

# Star Excursion Balance Test as an Exercise to Improve Static and Dynamic Balance in Community-Dwelling Persons with Unilateral Osteoarthritis of Knee

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## Abstract

Knee joint stability is important for postural stability. Abnormal weight distribution is common in individuals with unilateral osteoarthritis of knee (OA knee) as compensatory mechanism for pain and joint malalignments. Various forms of conventional physiotherapy interventions have been used to prevent further degenerative process. Star excursion balance test (SEBT) has been invented to assess dynamic postural stability. This present study was aimed to investigate effects of SEBT as a postural control exercise training tool (SEBTx) in persons with unilateral OA knee. Fourteen participants were randomly assigned to control group (n = 7) and SEBTx group (n = 7). The control group received weekly routine physiotherapy interventions (joint mobilization, ultrasound therapy, transcutaneous electrical nerve stimulation, and taping). In addition to the routine interventions, the SEBTx group was instructed to perform SEBTx for 30 min/session, 3 sessions/week, for 4 weeks. Primary outcome (weight distribution on posturography in 8 directions – anterior, Rt. anterolateral, Rt. lateral, Rt. posterolateral, posterior, Lt. posterolateral, Lt. lateral, Lt. anterolateral) was measured at baseline and 4 weeks post-intervention. Secondary outcomes numeric pain rating scale (NPRS) and Timed Up and Go test (TUG) were used to assess pain and dynamic balance, respectively. Results showed that weight distribution in SEBTx group significantly improved in the Lt. posterolateral and posterior directions post-intervention. Moreover, NPRS in SEBTx group significantly reduced from 47.9±7.4 to 33.3±6.0. Lastly, TUG significantly reduced from 13.5±0.9 to 11.5±0.7 s in SEBTx group. In conclusion, the SEBTx should be applied to improve postural balance in individuals with unilateral (OA knee).

**Keywords:** osteoarthritis of knee, star excursion balance test, dynamic postural control, Timed Up and Go, knee pain

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## Introduction

Knee joint stability is important for postural stability of the entire body.<sup>1</sup> Therefore, accumulative abnormal biomechanical knee joint loading essentially leads to afferent somatosensory dysfunction in osteoarthritis of knee (OA knee), resulting in postural sway.<sup>2, 3</sup> Postural

sway in OA knees attributed to lack of accurate proprioceptive feedback.<sup>3</sup> When knee proprioception is altered, proprioceptive input is compensated by foot and ankle mechanoreceptors.<sup>4,5</sup> Moreover, an inter-limb weight-bearing asymmetry is also observed as off-loading mechanism on affected knee.<sup>6</sup> This increases risk of further damage, particularly on the unaffected side.<sup>7</sup> For this reason, treatments of postural sway would be useful to persons with knee OA.<sup>8</sup>

Balance training exercise was reported to improve OA knee patients' abilities in controlling posture. In this way, strengthening exercises and dynamic balance training can improve ability to balance in OA knee patients.<sup>9,10</sup> Previous studies showed that dynamic balance training showed improvement in postural sway in diabetic neuropathy patients.<sup>11</sup> Star excursion balance test (SEBT) has been commonly used for assessing dynamic postural stability.<sup>12</sup> The test consists of a person balancing on one leg and repeatedly performing single-leg squat movements to use the non-stance leg to reach maximally along one of eight diagonal lines, each at 45° intervals from each other.<sup>13</sup> Participants are instructed to touch all 8 lines 6 times before measurements were made. Interestingly, a study showed that these repetitive movements result in sensorimotor learning from vestibular, visual, and somatosensory feedbacks.<sup>14</sup> Therefore, this present study was aimed to investigate effects of SEBT as a postural control exercise training tool (SEBTx) on static and dynamic postural balance and pain level in persons with unilateral OA knee.

## Materials and Methods

### Human subjects

Fourteen participants with unilateral OA knee from neighborhood community were allocated to control group (n = 7) and SEBTx group (n = 7) after being assessed for eligibility. Inclusion criteria were OA knee according to the American College of Rheumatology (ACR) clinical classification criteria for OA knee, ability to write and speak Thai, and informed consent. Exclusion criteria were cognitive impairment and uncontrolled cardiovascular diseases.

### Baseline Assessments

The community-dwelling subjects were evaluated

for years of knee pain, number of falls in 1 year, and other demographic data. The data of the completed subjects are shown in Table 1. The subjects were re-confirmed for the OA knee with the ACR clinical classification criteria.

### Intervention and exercise procedures

Both control and experimental groups received weekly routine physiotherapy interventions (joint mobilization, ultrasound therapy, transcutaneous electrical nerve stimulation, and taping when appropriate). In addition to the routine interventions, the SEBTx group was instructed to perform SEBTx.<sup>12</sup> Directional mapping of SEBTx and other details were described.<sup>15</sup> The SEBTx was performed for 30 min/session, 3 sessions/week, for 4 weeks.

### Outcome Measurements

Primary outcome – weight distribution used as a proxy of static postural sway machine was measured with biofeedback posturography (Fig. 1). The machine consisted of load cell transducers collecting frequency of weight distribution for 10 s in 8 directions. A processor (node micro-controller unit, NodeMCU) received signals from the transducer-connected hx711 amplifier. The data were displayed on the Raspberry Pi. The monitor showed frequency of weight distribution in each direction proportionally to body weight. Secondary outcomes – 100-point numeric pain rating scale (NPRS) and Timed Up and Go test (TUG) were used to assess pain and dynamic balance, respectively.<sup>16</sup>

### Statistical Analysis

If not specified otherwise, the data are expressed as mean ± SEM. Normality of sample data was tested by Kolmogorov-Smirnov test. Means of two dependent groups were compared by Wilcoxon signed-rank test. The level of statistical significance was P < 0.05. All data were analyzed by IBM SPSS v.26.

## Results

### Baseline Assessments

Fourteen patients completed the program (control, n = 7 and SEBT, n = 7). All subjects had unilateral knee pain. All basic demographic data are shown in Table 1.

Star excursion balance exercise improves static postural stability in a patient with OA knee

In clinical setting, the SEBT is a series of 8 lower-extremity-reaching tasks purported to be useful in identifying lower extremity functional deficits. Here we used the SEBT as the exercise and found that it reduced the static postural sways in the left anterolateral (0.6±0.1 to 0.0±0.0) and posterior directions (5.4±1.0 to 0.0±0.0) (Fig. 2B). Meanwhile, none of the post-intervention static postural sways were changed in the control group (Fig. 2A)

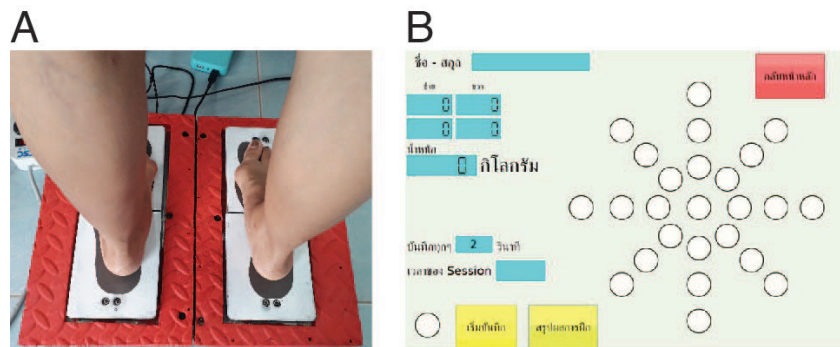
**Star excursion balance exercise reduces pain**

The numeric pain rating scale (NPRS) in control

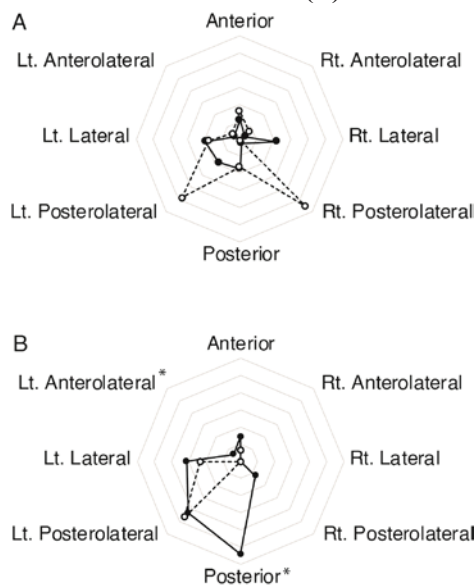
was not changed (62.9±4.3 to 54.3±5.5 in baseline and post-intervention, respectively), but significantly reduced from 47.9±7.4 to 33.3±6.0 in the exercise group (Fig. 3A).

**Star excursion balance exercise improves dynamic balance during walking**

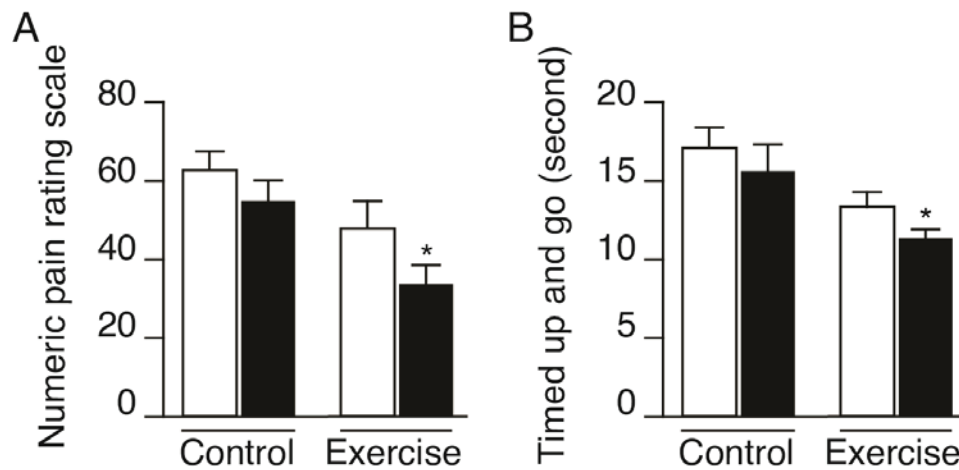
The TUG developed by Podsiadlo and Richardson is a method for evaluating for the dynamic balance during walking.<sup>17</sup>In control group, post-intervention TUG was not significantly different from baseline (17.25±1.5 vs 15.7±1.7 s in baseline and post-intervention, respectively). In contrast, the TUG statistically reduced from 13.5±0.9 to 11.5±0.7s in exercise group(Fig. 3B).



**Figure 1** Measurement of static postural stability in a patient with OA knee on the biofeedback posturography machine (A). Directional mapping of the biofeedback posturography machine. 1, Anterior; 2, Rt. Anterolateral; 3, Rt. Lateral; 4, Rt. Posterolateral; 5 Posterior; 6 Lt. Posterolateral; 7, Lt. Lateral; 8, Lt. Anterolateral (B).



**Figure 2** Mean of frequency of weight distribution at baseline (0-week, solid line) compared to 4-week post-intervention (dotted line) in control (A) and SEBTx (B) groups. \*P<0.05 compared to respective baseline.



**Figure 3** Level of numeric pain rating scale at baseline (white bar) and 4-week post-intervention (black bar) in control and SEBTx(exercise) groups (A). Timed Up and Go at baseline (white bar) (B). \*P<0.05 compared to respective baseline.

**TABLE 1** Basic characteristics of subjects at baseline

Variable	Control	Exercise
Age (years)	57.6 ± 2.5	62.6 ± 2.4
Years of knee pain	3.3 ± 1.0	2.5 ± 0.5
Number of falls in 1 year	0.7 ± 0.3	1.3 ± 0.5
Gender		
Male	0	1
Female	7	6
Height (cm)	153.2 ± 1.2	156.4 ± 1.6
Weight (Kg)	59.9 ± 1.9	62.0 ± 2.5
BMI (Kg/m <sup>2</sup> )	25.5 ± 0.9	25.5 ± 1.2

**Discussion**

This present study shows that the star excursion balance exercise improves postural and dynamic stability and reduced pain in persons with unilateral osteoarthritis of knee. Our conclusion is based on the

following findings: (1) The exercise *reduces* the standing postural sways. (2) The exercise reduces time spent for the TUG test. (3) *The* exercise reduces pain level.

Postural sway has been used to characterize deficits of postural control system during quiet stance.<sup>3, 18</sup> The

postural stability involves coordinated functions of sensorimotor system including muscle activities and mechanosensation in joint capsule.<sup>19</sup> It can be insinuated that the SEBTx augmented postural stability in OA knee by means of activating foot muscle activities and knee joint mechanosensors.

On two-barefoot standing, healthy older individuals had higher plantar pressure on the anterior halves of the feet than the posterior ones (approximately 6:4 ratio).<sup>20</sup> In contrast, this present study found higher plantar pressure on the posterior halves. Moreover, we also found positive effects of the SEBTx on the plantar pressure distribution, especially in the posterior parts of the feet. A previous study showed that SEBTx activated electromyogram signals of tibialis anterior, peroneus brevis, and gastrocnemius muscles. The tibialis anterior activity was particularly activated during posterior-oriented SEBT reaches.<sup>21</sup> Moreover, the tibialis anterior was also highly correlated with improved postural stability after balance board exercise.<sup>22</sup> Therefore, an improvement of the plantar distribution in the present study might be attributed to the enhanced activity of tibialis anterior muscles.

The joint capsule has 4 types of joint receptors in different areas – free nerve endings (pain receptors), Golgi tendon organ (GTO)-like receptors (proprioceptors), Ruffini corpuscles (stretch receptors), and Pacinian corpuscles (mechanoreceptors).<sup>23-25</sup> All these joint receptors maintain normal joint sensation.<sup>26</sup> However, only the Pacinian corpuscles sense mechanical stress and provide afferent information on joint position and velocity.<sup>27</sup> Moreover, functions of these mechanoreceptors are impaired in OA knee.<sup>28</sup> Additionally, TGFβ1-mediated inflammation in OA knee might lead to intra-articular ligament dysfunctions.<sup>29</sup> Therefore, further study might be beneficial to investigate whether the SEBTx exercise probably stimulate mechanical functions of the Pacinian corpuscles through inhibition of TGFβ1-mediated pathway.

Effects of exercises on pain reduction have been widely studied. Takacs and co-workers reported that balance training program improved and numeric pain rating scale (NPRS) in the persons with OA knee.<sup>10</sup> It has been shown that long-term exercise reduced pro-inflammatory substances including substance P and

interleulin-6.<sup>30</sup> Mechanistically, the SEBTx exercise might reduce pain scale through neuromodulation system.

Dynamic balance during walking in community is challenging for the persons with OA knee.<sup>31</sup> In this present study, the post-intervention dynamic balance improved in the exercise group as measured by the TUG. Our finding was in line with UzunkulaoGlu et al. who recently illustrated that the balance training with tandem movements improved from 13.2 to 11.2 s.<sup>32</sup> Moreover, the time spent for TUG in the present study was lower than those previously reported fall risk cut-off points.<sup>33,34</sup>

In conclusion, these findings suggested that 30-minute SEBT exercise training 3 times/week for 4 weeks was efficient to improve static and dynamic balance in the persons with the unilateral OA knee. Further study should invest more time per training session to see if it can fall rate per year.

**Conflict of Interest:** The authors declare that they have no conflict of interest.

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**Informed Consent:** Informed consent was obtained from all individual participants included in the study.

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