



Original Article

## Relationship between trunk function evaluated using the trunk righting test and physical function in patients with knee osteoarthritis

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**Abstract.** [Purpose] The present study was to validate the importance of the trunk function evaluated by trunk righting test (TRT) with motor function in patients with knee osteoarthritis (OA) and to show the clinical use of TRT. [Subjects and Methods] This study included 50 patients with knee osteoarthritis who underwent total knee arthroplasty in our hospital. Correlations between physical functional test, such as muscle strength, balance function, and performance and TRT were statistically evaluated. [Results] The independent factors for ipsilateral TRT were maximal isometric knee extensor strength test and ipsilateral step test. The operator and non-operator side TRT were significantly associated with TUG. [Conclusion] The results showed that the physical functions are correlated with the trunk function evaluated by TRT of patients with knee OA, suggesting that healthcare workers must take into consideration the trunk function, as well as lower extremity function to improve physical function.

**Key words:** Knee osteoarthritis, Trunk function, Trunk Righting Test

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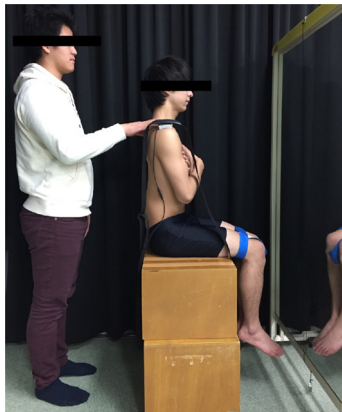
### INTRODUCTION

Knee osteoarthritis (OA) is a degenerative joint disease characterized by accumulated mechanical stress leading to pathological changes, such as articular cartilage degeneration, failure, loss, and osteophyte formation<sup>1</sup>). Knee OA ultimately leading to knee joint malalignment, and tectonic problems are increased, such as varus deformity of the knee<sup>3</sup>) and knee instability<sup>4</sup>), thereby impeding the ability to perform many motions used in daily life. Furthermore, the knee index is influenced by the functional alignment of the trunk, pelvis, and lower limb segments with respect to the knee during movement and ground reaction force generated<sup>5</sup>). Knee joint malalignment is known to induce problems with the trunk. The knee does not function in isolation from the rest of the lower extremity, hip, pelvis, and trunk may play a role in influencing medial knee load during ambulation<sup>6, 7</sup>). In addition, knee OA has highlighted the importance of the kinematic chain<sup>8</sup>). Therefore, it is considered that comprehensive physical therapy is needed, including hip, ankle, and trunk function to improve physical function in patients with OA. Trunk stability is integral to the performance of activities of daily living<sup>9</sup>). For example, lower levels of trunk muscle attenuation have been associated with reduced functional capacity in healthy older adults<sup>10</sup>). Furthermore, the cross-sectional studies reported small-to-medium correlations between trunk muscle strength and balance, functional performance, and falls in older adults<sup>11</sup>).

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**Fig. 1.** Start position of the trunk righting test  
The examiner palpates the line in the upper portion of the trapezius muscle. The examiner prevents the compensation. The subject confirms the position of the plate while looking at the mirror.



**Fig. 2.** The length of the belt is decided according to the start position  
The sensor of the handheld dynamometer is placed on the inner part of the acromioclavicular joint (a). The position of the belt is moved by 10 cm toward the side (b).

Generally, the trunk function was evaluated subjectively. Few reports evaluated trunk function quantitatively, such as measurement of muscle thickness of the abdomen using ultrasonography<sup>12)</sup>, electromyography<sup>13)</sup>, assessment of core strength endurance of ventral and dorsal trunk muscle chains<sup>14)</sup>, and isokinetic and isometric trunk extensor and flexor tests on dynamometer<sup>15)</sup>. These are considered to be valid in evaluating trunk muscle function. However, trunk function should be evaluated with more physiological conditions, such as an anti-gravity position. Novel objective evaluation method for trunk function (trunk righting test, TRT) was recently established<sup>16)</sup>. TRT is considered to be reasonable because the test was performed under loaded sitting position. Therefore, we hypothesized that TRT and motor function of patients with knee OA are correlated and TRT can better evaluate the trunk function of patients with knee OA. The purpose of the present study was to validate the importance of the trunk function with motor function in patients with knee OA and to show the clinical use of TRT.

## SUBJECTS AND METHODS

This study included 50 patients with varus OA who planned to undergo total knee arthroplasty in our hospital (12 males and 38 females, age:  $73.4 \pm 9.4$  years, height:  $153.8 \pm 8.9$  cm, weight:  $60.0 \pm 12.9$  kg, BMI:  $25.2 \pm 3.9$ ). Kellgren-Lawrence classification in the operated side was as follows: grade II: 2 patients, grade III: 23 patients, grade IV: 25 patients; non-operated side: grade I: 2 patients, grade II: 9 patients, grade III: 25 patients, grade IV: 14 patients. Patients with nervous system disease were excluded from this study. All the patients understood the purpose of this study and provided informed consent prior to participation according to the ethical standards of the Declaration of Helsinki.

Trunk function and physical were evaluated via the following tests: TRT<sup>16)</sup>, maximal isometric knee extensor strength test<sup>17)</sup>, time of standing on one leg, dynamic standing balance test (step test, ST)<sup>18)</sup>, timed-up-and-go test<sup>19)</sup>, 5-times sit-to-stand test (5STS)<sup>20)</sup>, and 30-s chair stand test (CS-30)<sup>21)</sup>.

TRT was performed based on a previous report<sup>16)</sup>. Briefly, the subjects were seated on a box with their feet above the ground. The sensor pad was fixed on the inner part of the acromioclavicular joint by adjusting the length of the belt restraint strap to be perpendicular to the bearing surface (Fig. 1). Subsequently, the subjects were asked to move their shoulders with the sensor, 10 cm outward from the original position (Fig. 2). The subjects applied maximum power to the belt for 5 s, and the highest values were measured using a handheld dynamometer ( $\mu$ Tas F-1; ANIMA Co., Tokyo, Japan). The measurements were repeated thrice with at least a >30-s interval to negate the influence of fatigue. Patients were confirmed verbally no fatigue. The mean of the three measurements was normalized by dividing the body weight. The measurements were performed in both sides.

The subjects were instructed to remain seated in an upright position and place both hands on the upper legs to prevent compensation during the maximal isometric knee extensor strength test<sup>17)</sup>. Straps were fixated to standardized attachments on the treatment table leg. The strap length allowed for an isometric contraction to be performed with the knee at 90° during extension. Discrepancies between patients' knee angles were minimized using standardized strap lengths. The handheld dynamometer was positioned perpendicular to the anterior aspect of the tibia, center of the medial malleolus. Maximum isometric knee extensor strength was measured thrice. The mean of the three measurements were normalized by dividing the body weight, and the values were used in this study.

Single-leg standing time was performed with eye-opening and hands on hips. Standing was performed with hip and knee

joints in the extended position. The hip was in a neutral position, and the knee was slightly flexed in the contralateral side. The subjects were instructed to keep both acromions parallel to the ground. The measurements were maintained at maximum for up to 180 s. The measurements were performed thrice, and the mean was used in this study.

The method used to perform ST was a minor modification of that reported by Hill et al<sup>18</sup>). Briefly, the subjects step one foot onto a 20-cm high block, and then, quickly retract the foot from the block to the ground. The subjects repeated this motion 10 times, and the total times were measured. The subjects were instructed to perform the motion as quickly as possible. The support legs were regarded as the measured foot. The examinations were repeated twice, and the mean values were used.

TUG<sup>19</sup>) measurement started with the patients sitting with their feet on the floor and their arms resting on the chair armrest. The patients were asked to stand up without using their arms, walk for 3 m, turn around, walk back, and sit down. The measurement ended when the subject's buttocks regained contact with the chair. The examinations were repeated thrice, and the mean values were used.

The patients were instructed to stand up from and sit down on a chair as quick as possible with their arms folded across their chests during the 5-times sit-to-stand test (5STS)<sup>20</sup>) and 30-s chair stand test (CS-30)<sup>21</sup>). The height of chair was 0.40 m without armrests. The 5STS was defined as the time with 5 cycles of standing up and sitting down. The CS-30 was defined as the cycles of standing up and sitting down within 30 s. The examinations were repeated twice, and the mean values were used.

Statistical analysis was performed using the SPSS statistical program (version 21, IBM Corporation). The first study included to 100 knees with 50 cases. The relationships between various physical functions, including ipsilateral maximal isometric knee extensor strength test, ipsilateral single-leg standing time, and ipsilateral ST, and ipsilateral TRT were evaluated using Spearman rank correlation coefficient and regression analyses. In addition, stepwise multiple regression analysis was used, and various potential confounders (maximal isometric knee extensor strength test, single leg standing time, ST) were included as independent variables and TRT as dependent variables. The second study investigated the relationship between the TUG, 5STS and CS-30, and bilateral TRT using Spearman rank correlation coefficient and regression analyses in 50 patients. Stepwise multiple regression analysis was used, and various potential confounders (TUG, 5STS, CS-30) were included as independent variables and TRT as dependent variables. We included 50 patients after we calculated the sample size with the G\*power 3.1.9 program with an  $\alpha$  level of 0.05 and power analysis of 0.80, with an estimated effect size of 0.50. The total sample size was 26. Post hoc power analysis further confirmed that the power of the present study is 0.98. A significance level of  $p < 0.05$  was selected.

## RESULTS

TRT was middle positively correlated with ipsilateral maximal isometric knee extensor strength test and ipsilateral ST ( $r=0.51$ ;  $p < 0.01$ ,  $r=0.46$ ;  $p < 0.01$ , respectively). In addition TRT was mild positively correlated with Time of standing on one leg ( $r=0.26$ ;  $p < 0.01$ ) (Table 1). We conducted multiple regression analysis adjusted for ipsilateral maximal isometric knee extensor strength test, ipsilateral time of standing on one leg and ipsilateral ST. The result showed that the independent factors for ipsilateral TRT were maximal isometric knee extensor strength test and ipsilateral ST ( $p=0.003$ ,  $p=0.016$ , respectively) (Table 2).

The studies to investigate the relationship between the TUG, 5STS and CS-30, and bilateral TRT showed that the operator side TRT was significantly associated with TUG and 5STS ( $r=-0.50$ ;  $p < 0.01$ ,  $r=-0.39$ ;  $p < 0.01$ , respectively) (Table 1). The non-operator side TRT was significantly associated with TUG ( $r=-0.48$ ,  $p < 0.01$ ) (Table 1). We conducted multiple regression analysis adjusted for TUG, 5STS, and CS-30. The operator and non-operator side TRT were significantly associated with TUG (Table 3).

## DISCUSSION

The most important finding of this study was that the load-bearing function of the trunk was correlated with motor function of patients with knee OA. This study evaluated the body trunk function using TRT and examined the relationship between TRT and physical function in patients with knee OA. The results showed that TRT was associated with maximal isometric knee extensor strength test, time of single-leg standing time, and ST. TRT is particularly significantly related to ipsilateral maximal isometric knee extensor strength test and ipsilateral ST. Because maximal isometric knee extensor strength test and ST are tests that evaluate lower limb power and dynamic balance, respectively, the results suggested that trunk function were moderately correlated with ipsilateral lower limb power and dynamic balance.

The results of this study support the findings of several previous studies<sup>22, 23</sup>). Sato et al.<sup>22</sup>) examined the effects of 6-week core strength training on ground reaction forces, lower extremity stability, and overall running performance in recreational and competitive runners. The result showed that the core strength training group showed faster times in the 5,000-m run after 6 weeks. They suggested that core strength training may be an effective training method for improving performance in runners. The target is different from 5,000-m runners and knee OA, but it shows the influence of trunk function on physical function. Rivera<sup>23</sup>) also reported that core muscles provide stability that allows generation of force and motion in the lower extremities, as well as distributing impact forces and allowing controlled and efficient body movements. Because imbalances or deficiencies in the core muscles can result in increased fatigue, decreased endurance, and injury in runners,

**Table 1.** TRT and relationship between each measurement item

	Maximal isometric knee extensor strength test	Time of standing on one leg	ST	TUG	5STS	CS-30
TRT	0.51**	0.26**	0.46**			
TRT operator side				-0.54**	-0.39**	0.28 (p=0.057)
TRT non-operator side				-0.48**	-0.36*	0.32*

\*p<0.05, \*\*p<0.01 Spearman's rank correlation coefficient

**Table 2.** Stepwise multiple regression analyses for the repeated TRT

Predictor	Standardized coefficient	p value	VIF
Maximal isometric knee extensor strength test	0.33	0.003	1.441
ST	0.26	0.016	1.441

(R: 0.53, R<sup>2</sup>: 0.28)

R=multiple-correlation coefficient

R<sup>2</sup>=shared variance

VIF: variance inflation factor

**Table 3.** Stepwise multiple regression analyses for the repeated TRT operator side and non-operator side

	Predictor	Standardized coefficient	R <sup>2</sup>	p value	VIF
Operator Side	TUG	-0.59	0.35	0.000	1.000
Non-Operator Side	TUG	-0.51	0.27	0.000	1.000

R<sup>2</sup>=shared variance

VIF: variance inflation factor

they emphasized that core strengthening should incorporate the intrinsic needs of the core for flexibility, strength, balance, and endurance, and the function of the core in relation to its role in extremity function and dysfunction. We also considered that the load-bearing function of the trunk is an important element for physical activity, which is supported by the lower extremities. The maximal isometric knee extensor strength is mainly dependent on quadriceps contraction. Patients with knee OA with superior quadriceps muscle and dynamic balance expressed by ST are suggested to be likely stronger to support the lower limbs. The results suggested that the sides with stronger or dominant support from the lower leg also acquired stronger load from the trunk. We considered that the trunk load function is the foundation of both the muscle strength in the lower limb and balance ability in the one-leg support. We previously discussed the relationship between the trunk function and lower extremities<sup>16</sup>). In our hypothesis, supporting force from trunk muscle was transmitted to the lower extremities and combined with the force from lower extremities itself while standing. The combined force would be a power against the floor force and be a mechanical base for body movements and posture stability of gravity. Thus, the force from the trunk, transmitted to the lower extremities, is considered to be essential for such movements and stability<sup>16</sup>). It is also conceivable in 5STS and TUG. 5STS performance is influenced by multiple physiological and psychological processes and represents a particular transfer skill, rather than a proxy measure of lower limb strength<sup>20</sup>). Therefore, the load-bearing function of the inferior side of the trunk could be suggested to be a finding that indicates physical activity capacity in patients with knee OA. In contrast, TUG includes sitting, standing, walking and change of direction comprises repetition of the smooth weight transfer toward the bilateral lower limbs and anti-gravity activities of the lower limbs. Therefore, both sides of the TRT are considered to be correlated to TUG.

Based on the present study, patients with stronger trunk load before surgery might achieve faster recovery in total knee arthroplasty. In addition, the results also suggested that therapy to improve the load bearing of the trunk might be used as an acceptable treatment for patients with knee OA. These hypotheses need further investigation because no consistent evidence supports the effect of trunk reinforcement on the treatment of knee OA.

This study has several limitations. First, the inclusion of patients with unilateral and bilateral knee OA might affect the results. Second, the inferior side was not always the operated side. These facts might be confusing in the current results. Finally, because this study is a cross-sectional study, the question whether TRT leads to the improvement of the trunk function remains unknown. A longitudinal future study is important to verify the question.

In summary, the relationship between the load-bearing function of the trunk and physical function of patients with knee OA was examined. The results showed that the physical functions are correlated with the load-bearing function of the trunk

of patients with knee OA, suggesting that healthcare workers must take into consideration the trunk function, as well as lower extremity function to improve physical function.

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