of the TBT test for quantitatively evaluating functional instability under weightbearing conditions due to ACLD.

METHODS

Participants

A total of 182 patients who visited our institution between February 2017 and November 2018 and who were diagnosed with a unilateral ACL injury were considered as candidates for this study. The diagnosis of an ACL injury was made by a sports orthopaedic surgeon (S.N., K.S.) using magnetic resonance imaging, manual instability tests (Lachman test and pivot-shift test), and KT-1000 arthrometer measurements. Patients with complex knee ligament injuries, such as graft tears after ACL reconstruction, limited joint range of motion (ROM), joint swelling, and pain, were excluded. Cases in which meniscal injuries were detected during ACL reconstruction were also excluded ($n = 132$).

After the above exclusions, the study group consisted of 50 participants (male: $n = 22$; female: $n = 28$). The mean time from injury to inclusion in the study was 2.3 ± 1.7 months. Only patients with limited knee joint ROM up to

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Ethical approval for this study was obtained from Osaka Yukioka College of Health Science.

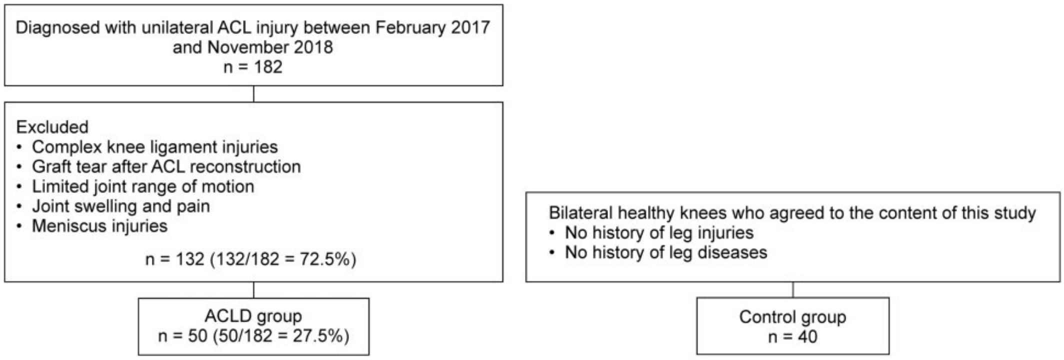

Figure 1. Flowchart of participants. ACL, anterior cruciate ligament; ACLD, anterior cruciate ligament deficiency; MRI, magnetic resonance imaging.

the time of testing performed any ROM exercises, and no other physical therapy was administered. A control group of 40 participants with bilateral healthy knees (male: n = 16; female: n = 24) and no history of leg injuries or diseases was also enrolled (Figure 1). No joint ROM limitations or marked differences between the left and right sides of the hip joint, ankle joint, or shoulder girdle were noted in either group. The sample size was analyzed and calculated as 3 groups, comprising 7 participants per group, considering an effect size of 0.8, significance level of .05, and power of 0.8. This study conformed to the guidelines set forth by the Declaration of Helsinki. Participants were given explanations of the aim and details of the study, and they consented to participation in the study and to publication of the results. This study was approved by the ethics committee of our institution.

TBT Test

The TBT test was performed as follows. We used a custom-made device (Figure 2A) with a metal post and wooden and plastic materials to block forward tilt of the index leg. Both hands were placed against the umbilical region, and the knee of the index leg was held in an extended position as much as possible. The participants were instructed to tilt their trunks backward as far as possible, and the contralateral leg was elevated with the knee extended (Figure 2, B and C). Patients were instructed not to push the custom-made device forward with the index leg. For the consideration of safety, TBT was performed as slowly as possible. The body weight was supported by the heel as much as possible while maintaining the TBT posture. The holding time was set to 3 seconds, and we conducted a preliminary study to determine the length of time that patients could maintain backward tilting on the injured knee. After 3 practice rounds by the participants of both groups, 2 subsequent measurements were taken. The rest period between measurements was 5 seconds. To verify the reliability of the TBT test, a third measurement was added as well as 1 measurement by another tester. If lateral bending and rotation of the trunk were observed during the test, it was administered again. The measurement order on the left and right knees was performed randomly.

A total of 8 markers (on the lateral malleolus of the left and right fibulas, head of the left and right fibulas, left and right greater trochanters, and left and right acromial processes) were affixed onto each participant. A digital camera (EX-ZR300; Casio Computer) was held 2 m laterally and used to capture the participants' postures in a side view during maximum TBT. The images were analyzed using ImageJ version 1.47 (National Institutes of Health). Parameters were the TBT angle (the angle formed by a line perpendicular to the ground and passing through the greater trochanter of the index leg, and a line joining the greater trochanter of the index leg with the acromial process) and the leg forward tilt (LFT) angle (the angle formed by a line perpendicular to the ground and passing through the lateral malleolus of the index leg, and a line joining the lateral malleolus of the index leg and the head of the fibula) (Figure 2B). TBT test photographing and image analysis were performed by 2 testers (T. Matsuo, R.O.). One tester took a picture of the TBT test, and the other analyzed the image on another day. The average value of the 2 measurements was used as a parameter. The TBT test parameters in the control group were the average values of the left and right knees. Overall, we compared 3 sets of data: the injured side, the uninjured side, and healthy knees. Subjective knee instability during the test was recorded using a visual analog scale (VAS) (no instability: 0 mm; extreme instability: 100 mm).

Muscle Strength and Knee Joint Laxity Test

Knee extension and flexion muscle strength and knee instability were measured in the study patients. Muscle strength was measured using Biodex System 4 (Biodex Medical Systems). The participants were seated and belted during the measurements involving the pelvis, trunk, and femur on the measurement side. Isokinetic muscle strength was measured on both sides 5 times, with knee ROM of 0° to 100°, a concentric contraction/concentric contraction mode, and an angular velocity of 60 deg/s. Maximum extension and flexion torques were calculated, and the injured/uninjured side (I/U) ratio was used as the index. Knee instability measurements were performed using a KT-1000 arthrometer (MEDmetric) with the participants awake. We

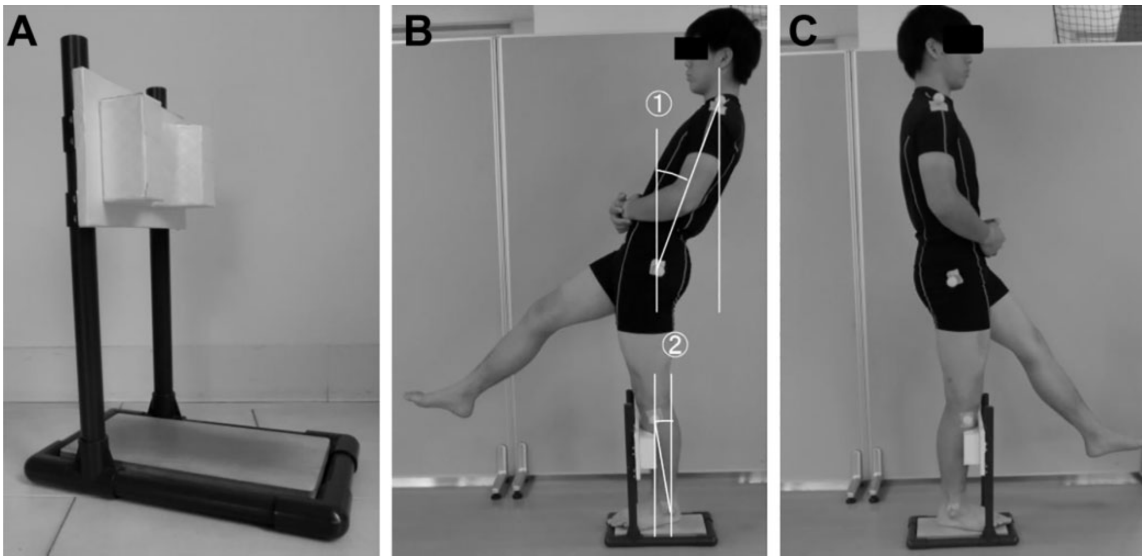

Figure 2. Trunk backward tilt test. The participant kept the knee joint of the index leg fully extended, blocking forward tilt of the index leg, and tilted the trunk backward as far as possible while the contralateral lower limb was elevated (hip flexed and knee fully extended). (A) Custom-made device. (B) Uninjured side tested. (C) Injured side tested. ① Trunk backward tilt angle: The angle between a line perpendicular to the ground and running through the greater trochanter of the index leg, and a line from the greater trochanter to the acromion. ② Leg forward tilt angle: The angle between a perpendicular line from the lateral malleolus to the ground and a line from the lateral malleolus to the fibular head of the index leg.

measured anterior translation of the tibia during maximal manual testing and used the side-to-side difference (SSD) as the index.

Statistical Analysis

Chi-square analysis was used to compare the participants according to sex. The Mann-Whitney *U* test was used to compare the participants by height, weight, body mass index, and age.

The reliability of the TBT test was determined using 20 participants selected from the control group and 20 from the ACLD group. The relative reliability of the TBT test was calculated with the intraclass correlation coefficient (ICC; ICC(1,1), ICC(1,3), ICC(2,1)). The absolute reliability was checked for the presence or absence of systematic bias using Bland-Altman analysis,[6] the minimal detectable change (MDC) and the standard error of measurement (SEM) were calculated using ICC(1,1) and ICC(2,1), and the measurement error was verified.

The TBT test parameters were not normally distributed. Therefore, they were statistically assessed using the Kruskal-Wallis test and the Steel-Dwass test. Multiple regression analysis was performed with the I/U ratio of the TBT angle as the dependent variable and the following independent variables: (1) I/U ratio of knee extension muscle strength, (2) I/U ratio of knee flexion muscle strength, (3) SSD of the KT-1000 arthrometer measurement, (4) sex, and (5) SSD of the VAS score. Statistical software EZR (Easy R; http://www.jichi.ac.jp/saitama-sct/SaitamaHP.files/stat medEN.html) was used for all statistical analyses.[27] For each test, the level of statistical significance was set at 5%.

RESULTS

Table 1 shows participant demographics. There were no significant differences between the 2 groups with respect to any of the variables.

Table 2 shows the results of the relative reliability of the TBT test in healthy participants and those with ACLD. For all parameters, the intrarater and interrater ICCs were $\geq$0.90 in both groups, and the relative reliability was high. Table 3 shows the results of the absolute reliability of the TBT test. There was no additional fixed bias or proportional bias for the intrarater and interrater ICCs in both groups. Table 4 shows the results of the MDC and SEM of the TBT test. The 95% CI of the MDC (MDC_{95}) of the TBT angle was less than 4° for the intrarater and interrater ICCs in both groups, and the SEM was low. The MDC_{95} of the LFT angle was less than 2° for the intrarater and interrater ICCs in both groups, and the SEM was low.

Figure 3 shows the results of the TBT test. The TBT angle of the injured side was 15.0°, indicating a significantly lower value than that of the uninjured side and of healthy knees ($P < .001$ for both). No significant differences were observed in the LFT angle. The VAS score of the injured side was 53.5 mm, which was significantly higher than that of the uninjured side and of healthy knees ($P < .001$ for both).

Table 5 shows the results of muscle strength and knee joint laxity tests, and Table 6 shows the correlation between

TABLE 1
Participant Demographics[a]

	ACLD Group (n = 50)	Control Group (n = 40)	*P* Value
Sex, male/female, n	22/28	16/24	.70
Height, cm	164.5 (159.0-169.8)	165.0 (163.0-170.3)	.20
Weight, kg	57.0 (50.3-70.0)	61.0 (56.4-67.8)	.21
Body mass index, kg/m^2	22.0 (20.3-23.9)	21.7 (20.9-23.6)	.96
Age, y	19.5 (17.0-29.8)	21.0 (19.0-26.0)	.27

[a]Data are presented as median (interquartile range) unless otherwise specified. ACLD, anterior cruciate ligament deficiency.

TABLE 2
Results of Relative Reliability[a]

	TBT Angle				LFT Angle			
	Dominant	Nondominant	Uninjured	Injured	Dominant	Nondominant	Uninjured	Injured
ICC(1,1)	0.96 (0.91-0.99)	0.95 (0.88-0.98)	0.96 (0.89-0.98)	0.97 (0.93-0.99)	0.96 (0.89-0.98)	0.94 (0.85-0.98)	0.91 (0.79-0.96)	0.91 (0.80-0.96)
ICC(1,3)	0.99 (0.97-1.00)	0.95 (0.90-0.98)	0.99 (0.98-1.00)	0.99 (0.93-1.00)	0.98 (0.96-0.99)	0.97 (0.93-0.99)	0.96 (0.91-0.98)	0.95 (0.90-0.98)
ICC(2,1)	0.97 (0.93-0.99)	0.96 (0.91-0.98)	0.99 (0.98-1.00)	0.99 (0.97-1.00)	0.95 (0.87-0.98)	0.90 (0.76-0.96)	0.97 (0.93-0.99)	0.95 (0.87-0.98)

[a]Dominant and nondominant refer to the healthy control knees. Data in parentheses indicate 95% CIs. $P < .001$ for the significance probability in the F test of the ICC. 0.90-1.00 = clinical measures, 0.75-0.89 = good, 0.50-0.74 = poor to moderate. ICC, intraclass correlation coefficient; LFT, leg forward tilt; TBT, trunk backward tilt.

TABLE 3
Results of Absolute Reliability[a]

	TBT Angle				LFT Angle			
	Dominant	Nondominant	Uninjured	Injured	Dominant	Nondominant	Uninjured	Injured
ICC(1,1)								
Fixed bias								
95% CI	0.44 to –1.18	1.74 to –0.07	0.13 to –1.52	0.09 to –1.42	0.60 to –0.22	0.27 to –0.47	0.17 to –0.28	0.28 to –0.29
Proportional bias								
Regression line	–0.21	–0.17	–0.26	–0.31	0.15	–0.01	–0.06	–0.16
P value	.37	.48	.26	.18	.52	.96	.79	.51
ICC(2,1)								
Fixed bias								
95% CI	0.08 to –1.19	1.23 to –0.54	0.09 to –0.55	0.20 to –0.81	0.51 to –0.43	0.87 to –0.03	0.16 to –0.07	0.27 to –0.17
Proportional bias								
Regression line	–0.03	–0.44	–0.19	–0.20	–0.03	–0.16	0.27	<–0.01
P value	.90	.06	.43	.37	.89	.51	.24	.99

[a]Dominant and nondominant refer to the healthy control knees. ICC, intraclass correlation coefficient; LFT, leg forward tilt; TBT, trunk backward tilt.

the independent variables. Among the independent variables, no variable was found to have a correlation coefficient of ≥0.90. The coefficient of determination (R^2) was 0.59 ($P <$ .001). Among the independent variables, the SSD of the VAS score was found to have a weak negative effect on the I/U ratio of the TBT angle (partial regression coefficient estimated value: –0.007; $P < .001$), while the other independent variables had no statistically significant influence. We formulated a multiple regression equation as follows: *I/U ratio of TBT angle* = –0.007 × (*SSD of VAS*) + 1.014.

DISCUSSION

With the TBT test that was developed, which blocked LFT, we found that knees with ACLD exhibited a significantly

TABLE 4
MDC_{95} and SEM Results[a]

	TBT Angle, deg				LFT Angle, deg			
	Dominant	Nondominant	Uninjured	Injured	Dominant	Nondominant	Uninjured	Injured
ICC(1,1)								
MDC_{95}	3.48	3.79	3.45	3.18	1.71	1.56	0.95	1.20
SEM	1.39	1.46	1.38	1.57	0.65	0.49	0.25	0.31
ICC(2,1)								
MDC_{95}	2.67	3.71	1.34	2.12	1.95	1.87	0.49	0.92
SEM	1.36	1.52	1.36	1.55	0.67	0.50	0.24	0.31

[a]Dominant and nondominant refer to the healthy control knees. ICC, intraclass correlation coefficient; LFT, leg forward tilt; MDC_{95}, 95% CI of minimal detectable change; SEM, standard error of measurement; TBT, trunk backward tilt.

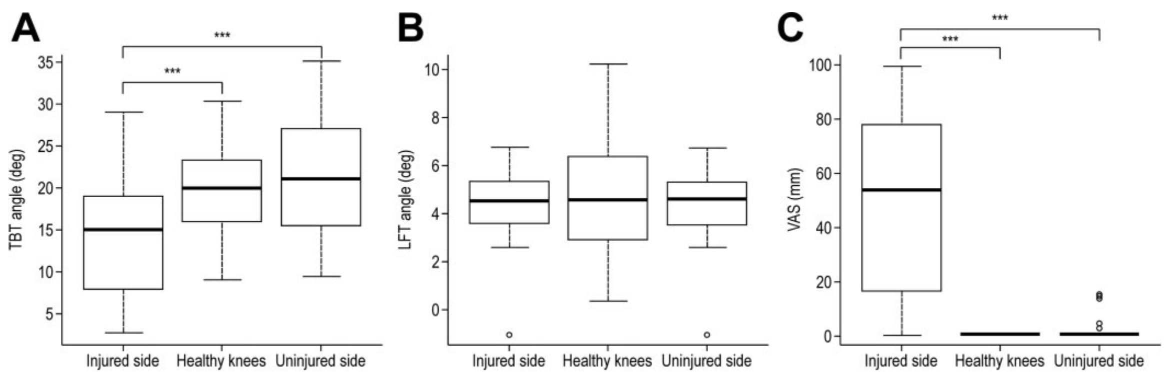

Figure 3. Results of the trunk backward tilt (TBT) test. (A) The TBT angle of the injured side was significantly less than that of the uninjured side and of the healthy knees. (B) There was no significant difference in the leg forward tilt (LFT) angle among the 3 groups. (C) The visual analog scale (VAS) score of the injured side was significantly higher than that of the uninjured side and of the healthy knees. Data are presented as median (interquartile range); circles indicate outliers. ***$P < .001$.

TABLE 5
Results of Muscle Strength and Knee Joint Laxity Tests[a]

	I/U Ratio of Muscle Strength		SSD of KT-1000 Arthrometer, mm
	Extension	Flexion	
ACLD group	0.71 ± 0.21	0.80 ± 0.23	5.8 ± 2.3

[a]Data are presented as mean ± SD. ACLD, anterior cruciate ligament deficiency; I/U, injured/uninjured; SSD, side-to-side difference.

TABLE 6
Correlation Coefficients Between Independent Variables[a]

	I/U Ratio, Extension Strength	I/U Ratio, Flexion Strength	SSD of KT-1000 Arthrometer	Sex
I/U ratio, flexion strength	0.66	—	—	—
SSD of KT-1000 arthrometer	0.04	0.10	—	—
Sex	–0.34	–0.28	0.19	—
SSD of VAS	–0.48	–0.39	–0.21	0.27

[a]I/U, injured/uninjured; SSD, side-to-side difference; VAS, visual analog scale.

greater decrease in TBT angles and significantly higher VAS scores compared with the uninjured contralateral knees and with healthy knees. In the TBT test, the participant was asked to maximally tilt the trunk backward in a single-leg standing position, while forward tilt of the index leg was blocked with a custom-made device. Consequently, this test generated the aforementioned anterior shear force on the tibia, resulting from a physiological posterior tibial slope and from contraction of the quadriceps femoris muscle, thereby requiring the ACL to restrict posterior translation of the femur on the tibial plateau. Therefore, we speculated that in knees with ACLD, backward tilt of the trunk resulted in induced posterior displacement of the femur, which subsequently increased the feeling of subjective knee instability.[32,50] Reduction of the TBT angle in patients with ACLD was speculated to be a postural strategy to avoid anterior shear force and anterior tibial subluxation of the knee joint.

To clarify the variables that affected the TBT angle, we performed multiple regression analysis using the I/U ratio of the TBT angle as the dependent variable. Results indicated that only the SSD of the VAS score negatively affected the I/U ratio of the TBT angle, while the other variables (I/U ratio of knee extension muscle strength, I/U ratio of knee flexion muscle strength, KT-1000 arthrometer SSD, and sex) had no statistically significant influence. Multiple regression showed that the TBT test was associated with subjective knee instability under weightbearing conditions in ACLD and was not significantly affected by factors such as muscle strength, KT-1000 arthrometer SSD, or sex.

It has been reported that mechanoreceptors exist in the ACL[4,17,38] and that proprioception reduces when the ACL tears.[20,21] In addition, a correlation between proprioceptive abilities and subjective feeling has been suggested.[19-21] Therefore, subjective knee instability in the TBT test may be reflective of proprioceptive abilities.

Patients with ACLD have been classified as noncopers and copers, and subjective knee instability is an important determining factor.[24,42,43,47] Eastlack et al[18] reported that the hop test is useful for discriminating between noncopers and copers. However, the hop test is a functional test that evaluates jumping performance, and it is unknown whether it accurately reflects functional instability.[42,43] In addition, as the hop test involves dynamic, intense, and fast movements that potentially produce a high risk of reinjuries, the results are affected by decreased knee strength.[28,36,39,53] The presented TBT test involves slow and gradual movements that can be well-controlled. Thus, the results are not noticeably affected by decreased knee strength, and a high level of safety can be guaranteed in clinical settings.

In all parameters of the TBT test, in both healthy participants and those with ACLD, the intrarater and interrater ICCs were $\geq$0.90, and the relative reliability was high. Portney and Watkins[37] suggested that an ICC of $\geq$0.90 would be appropriate for a clinical test. In addition, because ICC(1,1) and ICC(2,1) were $\geq$0.90, 1 measurement is considered sufficient to obtain accurate results, minimizing physical and emotional stress on the patient. The absolute reliability of the TBT test showed no systematic bias for the intrarater or interrater measurements based on Bland-Altman analysis.[6] Changes below the MDC_{95} in the TBT angle and LFT angle can be attributed to measurement errors. From this result, the TBT test can measure small angle changes of TBT. Therefore, the TBT test is considered to have high relative reliability and high absolute reliability. For the above reasons, it appears that the TBT test is a simple, safe, and highly reliable method for quantitatively evaluating functional instability due to ACLD under weightbearing conditions that reflect subjective knee instability.

This study has some limitations. First, the analyzed participants with ACLD had a mean time from injury of 2.3 $\pm$ 1.7 months, indicating that they were mostly “fresh injury” cases. This may have been because our exclusion of meniscal injuries discounted “chronic injury” cases. Therefore, the results of the test are unknown in chronic injury cases. We excluded meniscal injuries in this study to examine only the symptoms of ACLD. A meniscal injury is a major complication of an ACL injury. Therefore, the study excluded the majority of potential participants. In the future, verification by including chronic injury cases and meniscal injuries should be carried out. Second, we performed 2-dimensional evaluations that did not take into account trunk rotation elements because of safety concerns. Our assessments were conducted by several observers viewing the same photographs as opposed to several observers taking their own photographs for analysis. Third, in this TBT test, measurements of anterior translation of the tibia and muscle activity analysis were not performed.

Herrington and Fowler[24] previously stated that a single evaluation of objective knee function was insufficient for differentiating noncopers from copers and that evaluation methods of patient subjective instability such as the Knee Outcome Survey–Sports and Global Knee Function Rating Scale should be added to the hop test and quadriceps femoris muscle testing. In the future, the TBT test could be a useful method for differentiating noncopers from copers, and we plan to test this hypothesis.

CONCLUSION

The TBT test, in which LFT was blocked in participants with ACLD, showed that the TBT angle was significantly decreased and subjective knee instability was significantly increased in injured knees compared with the uninjured side and with healthy knees. The TBT test is simple and safe and appears to be a highly reliable method for quantitatively evaluating functional instability due to ACLD under weightbearing conditions that reflect subjective knee instability. The test can be an index of treatment outcomes and return to sports through additional objective measurements before and after ACL reconstruction.

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