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Effect of sling exercise on running speed, reaction time, and dynamic balance in people with chronic ankle instability

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KEYWORDS
Chronic ankle instability;
Sling exercise;
Running performance;
Core stability.

ABSTRACT

Chronic ankle instability can affect speed, plantar flexion reaction time and, dynamic balance, all of which are important aspects of running performance. Core muscle activity on both a stable and an unstable exercise can directly enhance performance. However, there remains a paucity of understanding about the effects of different types of exercise on running performance. Thus, the purpose of this research was to compare the effects of sling and floor exercise on running speed, plantar flexion reaction time, and dynamic balance. Twenty-two participants with chronic ankle instability were enrolled in this study. Participants were split into two groups, each receiving core muscle training three times per week for four weeks. Running speed, plantar flexion reaction time, and dynamic balance were assessed using a single beam photocell timer, electromyography, and Y Balance Test™ at baseline and after four weeks of training. As a result, statistical improvements in running speed, plantar flexion reaction time and dynamic balance were shown in the sling group (11.50 vs. 10.95, *p*-value = 0.016, 369.08 vs. 240.15, *p*-value = 0.006 and 79.61 vs. 86.27, *p*-value = 0.036, respectively). However, the floor group showed only dynamic balance (84.98 vs. 96.53, *p*-value < 0.001) compared to the baseline. Further, there was a statistical difference after exercise in plantar flexion reaction time and dynamic balance (240.15 vs. 334.19, *p*-value = 0.042 and 86.27 vs. 96.53, *p*-value = 0.005, respectively). Thus, the results showed that four weeks of a sling and floor-based core muscle training program could increase running performance. To summarize, sling exercise focuses on speed, whereas floor exercise emphasizes balance.

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Introduction

Running is the most popular type of exercise for people of all ages. Furthermore, running benefits total functional performance, including cardiorespiratory capacity development[1]. On the other hand, it can result in injuries to the body structure due to accidents or the usage of the wrong shoes or field. A simple self-assessment questionnaire found that 45 amateur runners in Thailand had a history of injury (48.9% ankle joints, 28.9% knee joints, 17.8% back, and 4.4% hip joints). Based on statistical data from the amateur runners, ankle sprains were not the injury with the highest prevalence (20.2% of the most common injury sites) and incidence (62.5-111 per 1000 person-year) in runners following knee pain[2]. However, most ankle sprains result in recurrent injuries to the same joint (lateral ankle sprain) and lead to chronic ankle instability (CAI)[3]. The CAI has been linked to a reduction in ankle muscle strength, neuromuscular control, postural control, ankle joint position sense, and kinesthesia[4, 5]. Summarized to a delayed reaction time, it affects the motor time of muscles around the joint[6]. These limitations will have a direct impact on running pace and performance.

The fundamental treatment for an ankle sprain in its early stages is ice compression and anti-inflammatory medication. During the stable period, rehabilitation exercise for strengthening, proprioceptive awareness, strength, flexibility, and balance is employed[7]. Furthermore, a previous study by Dastmanesh and Shinkle (2012) found a relationship between core muscle strength, stability, and improved running performance after an ankle sprain[4]. The exercises for core muscle strength can improve postural control and functional mobility. Additionally, they can reduce the risk of lower-limb injuries when running[4, 8]. The anatomy training approach is used to describe the effectiveness due to the fascia lines system, such as the superficial back line, superficial front line, lateral line, spiral line, functional line, and deep front line. This is explained by the link of body soft tissue as muscle activation transmission[9], which affects running performance. Core muscle training is being used in a variety of ways. The term "floor exercise" refers to a static contraction of the core muscle that is aided by limb movement or external disturbance on a stable surface. This results in a considerable increase in core stability. Sling exercise, on the other hand, is an unstable support exercise that consists of multi-planar and multi-joint motions against gravity with body weight as resistance, which can help with a proprioceptive sense of the spinal joint and core stability muscle strength through neuromuscular control[10, 11]. Furthermore, the unstable support exercise was found to increase muscle activation and proprioceptive sensitivity more than the stable support exercise in a prior study[12, 13]. However, there was a lack of evidence concerning the improvement in ankle proprioceptive sensibility or running performance following a session of sling exercise training. As a result, the purpose of this research is to compare the effects of sling exercise and floor exercise after four weeks of training.

Materials and methods

Participants

A randomized control trial was used in this study. The main outcome is running speed. The sample size was calculated using the G-power program (version 3.0.1) based on assumption with the following parameters: ANOVA: Repeated measures, within-between interaction, effect size of 0.5, significance level (α) of 0.05, desired power (1-β) of 0.95, and 30% dropout rate. Twenty-two participants were assessed. All participants were allocated equally to two groups with sex matched-pairs by sealed envelope randomization, sling group, and floor group. The inclusion criteria were as follows[14]: (1) Age between 18-23 years old, (2) Exercise in running at least 30 minutes per day, three days per week, (3) Normal body build (BMI = 18.5-22.9 kg/m^2), (4) History of an ankle sprain on the "kick-off" side, (5) Cumberland Ankle Instability Tool < 24, (6) Positive for any anterior drawer test or talar tilt test, (7) Level of core stability test 0-2 by pressure biofeedback. The exclusion criteria were as follows: (1) History of lower limb surgery in the six months before participation, (2) Acute injury of a lower limb during the testing period, (3) Diagnosed with heart disease, (4) Taking any medication causing drowsiness during the testing period, (5) Hearing impairment or deafness. The study was approved by the ethics review board of Rangsit University (Approval number RSUERB2020-0077).

Protocols

Before the group's allocation, all participants who satisfied the inclusion and exclusion criteria were put through a single 60-meter sprint race trial. Participants were told to run as quickly as they could following the start sound, and the highest running speed was recorded by a single beam photocell timer (Dashr, USA) from the starting point to the endpoint[15, 16]. All participants were allowed one round of practice, but they had to rest for at least five minutes before data collection. The plantarflexion reaction time was measured using surface electromyography (DELSYS, Delsys Incorporated, USA) located at the sprained leg on the middle part of the medial gastrocnemius. Participants were allowed to set in the block as starting position with a sprained leg on the back. When the starting sound was heard, the participants began to run as fast as possible. The delay of the graph from the initial signal to the first muscle activation was recorded as plantarflexion reaction time, and the average of two testing times was employed in this study[17]. Measurement of dynamic balance with a Y Balance Test™ (modified Star Excursion Balance Test; mSEBT) was reported to be reliable with the standardized equipment and methods[18]. The instruction was to execute a single-leg stand in the middle of the Y-balance kit platform (FMS Y-BALANCE) on the injured ankle. Both hands were placed on the hips during the test, and one leg was used to push a box as far as possible with the big toe and return to the initial two-foot standing position, three times for practice and three times for the test in each direction[19]. Each subject was allowed to bend the knee and hip of the fixed leg to reach as far as possible while reaching for the leg. However, the task resulted in failure and would have to be redone if the subject 1) could not stand on one leg, 2) moved the fixed leg from the marked point, 3) could not hold both hands on the hips, 4) could not return to the initial two-foot standing position, 5) showed obvious swaying during the test, 6) the big toe on the reached leg touched the ground before returning to the center, or 7) the reached leg showed pushing force onto the box. The greatest distance in each direction was used to calculate by the formula for composite reach distance, which is the total of three directions of reach distance divided by three times the leg length and multiplied by 100[20]. All of the data collection was recorded by the researcher (A), an experienced physiotherapist, and a researcher on the sports field.

Exercise protocols

Participants were given five models of sling exercises (Redcord®) or floor exercises, as indicated in Table 1, under the supervision of the researcher (B), an experienced sports physiotherapist, and rehabilitation exercise. The experimental group was given the sling exercise, which was recommended by the Redcord® fitness program for running and theory Redcord active introduction handbook (Figure 1). The control group, on the other hand, received the floor exercise, which was devised similarly to the experimental group (Figure 2). All participants began with the basic protocol and gradually increased the level of difficulty based on their performance each week by adjusting the lever arm and the height of the strap, as judged by exercise effort and participant feedback. After 12 sessions during the four weeks of training, the procedures were complete.

Table 1 Exercise protocols

Group	Exercise	Intensity
Sling	Supine bridging - one leg	Hold 6 sec./rep 6 rep/ set 6 set
	Supine knee flexion - straight hips	Hold 6 sec./rep 6 rep/ set 6 set
	Side-lying - hips abduction	Hold 6 sec./rep 6 rep/ set 6 set
	Prone plank with cycling	20 rep/ set 3 set
	Backward lunge + hip pull and raise	20 rep/ set 3 set
Floor	Supine bridging	Hold 6 sec./rep 6 rep/ set 6 set
	Bridging with step	Hold 6 sec./rep 6 rep/ set 6 set
	Side plank with hip abduction	Hold 6 sec./rep 6 rep/ set 6 set
	Mountain climber	20 rep/ set 3 set
	Backward lunge with heel raise	20 rep/ set 3 set

Figure 1 Models for sling exercise (a) Supine bridging - one leg, (b) Supine knee flexion - straight hips, (c) Side-lying - hip abduction, (d) Prone plank with cycling, (e) Backward lunge - hip pull and raise.

Figure 2 Models for floor exercise (a) Supine bridging – one leg, (b) Bridging with step, (c) Side plank with hip abduction, (d) Mountain climber, (e) Backward lunge with heel rise

Statistical analysis

In this study, IBM SPSS Statistics Version 22 was utilized for data analysis. The Shapiro-Wilk test was used to determine the normality of data. Descriptive statistic was used to test the general characteristics. The differences in running speed, plantar flexion reaction time, and dynamic balance across times and groups were compared using a two-way mixed repeated ANOVA. The differences between those times and groups were analyzed using the Bonferroni post hoc test. A statistically significant difference was defined as a *p*-value < 0.05.

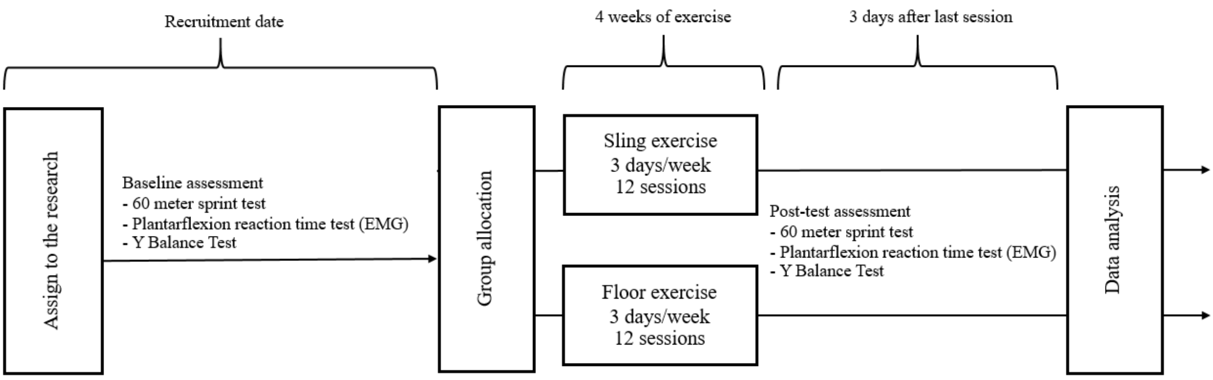

Figure 3 Flow chart diagram

Results

During the study, participants did not report any adverse side effects, and all subjects completed the study. The characteristics of the 22 subjects are shown in Table 2.

Table 2 Demographic and clinical characteristics

Variable	Sling exercise (n = 11)	Floor exercise (n = 11)	*p*-value
Age (years)	19.73 ± 1.27	19.73 ± 0.9	1.00
Gender [Female; n (%)]	7 (63.64%)	7 (63.64%)	
BMI (kg/m^2)	20.30 ± 1.75	20.68 ± 2.09	0.651
Core stability (grade)	1.09 ± 0.7	1.18 ± 0.6	0.748
CAIT (points)	19.27 ± 4.23	18.82 ± 4.35	0.806

Note: Values are shown as means ± SD; BMI, Body mass index; CAIT, Cumberland Ankle Instability Tools

For the results, the changes in running performance in both groups are shown in Table 3. Sling exercise showed a significant change in running speed, plantar flexion reaction time, and dynamic balance compared to baseline (*p*-value = 0.016, 0.006, and 0.036, respectively). However, the floor group only showed a significant change in dynamic balance compared to baseline (*p*-value < 0.001). In addition, there was a significant difference between the groups at weeks 4 for plantar flexion reaction time and dynamic balance (*p*-value = 0.042 and 0.005, respectively) (Figure 4).

Table 3 Comparison of running speed, plantarflexion reaction time, and dynamic balance between groups and within groups

Variable		Sling exercise (n = 11)	Floor exercise (n = 11)	*p*-value
Running speed (seconds)	Pretest	11.50 ± 1.87	11.58 ± 1.64	0.908
	Posttest	10.95 ± 1.72	11.38 ± 1.62	0.402
	p-value	0.016*	0.405	
Plantarflexion reaction time [milliseconds]	Pretest	369.08 ± 101.17	391.08 ± 144.25	0.642
	Posttest	240.15 ± 72.93	334.19 ± 91.28	0.042*
	p-value	0.006*	0.266	
Composite reach distance (%)	Pretest	79.61 ± 6.32	84.98 ± 3.71	0.055
	Posttest	86.27 ± 6.55	96.53 ± 3.10	0.005*
	p-value	0.036*	< 0.001**	

Note: Values are given as means ± SD; *significant difference (*p*-value < 0.05); **significant difference (*p*-value < 0.001)

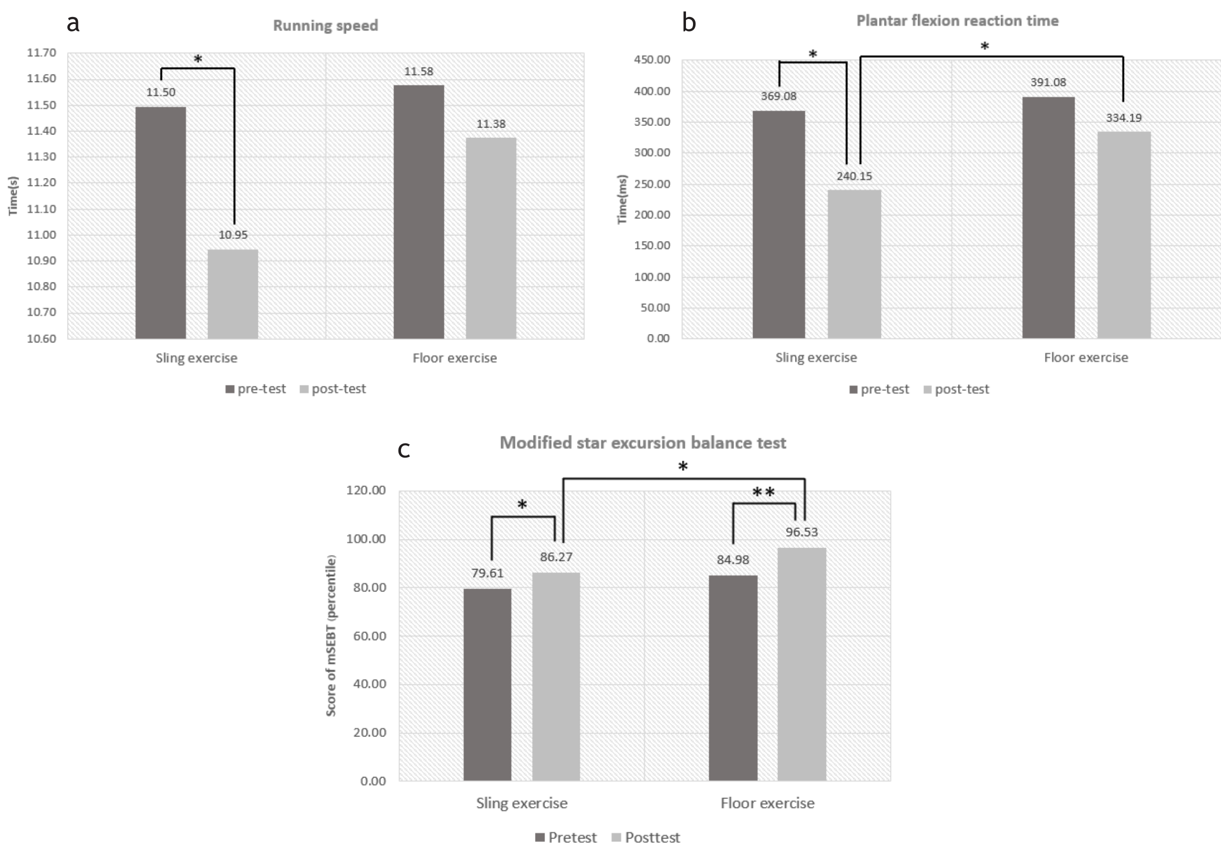

Figure 4 Comparison of (a) the running speed, (b) plantar flexion reaction time, and (c) composite reach distance within and between groups

Note: *significant difference (*p*-value < 0.05); **significant difference (*p*-value < 0.001)

Discussion

The main finding of the present study was that the four weeks of core stability training by sling exercise resulted in significant improvement in running speed, plantar flexion reaction time, and dynamic balance.

The impact of the training program on sling exercise can increase running speed and plantarflexion reaction time. Concentration was on activating the key muscle groups involved in running, such as the core, gluteus, thigh, and ankle plantar muscles. In this study, the protocol included a closed-chain isometric exercise with a single-limb component, which enhances target muscle activation the most. Co-contraction of the core body and surrounding the joint muscle should also be encouraged(21). As a consequence, the exercise program used in this study can help to stabilize the core and joint muscles.

The core muscles will be the first to operate as a central component, transferring power along the fascia line to the limb. The relationship between the core muscle and the limb muscle was described using the anatomical line including the superficial front line, superficial back line, and spiral line(9). Consequently, the limb muscle will react faster to the movement(22). Furthermore, core muscle activation involves anticipatory postural adjustment (APAs), which occurs before voluntary functional movements, and are essential aspects of postural control(23). The feed-forward postural response can be used to explain this phenomenon. In addition, the APAs operate to maintain lumbopelvic stability during predicted postural perturbations, just as those turned up during limb-oriented movements[24]. Conversely, the reaction force will send feedback to the core muscle when the action has occurred at the limb. Afterward, the core has to respond to work and achieve proper functioning in accordance and continuity with the movement[25]. In summary, the core muscle will influence all other segments in the chain to react and perform with proper timing and control.

Running is a unilateral hip flexion and extension activity that puts significant destabilizing torque on the trunk. Stronger core muscles allow for better control of the torque created when running, resulting in less energy wasted in unnecessary movement and improved performance[8]. Due to CAI problems, there is a proprioception deficit, a decrease in muscle activation around the ankle joint, a change in neuromuscular control, and leading to a decrease in running performance. The core-based exercise will help to generate muscular activity from the proximal to distal regions, as well as relearning of muscle activation patterns and improving proprioception. Same as previous studies, the specialized core stability and balance exercise can enhance core muscle strength, resulting in improved core stability, balance, and overall running performance[26].

The sling exercise has also proven to be considerably superior to the floor exercise because lowering the base of support with an unstable platform results in higher instability. In addition, the sling exercise involves higher activation of the core and gluteal muscles, which helps to improve stability levels[13, 27]. Furthermore, sling exercises increase the lever arm length, playing a significant role in producing an optimal amount of muscle activation[28].

Proprioceptive kinesthesia activation also occurred in instability training, which was one factor for the improvement of running performance. Proprioceptive kinesthesia is a mechanism of sensation that acts as the judgment of movement[5], which is related to the speed of the movement time due to strongly promoted by activation of the muscle spindle and Golgi organelles in cells of the joint tendons, and muscle spindles. In this study, increases in reaction time and running speed were shown to be superior in the sling exercise. Similar to previous studies of the sling exercise, the improvement of proprioceptive position sense and kinesthesia after training was shown better than the conventional group[29].

The composite reach distance improved substantially more in the floor exercise than in the sling exercise. Since floor exercises are included in active movement and balance exercises, it shows the higher change of balance outcome compared to the sling exercise that factor in the somatosensory stimulation with balance exercise[30]. Particularly, the floor exercise in this study focused mainly on ankle stability. Nonetheless, the somatosensory stimulation with balance exercise demonstrated the greatest improvement in the total clinical rating scale, as a metric mentioned above[30].

This research had a few limitations. First, this study did not follow up on long-term improvement in running performance after four weeks of exercise. Second, the whole-body functional balance assessment while jogging or running must be adequate for evaluating the effect of sling exercise and accurately detecting balance changes. Therefore, functional balance must be used to determine the change in core stability-related balance study due to the running skill movement. In addition, this technique should be used to study professional sprinters in future research.

Conclusion

Both core stability exercises can improve the running performance, such as running speed, plantar flexion reaction time, and dynamic balance. Particularly in sling exercise, a significant improvement of all parameters was shown after four weeks of exercise. On the other hand, floor exercise was improved significantly only in dynamic balance and was superior to the sling group.

Take home messages

Four weeks of sling exercise can increase running ability by enhancing the core muscles and proprioceptive awareness, particularly in terms of maximal sprint speed and muscular responsiveness to signaling.

Conflicts of interest

The authors declare no conflicts of interest.

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