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ORIGINAL ARTICLE

ผลทันทีของการออกกำลังกายเพื่อเพิ่มความมั่นคงของกระดูกสันหลังส่วนเอวต่อการรับรู้ตำแหน่งของกระดูกสันหลังส่วนเอว

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บทคัดย่อ

การออกกำลังกายเพื่อเพิ่มความมั่นคงของกระดูกสันหลังส่วนเอวเป็นวิธีการที่นักกายภาพบำบัดนิยมใช้ในการฝึกผู้ที่มีปัญหาเกี่ยวกับความมั่นคงของกระดูกสันหลังส่วนเอว เชื่อว่าผลของการออกกำลังกายทางคลินิกและทางชีวกลศาสตร์ที่ดีขึ้นอาจมาจากความสามารถในการรับรู้ตำแหน่งของกระดูกสันหลังส่วนเอวที่เพิ่มขึ้น อย่างไรก็ตามยังไม่มีการศึกษาใดที่ทำการวัดความเปลี่ยนแปลงของการรับรู้ตำแหน่งของกระดูกสันหลังส่วนเอว ดังนั้นงานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาผลทันทีของการออกกำลังกายเพื่อเพิ่มความมั่นคงของกระดูกสันหลังส่วนเอวต่อการรับรู้ตำแหน่งของกระดูกสันหลังส่วนเอว ผู้ที่มีสุขภาพดีจำนวน 60 คน จะถูกสุ่มให้อยู่ในกลุ่มควบคุม (30 คน) หรือกลุ่มออกกำลังกาย (30 คน) ไอโฟนที่มีแอปพลิเคชัน Goniometer G-pro จำนวน 2 เครื่อง ติดไว้ที่กระดูกสันหลังส่วนเอวระดับที่หนึ่ง และกระเบนเหน็บระดับที่สองโดยใช้สายรัด ผู้เข้าร่วมงานวิจัยทำการทดสอบโดยการก้มหลังที่มุมต่างๆ (30°, 45°, และ 60°) แบบสุ่มลำดับก่อนหลัง แต่ละครั้งผู้เข้าร่วมงานวิจัยต้องเคลื่อนกระดูกสันหลังส่วนเอวให้กลับไปอยู่ท่าเริ่มต้น/ท่ายืนตัวตรง ค่าความคลาดเคลื่อนเป็นตัวชี้วัดการรับรู้ตำแหน่งของกระดูกสันหลังส่วนเอวถูกบันทึกก่อนและหลังการทดลอง การวิเคราะห์ทางสถิติใช้ Mixed ANOVA ในการทดสอบผลทันทีของการออกกำลังกายเพื่อเพิ่มความมั่นคงของกระดูกสันหลังส่วนเอวต่อการรับรู้ตำแหน่งของกระดูกสันหลังส่วนเอว ผลการวิจัยพบความแตกต่างอย่างมีนัยสำคัญจากผลของเวลา ($F_{1,58}$ = 10.44, p = 0.002, η^2 = 0.15) การเปรียบเทียบระหว่างกลุ่มและเวลาพบว่ามีความแตกต่างอย่างมีนัยสำคัญระหว่างก่อนและหลังการออกกำลังกายในกลุ่มออกกำลังกาย (t_{29} = 2.36; p = 0.003; Cohen's d_z = 0.43) ผลงานวิจัยสามารถอธิบายได้ว่าการออกกำลังกายเพื่อเพิ่มความมั่นคงของกระดูกสันหลังส่วนเอวสามารถเพิ่มการรับรู้ตำแหน่งของกระดูกสันหลังส่วนเอวได้ อย่างไรก็ตามงานวิจัยในอนาคตควรศึกษาหาความสัมพันธ์ระหว่างการเปลี่ยนแปลงการรับรู้ตำแหน่งของกระดูกสันหลังส่วนเอวกับการเปลี่ยนแปลงทางคลินิกและทางชีวกลศาสตร์เพื่อใช้อธิบายกลไกของการออกกำลังกายเพื่อเพิ่มความมั่นคงของกระดูกสันหลังส่วนเอว

คำสำคัญ: การออกกำลังกายเพื่อเพิ่มความมั่นคง, การรับรู้ตำแหน่งของกระดูกสันหลัง, โซนการเคลื่อนไหวกระดูกสันหลัง, แกนกล้ามเนื้อ

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ORIGINAL ARTICLE

Immediate effect of lumbar stabilization exercise on lumbar position sense in healthy individuals

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Abstract

Lumbar stabilization exercise (LSE) is commonly prescribed by physical therapists for individuals with clinical lumbar instability. Enhanced lumbar position sense was believed to be partly responsible for clinical/biomechanical improvements. However, lumbar position sense has not been fully investigated. Therefore, this study aimed to investigate the immediate effect of LSE on lumbar position sense. Sixty participants were randomly assigned into either control (n = 30) or exercise (n = 30) group. Two iPhones with a Goniometer G-pro application were attached to the first segment of lumbar spine and the second segment of sacrum using Velcro straps. Each participant attempted to reposition their lumbar spine to starting/neutral position from three random orders of lumbar flexion angles (30°, 45°, and 60°). Absolute repositioning errors representing lumbar position sense were recorded at pre- and post-test. A mixed ANOVA was performed to determine the effect of LSE on lumbar position sense. Result demonstrated significant main effect of time ($F_{1,58}$= 10.44, p = 0.002, η^2 = 0.15). Post-hoc pairwise comparisons with LSD correction revealed significant difference between pre- and post-test in exercise group (t_{29} = 2.36; p = 0.003; Cohen's d_z = 0.43). This result suggests that LSE can enhance lumbar position sense. However, further study should establish the association between change in lumbar position sense and clinical/biomechanical outcomes to explain the underlying mechanism of LSE on improving lumbar stability.

Keywords: Lumbar stabilization exercise, Lumbar position sense, Neutral zone, Muscle spindle

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Introduction

Lumbar stabilization exercise (LSE) is one of physical therapy intervention commonly used to treat individuals with clinical lumbar instability[1-4]. This type of exercise is primarily designed to restore a precise co-contraction of transversus abdominis and lumbar multifidus muscles based upon motor learning concept[3,5,6]. The co-contraction of those muscles provides the lumbar stability in daily activities[3,5,6]. Several researchers have investigated the effect of LSE on clinical and biomechanical outcomes[6-12]. They found clinical improvement in pain, disability, as well as functional outcome after completion of the LSE program[8,11,12]. In terms of biomechanical evidences, they found improvement in trunk neuromuscular control and coordination, including muscle activation patterns and onset timing response[7,9,10].

Researchers believed that those clinical and biomechanical improvements may potentially result from restoration of lumbar position sense to some extent[7-12]. Boucher et al. have attempted to investigate the effect of an 8-week LSE on lumbar position sense[13]. They measured lumbar position sense operationally defined as the minimal degree of axial rotation where the participant could detect the movement. However, they did not find any significant improvement in lumbar position sense after the exercise program. They speculated that an unchanged result could be due to an inappropriate measurement in which they measured only passive osteoligamentous structures, while the exercise emphasizes on neural and active muscular structures. Therefore, measurement that includes the interaction between neural and active muscular structures may have ability to detect the improvement in lumbar position sense.

Another theory that can be used to explain this phenomenon is the neutral and elastic zones **(Figure 1)** proposed by Panjabi[14]. Based upon his experiment, the neutral zone of the spinal movement is the initial portion of the physiological movement with minimal resistance from osteoligamentous structures around the spine, whereas the elastic zone is the portion between the end of neutral zone and the end of physiological movement with considerable internal resistance from those osteoligamentous structures[14].

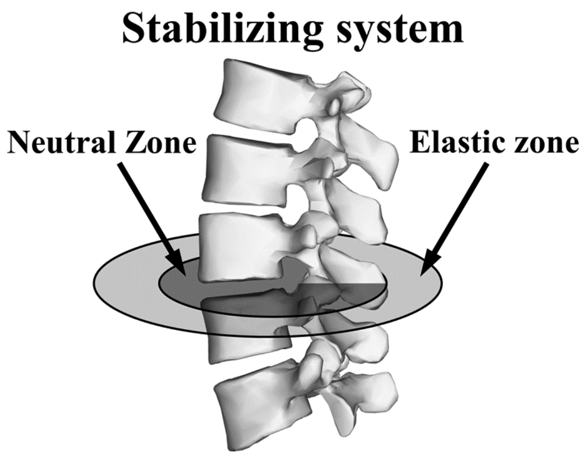

Figure 1 Neutral and elastic zones of the lumbar spine according to stabilizing system proposed by Panjabi

Lumbar position sense in the neutral zone is relied primarily on deep back muscles (e.g. lumbar multifidus and rotator muscles)[14,15]. These muscles attach merely one or two lumbar spinal segments. Muscle spindles located in these muscles are essential to provide precise lumbar position signals[16-18]. These position signals will integrate with neuromuscular control to stabilize the lumbar spine, or in other word, reduce size of neutral zone[14,18].

Interestingly, although those researchers implied that clinical and biomechanical improvements may result in part from improved lumbar position sense, none has directly investigated the effect of LSE on lumbar position sense with regard to active muscular system. Therefore, the purpose on this study was to systematically investigate the immediate effect of LSE on lumbar position sense. In addition, based on motor control training, repetitive focused movement in one session of LSE would demonstrate immediate improvement on muscle spindle activity, thereby could potentially enhance lumbar position sense[6]. We hypothesized that individuals who received one-session of LSE would demonstrate significantly improvement in lumbar position sense comparing with those who did not receive LSE. The contribution of this study was expected to provide biomechanical evidence to support the improvement in lumbar position sense after LSE, as well as feasibility information for future investigation in low back pain population.

Materials and Methods

Participants

Sample of convenience was recruited from Faculty of Physical therapy. Sixty physical therapy students participated in this study. The sample size was calculated using a G*Power program (G*Power version 3.1.9.2, University Kiel, Germany) to detect a medium effect size (Cohen's d = 0.5) at confidence level (α) of 0.05 and power (1-β) of 80%. The inclusion criteria were composed of 1) no episode of low back pain for 3 months prior to the participation, and 2) no regular exercise routine that involves lumbar stabilization exercise. The exclusion criteria included 1) clinical signs of systemic disease, 2) definitive neurologic signs including weakness or numbness in the lower extremity, 3) previous spinal surgery, 4) inflammatory joint disease, 5) any lower extremity condition that would potentially change lumbar movement, 6) vestibular dysfunction, 7) body mass index (BMI) greater than 30 kg/m^2, and 8) any condition that would preclude participation in any aspect of the study. All participants provided a written informed consent prior to data collection process.

Instrument and measures

This study used a goniometer G-pro application **(Figure 2A)** for iPhone (goniometer Pro version 2.7, 5fuf5 Co., Bloomfield, NJ, USA). This application can be used to measure angular motion of the lumbar spine by accessing and processing the data from built-in accelerometer and gyroscope in the iPhone. Previous study on test-retest reliability of our testing protocol using an iPhone application demonstrated adequate reliability ($ICC_{3,k}$ = 0.73; 95% Confidence interval was between 0.43 and 0.87) with standard error of measurement (SEM) equaled to 0.9 degrees[19]. For our measurement, the angle difference on the iPhone application between L1 and S2 represented the lumbar spine motion. We recorded starting/neutral lumbar position angle (L1 respects to S2), and set as a target repositioning task. We used absolute repositioning error (AE) in this study to represent lumbar position sense, in which greater AE means poorer lumbar position sense. AE was defined as the absolute amount of deviation away from starting/neutral lumbar position when the participant returned to upright position from lumbar flexion at different angles.

Procedure

Our testing protocol was approved by the university institutional review board (COA No. MU-CIRB 2016/047.0704). We utilized a randomized controlled trial design to investigate the immediate effect of LSE on lumbar position sense. Demographic data, including age, sex, and BMI, were obtained prior to data collection. The participant was asked to wear a comfortable cloth that can be exposed to his/her lower back. Two iPhones were attached to the lumbar spine (L1) and sacrum (S2) using Velcro straps. The top border of each Velcro strap was aligned to the superior border of the spinous process **(Figure 2B)**. One investigator prepared the participant and provided a verbal instruction during the test, while another investigator measured the lumbar position sense. Both investigators (4th year physical therapy students) were blinded to the group assignment. After setting up, the participant was asked to comfortably stand in upright position with feet shoulder width apart on a drawing paper to obtain neutral position data as a starting position. The investigator used a marker to draw foot position on the paper. This drawing paper was used to reposition the participant for post-test.

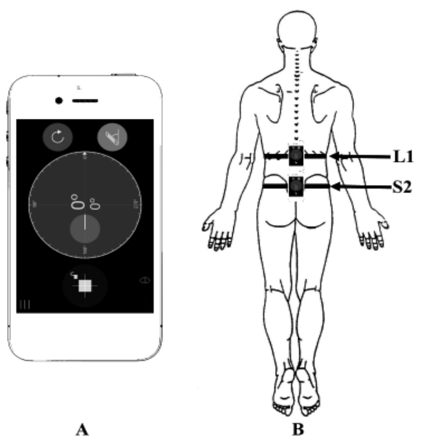

Figure 2 (A) Goniometer G-Pro application for an iPhone (B) Locations of two iPhones used to measure lumbar position sense (top border of each Velcro strap was aligned with the superior border of L1 and S2 spinous processes.

The participant had an opportunity to familiarize with the testing protocol by performing a practice trial. This practice trial also aimed to minimize the learning effect of our testing protocol. During the practice trial, the participant was instructed to perform repositioning task (return to starting/neutral position) from trunk flexion at 30°, 45°, and 60° (4 repetitions for each degree) with verbal feedbacks from investigator by reading the value from those iPhones. We asked the participant to performed repositioning from trunk flexion at those angles because the majority of daily activities involves movement in trunk flexion direction. In addition, we assumed that 30°, 45°, and 60° would have different activation on muscle spindles with regard to length-tension relationship[20]. Pre-test data were immediately collected following the practice trial. The participant was asked to perform 3 repetitions of repositioning task at those different angles by random order. When the participant returned to starting/neutral position for each repetition, lumbar and sacral angles were recorded. No resting period was provided between repetitions. The practice trial and data collection took approximately 15 minutes. After pre-test data were obtained, iPhones were taken off. The participant was randomized into either control or exercise group.

For exercise group, lumbar stability level was evaluated to assign an appropriate level of LSE **(Figure 3)**[21]. Each participant performed a 30-minute of LSE supervised by the third investigator (4th year physical therapy student) who underwent 2 training sessions provided by the principal investigator who had a doctoral degree in spinal rehabilitation and experience in musculoskeletal system for 14 years. The training sessions were composed of 1) understanding of operational definitions for grading level of LSE, 2) prescribing an exercise intensity (level), and 3) practicing with the classmates under supervision from the principal investigator. This study used 30 minutes of exercise because physical therapist commonly prescribes 30 minutes of exercise for patients with low back pain. Based upon motor learning, this exercise uses repeated intentional muscle contractions (10 repetitions per set) to develop an ability to automatically control co-contraction of transverse abdominis and lumbar multifidus muscles during daily activities(6). One-minute resting period was given after each set of exercise. After they completed one session of LSE, they underwent the same data collection protocol for post-test data collection. The participants in control group were asked to rest in sitting position for 15 minutes followed by post-test data collection as well. We have attempted to optimize resting time in control group by weighing between minimal testing time and adequate time to prevent muscle fatigue. We have decided to provide 15 minutes resting period in this study. The investigators were monitoring rating of perceived exertion (RPE) and heart rate throughout the protocol to prevent fatigue. Pre- and post-test data from the control and exercise groups were used to investigate the immediate effect of LSE on lumbar position sense. Overall study scheme is presented in **Figure 4**.

Statistical analysis

All Statistical analyses were performed using SPSS software (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY, USA). Descriptive statistics were performed on demographic data. Kolmogorov-Smirnov goodness-of-fit test was used to determine whether data were normally distributed. Data were transformed using logarithm (log10) when normality test was violated. Independent t-test was used to determine baseline comparison between control and exercise groups if the data showed normal distribution. Otherwise, non-parametric Mann-Whitney U test was performed. A mixed ANOVA was used to determine the immediate effect of LSE on lumbar position sense if normal distribution assumption was met. However, non-parametric Mann-Whitney U test was performed to compare the amount of change in lumbar position sense between those groups if transformation could not bring the data to normal distribution. Significance level (α) will be held at 0.05 for all analyses. Least significant difference (LSD) correction was used for post-hoc pairwise comparison. Effect size (Cohen's d) was also calculated.

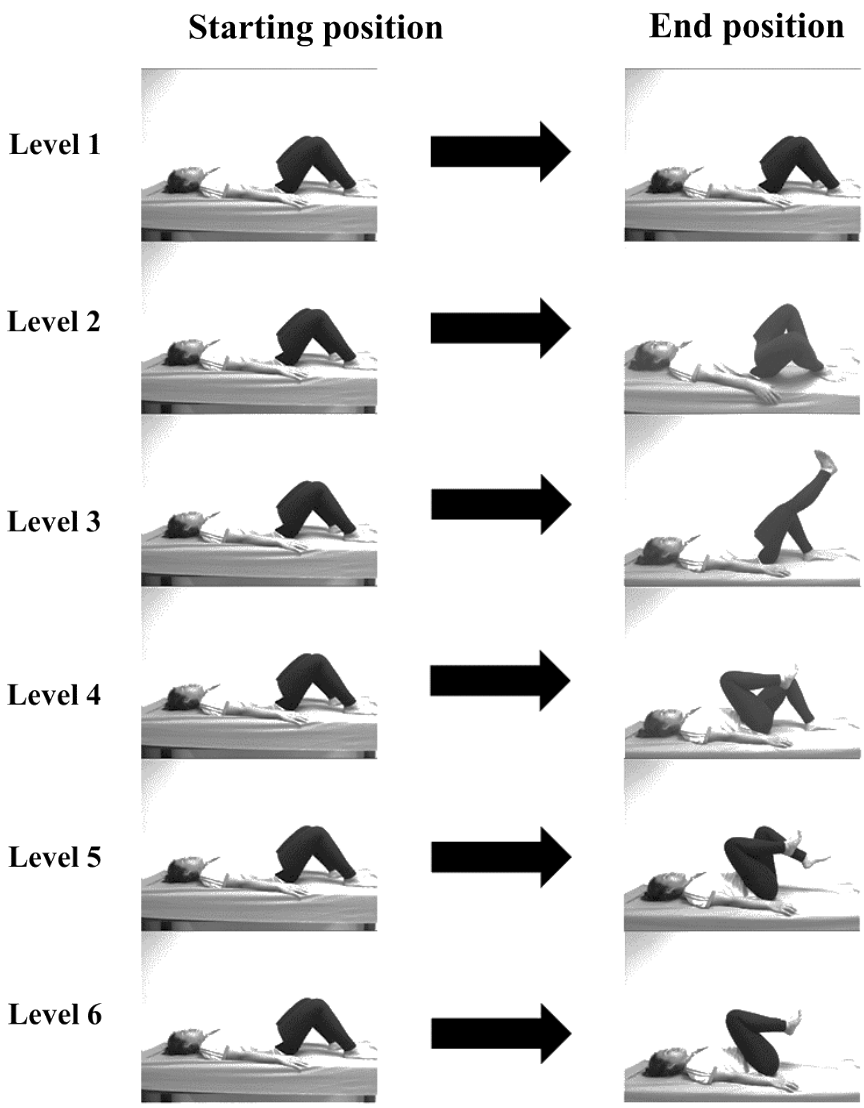

Figure 3 Lumbar stability level 1-6. Each participant in exercise group underwent lumbar stability assessment to determine his/her appropriate level of exercise. For level 1, the participant be able to perform 10 repetitions of 30-second co-contraction of transversus abdominis and lumbar multifidus muscles. For level 2-6, the participant must be able to hold his/her co-contraction throughout 10 repetitions to progress to the next level. Investigator monitors the participant's ability by palpation on both muscles.

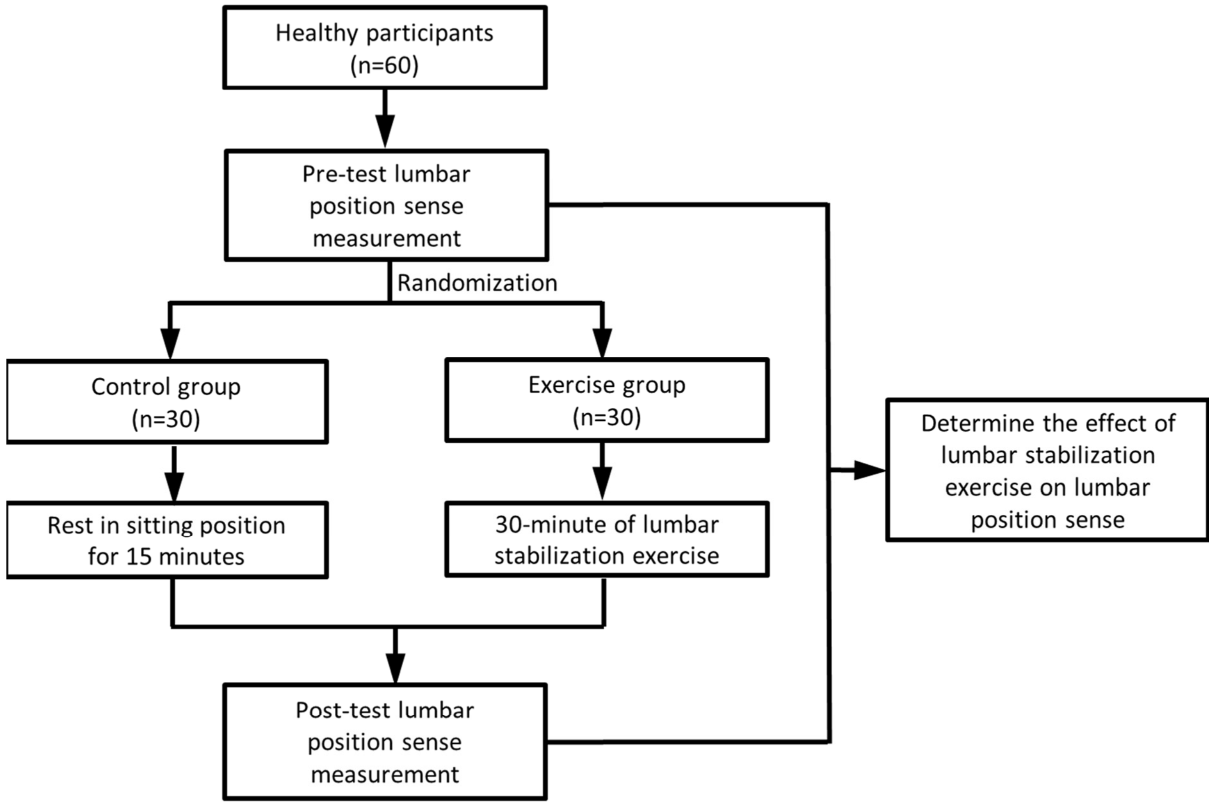

Figure 4 Overall study scheme

Results

Demographic data and baseline comparisons between control and exercise groups are presented in **Table 1**. Baseline comparison shows significant difference in age and sex between groups. However, the data demonstrate no significant difference in lumbar range of motion and AE at baseline comparison. There was no incidence of muscle fatigue or any adverse effect during and after receiving the LSE.

Pre- and post-test AE data were not normally distributed; therefore, logarithm (log10) was used to transform data. After transformation, data had normal distribution. A mixed ANOVA was used for statistical analysis. Our result demonstrated sphericity assumption was not met; thus, Greenhouse-Geisser correction was performed. We found merely the main effect of Time ($F_{1,58}$= 10.44, p = 0.002, η^2 = 0.15), while the interaction effect of Time*Group and the main effect of Group did not show any significance ($F_{1,58}$ = 1.22, p = 0.27, η^2 = 0.02; $F_{1,58}$ = 1.52, p = 0.22, η^2 = 0.03, respectively). Post-hoc pairwise comparison with LSD correction **(Table 2)** demonstrated significant difference between pre- and post-test in exercise group (t_{29} = 2.36; p = 0.003; Cohen's d_z = 0.43). However, other comparisons between groups and with-in group did not show any significance **(Table 2)**. **Figure 5** illustrates a profile plot from mixed ANOVA.

Table 1 Demographic data at baseline

Variable	Control (n=30)	Exercise (n=30)
Age (years)*	20.4±1.4	21.3±1.1
Sex (%male)*	6.7	26.7
BMI (kg/m^2)	21.0±2.7	21.2±2.4
LROM (degrees)	34.7±8.3	33.9±10.9
AE (degrees)	3.07±2.01	2.93±2.38

AE = Absolute repositioning error at angle; LROM = Lumbar range of motion

* Significant difference (p<0.05)

Table 2 Post-hoc pairwise comparison with least significant difference (LSD) correction

Between groups	Control (mean±SD)	Exercise (mean±SD)	Mean difference	*p-value*	Effect size (d)
Pre-test	3.07±2.01	2.93±2.38	0.14	0.623	0.06
Post-test	2.51±1.45	1.98±1.31	0.53	0.103	0.38
Within group	**Pre-test (mean±SD)**	**Post-test (mean±SD)**	**Mean difference**	***p-value***	**Effect size (d_z)**
Control	3.07±2.01	2.51±1.45	0.56	0.139	0.35
Exercise	2.93±2.38	1.98±1.31	0.95	0.003	0.43

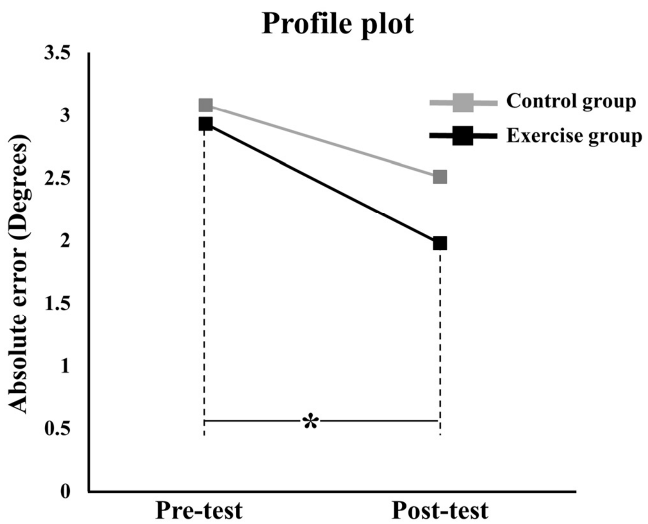

Figure 5 Profile plot from mixed ANOVA. Asterisk (*) indicates significant difference between pre- and post-test (p< 0.05) in an exercise group based on post-hoc pairwise comparison with least significant difference

Discussion

Our result demonstrated that participants in the exercise group had significantly greater reduction in AE (32% reduction) than those in the control group (18% reduction). Although both control and exercise groups demonstrated improvement in lumbar position sense indicated by decreased absolute error, only amount of change in the exercise group (0.95 degree) was greater than the measurement error (0.9 degree) which could be interpreted as a true change. This result has supported our hypothesis in which individuals who received one-session of LSE would show significant improvement in lumbar position sense comparing with those who did not receive LSE. Therefore, improvement in lumbar position sense would be one of the contributing factors to the lumbar stability.

Improvement in lumbar position sense in the exercise group may be resulted from the excitation of muscle spindle induced by repeated intentional muscle contraction of lumbar multifidus muscle[16-18,22]. Because the lumbar multifidus and rotator muscles are small and spanning over one or two lumbar spinal segments, they are responsible for lumbar spinal stability[14,15]. The immediate effect of LSE can increase the ability of muscle spindle to detect change in lumbar position when those lumbar spinal segments deviate from starting/initial neutral position[16-18]. This detecting ability will augment the accuracy and response time of trunk neuromuscular control, which in turn reducing the neutral zone according to Panjabi's spinal stability model[14]. Therefore, lumbar stability will be enhanced.

To the best of our knowledge, no researchers have investigated the immediate effect of LSE on lumbar position sense. However, some investigators have studied on the peripheral joint sense after stabilization exercise based on motor learning concept[22-24]. They found similar results to our study which were significant improvement in joint position sense after one-session of stabilization exercise. As opposed to immediate effect, one study on change in lumbar position sense after an 8-week LSE program[13]. They found no significant difference after the exercise program. Although their study and ours utilized the same motor learning concept proposed by Richardson et al.[6], their lumbar position sense measurement was differed from our measurement. They used motion perception threshold (minimal axial rotation angle that individual can identify) during passive axial rotation. Their negative result could be explained by the fact that they assessed only passive osteoligamentous structures, while our study assessed active muscular structures that we intended to emphasize on improving the ability of muscle spindle[14].

We found significant difference in age and sex between two groups. In terms of age difference, we selected a sample from physical therapy students with a narrow age range (between 18 and 22 years old) leading to small variance in both groups. Therefore, it would be easier to detect significance even a small difference[25]. Significant difference in sex between groups could have effect on our result with regard to physiological response of muscle spindle[26]. However, evidences to support the effect of sex on physiological response are still unclear[26]. In addition, although we found significant difference in age and sex between groups at baseline, participants in both groups had similar lumbar range of motion and absolute repositioning error at baseline.

Some limitations should be addressed in this study. First, there was a trend indicating improvement in lumbar position sense in control group even though they did not receive the LSE. This may be caused by the fact that we implemented several repetitions of repositioning task (4 repetitions X 3 different angles = 12 repetitions) during a practice trial. This may induce change in muscle spindle, thereby resulting in improvement in lumbar position sense in this study. Future study should concern about the appropriate practice trial that can minimize not merely the learning effect, but the physiological change as well. In addition, significant difference in age and sex between groups was potentially resulted from the simple randomization technique that we used. Future study may consider a more appropriate randomization technique, such as a block randomization or stratified randomization, to ensure a balance in participant's characteristics. Although our exercise was focusing on the deep back muscles, the superficial back muscles might have a contribution to achieve the exercise task. Therefore, the improvement in the lumbar position sense might not merely result from the deep back muscles. Muscle activity should be included in the future study to identify the contribution of deep and superficial back muscles. We used healthy individuals in this study which would limit the generalization into low back pain population. Therefore, clinicians should be cautious when applying into clinical practice. Future study in patients with low back pain is required.

Conclusion

One-session of LSE can improve lumbar position sense in healthy individuals. This current study provides biomechanical evidence to support the utility of LSE to enhance lumbar position sense, as well as the feasibility for our future study in low back pain population. However, future study should establish the relationship to answer the question whether this improvement in lumbar position sense is associated with the improvement in clinical and biomechanical outcomes.

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