Immediate Effects of Sling Exercise and Floor Exercise on Postural Stability in Non-Specific Chronic Low Back Pain

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Abstract

The patients with non-specific chronic low back pain (NCLBP) found a decrease in postural stability. However, only a few studies have been performed on the effects of sling exercise in NCLBP, and none of the studies examined postural stability after sling exercise. Therefore, the purpose of this study was to assess the anteroposterior (AP) and mediolateral (ML) postural stabilities of patients with NCLBP assessed on the sling and floor after exercise. Twenty patients with NCLBP aged 20 to 50 years were divided into sling exercise (n=10) and floor exercise (n=10). Both groups were trained 15 times/set for 3 sets, with 1-minute rest between a set. Postural stability was measured using an accelerometer in a seated position immediately after a training session. Before training, an appropriate training position for the patient's abilities was suitable for all participants. Repeated measure ANOVA was used to analyze the difference in outcome measures within each group and between groups. The results showed a significant decrease of sway area AP direction and sway velocity in all directions in sling exercise ($p<0.05$); however, that was not for the floor exercise. Besides, the reduction in sway area in ML direction and sway velocity in all directions of the sling exercise was found significantly higher than the floor exercise ($p<0.05$). The sling exercise can reduce sway area and sway velocity in AP and ML. However, exercise on the floor was reduced the sway area only ML direction. But found that the sway velocity did not change. These findings suggest that the sling exercise is more effective in increasing postural stability than the floor exercise in patients with NCLBP.

Keywords**:** *chronic low back pain, sling exercise, postural stability, postural sway*

1. Introduction

Low back pain (LBP) is common in 30-70% of school and working-age people in Thailand, largely due to abnormal co-contraction between muscles and loss of musculoskeletal function (Lopes et al., 2017). Chronic back pain causes a lack of postural control, which can negatively impact daily life or work performance. As a result, there is a loss of wages and an increase in debt costs. Besides, the signs of back pain contribute to stress, and anxiety can also lead to depression. Nonspecific chronic low back pain (NCLBP) is the most common, accounting for 85 percent of the total back pain population (O'Sullivan, 2005; Savigny et al., 2009). The patients with LBP have weak back muscles and have a harder time regulating their posture, leading to body instability (Akbari, Sarrafzadeh, Maroufi, and Haghani, 2015; Costa et al., 2009). The NCLBP is not considered a significant disease or a cause of radicular syndrome (Slade, Molloy, and Keating, 2009). NCLBP is diagnosed when a clinician concludes that there is no clear cause for the radicular syndrome, such as a herniated disc, cancer, vertebral fracture, stenosis, spondylitis, or extreme spondylolisthesis. (Childs et al., 2008; 2007: Chou et al.). LBP is characterized by discomfort in the lower back or below the rib cage, but not below the buttocks (Balagué, Mannion, Pellisé, and Cedraschi, 2012). Popular NCLBP diseases include muscle strain, ligament sprain, myofascial pain syndrome, and high tension of the muscles.

The stability system is composed of three subsystems that work together to keep the body stable. To perform various tasks, trunk and lumbar control must work together (Hodges, 2003; Hodges and Richardson, 1996). If the body is not stable, the operations are not successful. The passive, active, and neural subsystems make up body stability (Panjabi, 1992a). Non-contractile components such as joints, capsules, ligaments, and articulations are the passive subsystem. By reactive force, this mechanism provides support to the spine to control the spine in a neutral position. Contractile structures such as muscles and tendons form the active subsystem. There are two types of muscle groups in this subsystem: global and local. The local muscle is

responsible for maintaining spinal integrity, preventing lumbar spine damage from overuse, and transferring loads to the lumbar spine (Bergmark, 1989; Panjabi, 1992b). To track loads on the spine, the neural subsystem must cooperate with postural adjustment. All three mechanisms must cooperate to contribute to the stabilization of spinal movement during everyday activities, as they can help reduce neurological damage and nerve degeneration. If any system malfunctions, the lumbar spine becomes unstable (Panjabi, 1992a).

The musculoskeletal structures of patients with back pain are impaired. As a result, the synchronization of the musculoskeletal system with the nervous system shifts. In addition, back pain patients had poor muscle performance, resulting in difficulty with body regulation, pain, physical weakness, and delayed core muscle contraction (Akbari et al., 2015; Chou et al., 2007). Chronic LBP has been linked to several issues, including failure of neuromuscular function (Hodges, 2003). Also, their transversus abdominis function was reduced (França, Burke, Hanada, and Marques, 2010; Hodges and Richardson, 1996). Owing to a lack of motor coordination and proprioceptive feedback, the patients with LBP had impaired CNS control and delayed feedforward activation (Costa et al., 2009; Janda, 1978). Therefore, LBP patients had a poor anticipatory mechanism for planning before movement body stabilization and increasing postural sway, and poor control of the trunk (Shumway-Cook and Woollacott, 1995; Anne Shumway-Cook & Woollacott, 2007). Furthermore, the patients with LBP had a higher postural sway amplitude and velocity than healthy people, which was linked to a decreased ability to stabilize the body in an upright posture, reducing dynamic mobility activity (Hamaoui, Do, and Bouisset, 2004; Nies and Sinnott, 1991).

Sling exercise is one of the successful therapies in LBP patients that activates neuromuscular control, motor control and stimulates proprioceptive function (Leinonen, 2004). Neuromuscular regulation of the limbs and body can be facilitated as the patients perform sling exercises (Vikne, Oedegaard, Laerum, Ihlebaek, and Kirkesola, 2007). The muscle contractions affecting the muscle spindles can be strengthened with the unstable sling (Gojanovic, Feihl, Liaudet, Gremion, and Waeber, 2011). Sling exercise also helps facilitate synchronization between local and global muscles necessary for successful stabilization of the lumbar spine (Marshall & Murphy, 2005). The use of sling exercise reduced discomfort in chronic low back patients more than the use of stable surfaces, as shown in previous studies (You et al., 2015). Besides, sling training strengthens muscle power more than mat training. Yoo et al. (2015) investigated the effects of sling training on pain, physical impairment, muscle strength, and endurance in patients with low back pain over six weeks. The results suggest that sling training decreased the severity of pain and impairment and also increased trunk muscle strength in patients with low back pain. Another research by Kim et al. (2018) looked at the effects of sling-based stabilization exercises and push-ups on pain in LBP patients. For six weeks, each group did the exercise three times a week. The sling group reported a significant reduction in physical impairment relative to the push-ups group. These findings indicate that sling exercise combined with push-ups had a greater impact on lumbar stability (D.-H. Kim and Kim, 2018). Furthermore, Kim et al. (2013) explore the impact of the Neurac sling exercise on postural control, pain, impairment, and muscle function in patients with chronic low back pain. The patients were prepared four days a week for the exercise. In both the sling group and the conventional physical therapy group, the findings demonstrated a significant reduction in pain sensitivity and functional impairment. Important differences were observed between the sling and physical therapy groups for static and dynamic equilibrium sway area and sway length ($p<0.01$). The sling group had a significantly higher reduction in sway parameters than the physical therapy group (J. H. Kim, Kim, Bae, and Kim, 2013).

Most studies examined the effects of either core-stabilizing exercises on a flat surface or sling training from previous data. Few studies have been conducted on the effects of sling training. Also, there is a lack of studies comparing the results of core stabilization exercises performed on the floor versus in a sling. Most of the research examined the long-term effects of sling training. However, no studies have examined the immediate effects of post-sling training exercises on postural stability. If this study shows that sling training improves postural stability immediately after exercise. They can be used to prepare for the successful treatment of patients with low back pain. Therefore, this study compared postural stability, which consists of sway area in anteroposterior (AP) and mediolateral (ML) and sway velocity in AP and ML, between sling exercise and floor exercise in the patients with NCLBP.

2. Objectives

This study aimed to compare the effects of sling training and floor training on postural stability in patients with nonspecific chronic LBP. Moreover, it can be classified as 1) a comparison of postural stability in each group before and after training and 2) a comparison between sling training and floor training groups on postural stability.

The hypotheses of this study consist of sway area and the sway velocity of the sling exercise were significantly less than that of the floor exercise.

3. Materials and Methods

3.1 Participants

This research included twenty male and female NCLBP patients and volunteers. Rangsit University's Ethical Committee gave their approval to this report. All respondents were randomly divided into sling exercise (SG) or floor exercise (FG) classes. The G * power software was used to measure the sample size. The test power ($1-\beta$) was at 0.8, the significant level (α) was 0.05, the effect size was 0.5. The sample size was calculated with a drop out of 20%.

Inclusion criteria

1. Male and female with NCLBP more than three months. Non-specific LBP; pain area between coastal margins not below the gluteal fold
2. Age between 20-50 years
3. Body mass index (BMI) between 18.5-25 kg/m2

Exclusion criteria

1. Pregnancy
2. Red flags or back pain from serious diseases such as fractures, cancer, infection, cauda equine syndrome, human immunodeficiency virus (HIV), inflammation, infection
3. Radiate pain to the leg
4. Pain intensity more than 70 of 100 millimeters (mm) assessed by the visual analog scale (VAS)
5. Participants had previously performing sling exercises before participating in this study.

3.2 Procedures

Before the examination, all participants were allowed to assess their demographic records, weigh themselves, and measure their height to assess their BMI. Before and after checking for the protection of the exercise, the participants must monitor their blood pressure. Both exercise groups were scheduled to exercise and measure their values regularly to prevent cross-group knowledge sharing that may lead to bias. To eliminate data collection bias, the data collector would be someone other than the exercise supervisor. Before the exercise, the participants were assessed using an accelerometer for postural stability. In both AP and ML, the outcome measure was sway area and sway velocity. In each group, postural stability was assessed before and after the exercise.

The participants' postural stability was assessed using an OPAL accelerometer sensor placed on the lumbar spinous process at the level of the fifth level (L5). The OPAL accelerometer came from APDM wearable technologies and ERT company. This device had good validity and reliability for assessing postural stability. The OPAL motion sensor accurately captured motion with triaxial accelerometers and showed direct data in the mobility laboratory. To rule out bias in treatment administration, several researchers analyzed the treatment program, report outcomes, and data analyzes.

The patients were assessed in a seated position on the Neurocom- FOAM CTSIB. The leg hovered above the ground for 120 seconds for measuring Root Mean Square (RMS) sway and sway velocity values in the sagittal and coronal planes by the mobility laboratory. The patients were asked to sit for as long as possible without moving their bodies for 120 seconds. The outcome measures consisted of RMS sway sagittal plane (AP), RMS sway coronal plane (ML), sway velocity sagittal plane (AP), and sway velocity coronal plane (ML).

Figure 1 Postural stability test using accelerometer

Before an exercise session, the participants were given transversus abdominis contraction instruction for 10 minutes. This preparation would assist the participants to correctly contract the transversus abdominis. With knees bent and feet flat on the table, the participants were requested to lie on their back. When the participants inhaled, by expanding their abdomen, they were asked to keep their chest stable. The abdomen moved back toward the spine when they exhaled (abdominal drawing), and the participant continued with this pattern of breathing for ten minutes.

Both groups performed 15 exercises/sets in a total of 3 sets and a 1-minute rest between a set. Rest would be allowed if the person was exhausted or unable to proceed. The researcher had determined a suitable exercise position for the patient prior to exercise. A physiotherapist who specializes in the musculoskeletal system led this training. The exercise position was the position that was comfortable for the participant and represents the participant's best performance.

An exercise position used in the exercise session was a bridging exercise. The participants were told to lie down with their legs on the floor or in a sling. The participant tried out the abdominal drawing during exhalation, raising the pelvis, and keeping the pelvic lift in a neutral hip position. Then, the participant returned to the supine position. During exercise, the participants controlled pelvic and trunk without moving. The following are the three stages of difficulty for the bridging exercise:

Level 1: Bridging exercise with abdominal drawing. The participant was instructed to lie supine with their knees bent and both arms beside the trunk. The participant performed abdominal drawing while maintaining abdominal contraction during exhalation. The examiner advised the participant to contract the lower abdomen along with raising the pelvis and maintaining the pelvic lift in neutral. The participants were asked to abdominal drawing with a pelvic lift without shifting of the spine or pelvis for three breathing cycles.

Level 2: Bridging exercise with abdominal drawing, raising the right leg. The participant performed the first level by raising the right leg. The participant tried to control the pelvis at the same level for three breathing cycles while in this position.

Level 3: Bridging exercise with abdominal drawing, raising the right leg while crossing both arms on their chest. The participant performed the second level by cross both arms on their chest and control both hips at the same level for three breathing cycles.

The exercise was performed in the same way in both groups. During the exercise, the sling group used the Redcord Stimula that was hung on the support rope. This tool is an effective tool that, during treatment, applies vibration.

3.3 Statistical analysis

The SPSS version 24.0 was used for statistical analysis. The Shapiro-Wilk test was used to test the distribution of the data. Repeated measures ANOVA were used to analyze the time effect and interaction effects of postural stability in the coronal and sagittal planes. The level of statistical significance was set at $p < 0.05$.

Figure 2 Level of exercise position on floor group and sling group

4. Results and Discussion

4.1 Results

This research is a study investigating the immediate effects of sling exercise and floor exercise on postural stability in patients with NCLBP. Twenty participants with NCLBP were divided into two groups, the first group was the floor exercise group (n=10), and the second group was the sling exercise group (n=10) All demographic outcome data were normally distributed (Table 2). At the baseline, both groups were not significantly different in BMI, pain intensity, and baseline postural stability (Table 1).

Table 1 Baseline characteristics between floor exercise group (FG) and sling exercise group (SG)

Characteristics	FG	SG	*p*-value
BMI(kg/m2)Mean(SD)	22.863(4.343)	22.275(3.022)	0.729
VAS(mm) Mean(SD)	2.960(2.883)	4.000(1.616)	0.333
Level of lumbar Mean(SD)	2.800(1.135)	1.180(1.033)	0.054
Sway area anteroposterior (AP) Mean(SD)	0.185(0.301)	0.412(0.353)	0.138
Sway area mediolateral (ML) Mean(SD)	0.183(0.214)	0.204(0.198)	0.819
Sway velocity anteroposterior (AP) Mean(SD)	0.309(0.181)	0.409(0.170)	0.217
Sway velocity mediolateral (ML) Mean(SD)	0.187(0.087)	0.243(0.135)	0.284

SG = Sling group, FG = Floor group

Table 2 Data distribution of floor exercise group (FG) and sling exercise group (SG)

Characteristics	p-value FG	p-value SG
BMI(kg/m2)Mean(SD)	0.693	0.472
VAS(mm) Mean(SD)	0.151	0.605
Level of lumbar Mean(SD)	0.550	0.054
Sway area anteroposterior (AP) Mean(SD)	0.138	0.199
Sway area mediolateral (ML) Mean(SD)	0.819	0.815
Sway velocity anteroposterior (AP) Mean(SD)	0.476	0.229
Sway velocity mediolateral (ML) Mean(SD)	0.052	0.055

SG = Sling group, FG = Floor group

Table 3 Comparison of sway area and sway velocity between pre and post-exercise in the floor exercise group (FG) and sling exercise group (SG)

Parameters	Pretest Mean (SD)	Posttest Mean (SD)	Difference change Mean (SD)	P-value
Floor exercise group (FG)				
Sway area AP	0.185(0.104)	0.036(0.006)	0.149	0.179
Sway area ML	0.183(0.065)	0.024(0.004)	0.159	0.026
Sway velocity AP	0.309(0.056)	0.300(0.051)	0.009	0.885
Sway velocity ML	0.187(0.036)	0.217(0.027)	0.030	0.379
Sling exercise group (SG)				
Sway area AP	0.412(0.104)	0.022(0.006)	0.390	0.002
Sway area ML	0.204(0.065)	0.010(0.004)	0.194	0.008
Sway velocity AP	0.409(0.056)	.057(0.051)	0.353	0.000
Sway velocity ML	0.243(0.036)	0.026(0.027)	0.218	0.000

Analysis of the interaction effects of time and intervention on postural stability revealed a significant time effect ($p<.001$) in both groups. The results showed a significant decrease in sway area AP ($F = 61.57$, $df = 2$, $p<.001$), sway area ML ($F = 40.18$, $df = 2$, $p<.001$), sway velocity AP ($F = 55.13$, $df = 1$, $p<.001$) and sway velocity ML ($F = 36.56$, $df = 1$, $p<.001$) from the baseline in the sling group. However, the postural stability in the floor group was a significant decrease from the baseline only sway area ML ($F = 54.18$, $df = 2$, $p<.001$). The result from Table 3 showed the sling group was more improving in postural stability than the floor group. As Table 3 shows, sling exercises can increase postural stability in all directions with a significant difference from baseline. Postural stability in all directions showed a significant increase over time compared to the sling group at baseline. However, the floor group showed a significant decrease only in sway area ML.

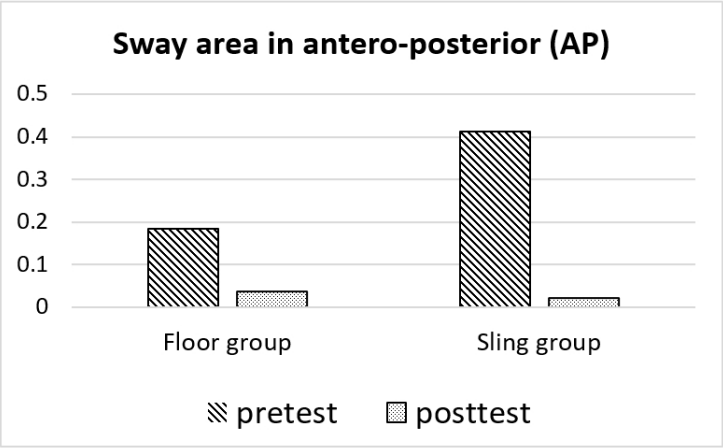

Figure 3 Mean RMS sway area in anteroposterior (AP) at pre and post-exercise for floor group and sling group

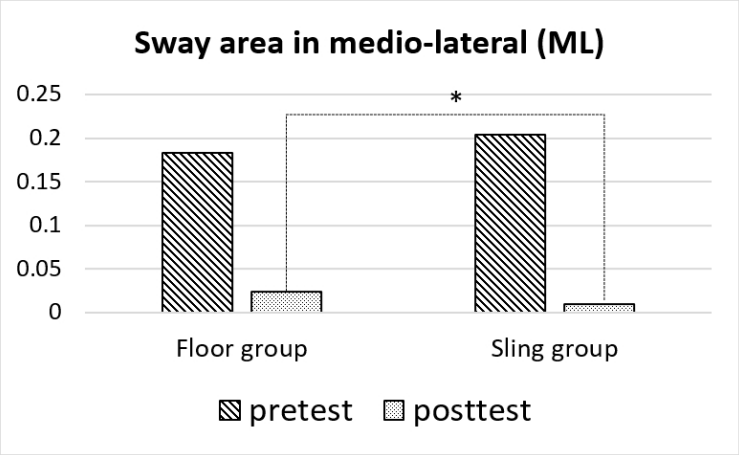

Figure 4 Mean RMS sway area in mediolateral (ML) at pre and post-exercise for floor group and sling group
* Significant difference (p<.05) between groups

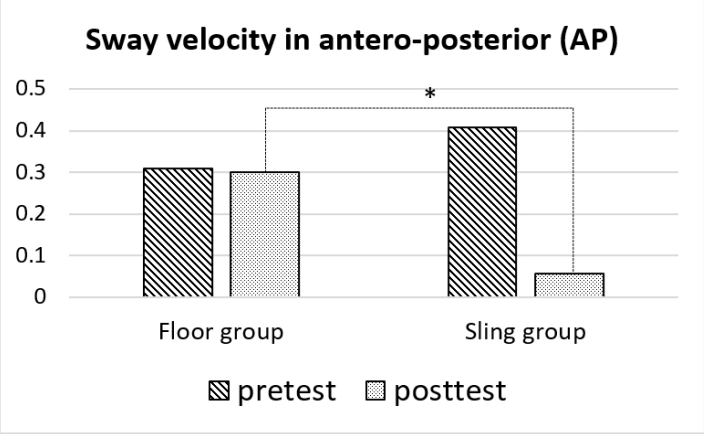

Figure 5 Sway velocity in anteroposterior (AP) at pre and post-exercise for floor group and sling group
* Significant difference (p<.05) between groups

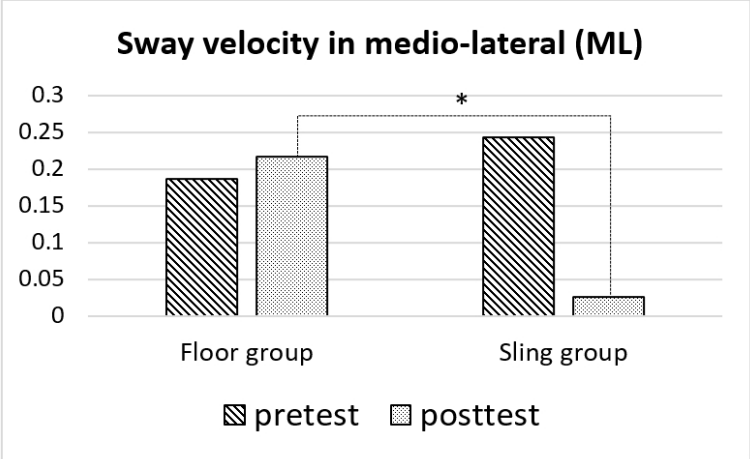

Figure 6 Sway velocity in mediolateral (ML) at pre and post-exercise for floor group and sling group
* Significant difference (p<.05) between groups

The results showed a significant difference between the sling group and floor group in sway area ML (F = 64.82, df = 2, p<.001), sway velocity AP (F = 18.99, df = 1, p<.001), and sway velocity ML (F = 32.67, df = 2, p<.001). Whereas, both groups found no significant difference in sway area AP (Figure 3). The Sling group showed significantly lesser sway than the floor group.

4.2 Discussion

The purposes of this study were to compare the effects of sling exercise and floor exercise on postural stability in patients with NCLBP. The findings of this study demonstrated a significant decrease in sway area and sway velocity AP and ML for the sling group, these findings were not found in the floor group. The floor exercise group demonstrated a reduction of sway area in ML direction. Moreover, the sling group showed a greater reduction in postural sway than the floor group

More improvement in postural stability was shown by the sling group, which can be represented by the effect of instability and vibration. One of the unstable techniques that activate neuromuscular control to give more muscle activity is sling exercise. The deep muscles are stimulated during exercise on a sling or unstable surface, which has the effect of enhancing proprioceptive stimulation (Lopes et al., 2017). Training on an unstable surface provides perturbation to the trunk that improves balance, proprioception, neuromuscular recruitment, and stability, as well as enhances the function of stabilizing core muscles training, such as sling exercises, is an important neuromuscular adaptation that improves stabilizer muscle coordination Neuromuscular adaptations improve the effectiveness of neural recruitment, increase central nervous system stimulation, improve motor unit synchronization, and decrease neural inhibitory reflexes (Kim et al., 2013).

The Redcord stimulation vibration is effective in relieving pain and enhancing core muscle activation. (Gojanovic et al., 2011; Kirkesola, 2009; Mikhael, Orr, Amsen, Greene, and Singh, 2010). This result was consistent with the Yoo et al. (2015) research that showed a significant reduction in the severity and impairment of back pain for the sling group (p<.001) (You et al., 2015). Activation of the trunk muscles should also be enhanced. The sling exercise that can encourage local muscle function, such as transversus abdominis and multifidus muscles, can explain this finding. During sling exercise, a disturbance that needs greater muscle contraction to control stability may be stimulated (Lehman, Hoda, and Oliver, 2005; Mutlu Cuğ, Özdemir, Korkusuz, and Behm, 2012). Exercise with the sling primarily activates the local stabilizer muscles, which are primary muscles for stabilizing the lumbar spine, and recruits the trunk muscles more than exercise on the floor. During exercise with the sling, the core muscles were strongly activated to control trunk stability and neutral spinal position from the unstable state. Besides, training with the sling increased the alternate recruitment of agonists and antagonists, such as the external and internal oblique abdominal

muscles, gluteus maximus, and gluteal muscles (Lehman, Hoda, and Oliver, 2005; Behm, 2012). NCLBP patients with delayed feedforward activation and core muscle contraction can demonstrate neural control insufficiency (Marshall and Murphy, 2010). Sling exercise facilitates core muscle activation and neuromuscular control. Core stabilizer muscles have been found to contract prior to limb movement. Feedforward activation and early recruitment are required by the neural subsystem to stabilize the body (Hodges and Richardson, 1997; Leinonen, 2004). Therefore, sling exercise may improve postural stability. Similarly, the study by Kim et al. (2013) found that Neurac sling training can improve postural balance and muscle function in chronic low back pain patients (Kim et al., 2013). Training in a sling provides an unstable environment that facilitates sensorimotor stimulation while strengthening the muscles that control the body at the base of support (Kirkesola, 2009).

The effect of sling exercise will enhance motor unit-related neural adaptation that enhances muscle coordination and recruitment (Choi and Kang, 2013; Kim et al., 2013; Kirkesola, 2009). Furthermore, vibration from sling exercise stimulates muscle co-contraction to improve postural stability. Decreasing of RMS sway and sway velocity represents increased ability to control body. On the other hand, increasing RMS sway and sway velocity shows decreased ability to maintain postural control (Geurts, Nienhuis, and Mulder, 1993; Palmieri, Ingersoll, Stone, and Krause, 2002).

The limitation of this study consists of a short duration of exercise and the surface EMG was not used to measure muscle activity of the core muscles during exercise. Our research investigates the immediate effects of sling exercise and floor exercise. Therefore, the duration of the research is relatively short, it may not be clear to detect the change of muscles.

5. Conclusion

The sling group had a significantly higher reduction in sway velocity and sway area in both coronal and sagittal planes than the floor group. The postural stability of the sling group was higher than the floor group. The findings of this study demonstrated sling exercise was more effective to improve postural stability. These results indicate that the use of sling exercise leads to more effective treatment and immediate results for the patients with NCLBP.

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