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Effects of combined hip exercise and passive stretching on muscle stiffness, pain perception and pain-related disability, and physical function in older adults with low back pain

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[Purpose] This study aimed to examine the effects of combined hip exercise and passive stretching as a novel treatment method for low back pain (LBP) in older adults.

[Methods] Altogether, 20 Koreans with LBP aged 60–79 years (67.3 ± 5.92 years) were randomly assigned to undertake combined exercise (CE; n = 10) or lumbar stabilization exercise (LSE; n = 10). All participants performed their respective exercise program for 25–30 min with an OMNI scale of 6–8 for 8 weeks, three times a week. Body composition, muscle stiffness, pain-visual analog scale (P-VAS), Oswestry disability index, and physical function were evaluated before and after the exercise intervention.

[Results] The CE group demonstrated greater improvements in lean body mass (η^2 = 0.402, p = 0.003) and percent body fat (η^2 = 0.222, p = 0.036) than the LSE group. Both groups demonstrated significant improvements in muscle stiffness, P-VAS scores, and Oswestry disability index scores, although no significant differences were observed between the interventions. All physical function parameters demonstrated a significant improvement in both groups, and the CE group demonstrated greater improvement in the YMCA sit-and-reach (η^2 = 0.338, p = 0.007) and straight leg raise tests (η^2 = 0.283, p = 0.016) than the LSE group.

[Conclusion] CE is comparable to LSE as an effective and successful exercise intervention that reduces muscle stiffness and P-VAS scores. Moreover, CE is more effective than LSE in enhancing the physical function of older adults with LBP.

[Keywords] hip exercise, passive stretching, muscle stiffness, physical function, elderly, low back pain

INTRODUCTION

Low back pain (LBP) is the most common health problem that results in pain and disability in older adults[1]. Most causes of back pain in older people are related to functional aspects caused by mechanical loads or are reported to be idiopathic[2]. Lachmann et al.[3] have reported that back pain is a common symptom in older people. Moreover, a sedentary lifestyle is a leading factor for back pain caused by mechanical tension, and it aggravates back pain, which progresses chronically. Individuals with chronic LBP have lower balance ability than normal individuals[4]. Additionally, LBP can cause postural adjustment disorder and abnormal spinal movements[5], and muscle imbalance can increase the risk of chronic damage[6]. Surgical therapy has no significant benefit for chronic LBP, and in most cases, conservative treatment is provided[7]. Exercise therapy is a widely applied conservative treatment method[8], which is intended to strengthen the deep muscles of the body, such as the diaphragm, pelvic floor, transverse abdominis muscle, and multifidus muscle, which are classified as the core muscles[9]. Most exercise therapies for LBP focus on these core muscles, such as the Williams exercise, Mackenzie exercise (with focus on the lumbar region), and lumbar stabilization exercise (LSE)[10-12]. LSE is reportedly very effective in reducing pain and dysfunction in patients with chronic LBP[13-17] by improving neuromuscular efficiency and lumbar stability through activating the core muscles[18]. Hence, LSE has been widely applied as an exercise therapy for chronic LBP.

However, back pain is closely associated with the lumbopelvic region, as well as muscle strength and stabilization of the lumbar region, which have direct and indirect associations with the risk of LBP and lower limb damage that may cause LBP or deteriorating factors related to lower limb function[19]. Back pain or lower extremity instability reportedly causes delayed contraction of the hip abductor muscle, gluteus maximus, and gluteus medius[20], and weakening of the hip joint muscles can result in low back pain by causing dysfunction of the lower extremities and hip joint[21]. Kendall et al.[22] have reported that performing hip muscle strengthening exercises simultaneously with pelvic exercises in patients with back pain were effective in reducing back pain. Another study has reported an immediate decrease in back pain after 20 min of hip muscle activation exercise[23].

Previous studies have demonstrated that hip muscle strength and function are closely related to LBP. The functional anatomy of the hip joint muscles contributes to the stability of the lateral and posterior parts of the pelvis and reduces stress in the lumbar region by playing an important role in transmitting force to the pelvis and lower extremities during gait[24]. Therefore, to understand various clinical aspects and reduce chronic LBP more effectively, the hip joint muscle function and strength need to be considered in order to stabilize the pelvis, lumbar spine, and lower extremities during more dynamic movements, in addition to exercises such as LSE for stabilizing the lumbar region in a static state.

Muscle stretching is a widely used method in sports and rehabilitation to prevent muscle weakness, shorten muscle length, and maintain joint range of motion[25-27]. In particular, passive static stretching has been reported to decrease muscle strength generation ability through changes in muscle mechanical and neuromuscular properties[28,29]. However, passive stretching reportedly improves the ability to perceive joint position[30-32] and decreases muscle–tendon unit stiffness, which can reduce stretch reflex activity[33].

Accordingly, the combination of hip joint function and hip muscle strength, as well as lower extremity stretching of the lumbar spine and hip joints, can have a positive effect in older adults with chronic back pain. Therefore, this study aimed to investigate the differences in the effectiveness of LSE, which is the most commonly applied method for improving chronic back pain, combined with hip joint muscle strengthening exercises and passive stretching of the hip and lower extremities for LBP, and to present effective and new exercise programs applicable to chronic LBP.

METHODS

Participants

The study included 20 older Koreans (6 men and 14 women) with chronic LBP (age, 67.5 ± 5.8 years), and their physical characteristics are presented in Table 1. Participants who had experienced LBP continuously for >3 months, visited the hospital for treatment and diagnosis, and performed exercise interventions were selected. Meanwhile, participants with metabolic disorders, cardiovascular diseases, pulmonary diseases, or diabetes were excluded. All study participants provided written informed consent prior to study initiation. Thereafter, they were randomly assigned equally by sex to perform either combined exercise (CE) comprising hip exercise and passive stretching (n = 10) or LSE (n = 10) using a computerized random number generator. The study was reviewed and approved by the Institutional Review Board of Konkuk University (7001355-202009-HR-400) and was conducted in accordance with the Declaration of Helsinki.

Experimental design

The study design comprised a 1-day pre-testing session, followed by an 8-week exercise intervention, and a 1-day post-testing session (Figure 1).

In the pre- and post-testing sessions, all participants fasted for >4 h, and after stabilization, their body composition, pain-visual analog scale (P-VAS), muscle stiffness, Oswestry disability index (ODI), and physical function were measured in that order.

During the exercise intervention period, the CE and LSE groups performed their assigned exercise intervention according to their strength level, using the OMNI-resistance exercise scale of perceived exertion (OMNI-scale: 0 as extremely easy to 10 as extremely hard) for 8 weeks at three times a week. The CE comprised hip muscle strength exercises and passive stretching of the lumbar, pelvic, hip, and lower extremity muscles, which have been reported to be highly related to LBP (Figure 2)[34]. In detail, hip muscle strength exercises comprising clamshells, hip-hinge, backward lunge, and passive stretching was performed on the gluteus, psoas, piriformis, hamstring, and tensor fascia muscles (Figures 3 and 4). The CE participants performed two sets of passive stretching for 15 s, and then performed hip muscle strength exercises with an OMNI scale of 6–8. Clamshells and hip-hinge were performed with 15–20 reps and backward lunge with 12–15 reps, and a total of two sets were conducted with a rest period of 1–1.5 min between

Table 1. Participants' characteristics.

Variables	LSE (n = 10)	CE (n = 10)	*p*-value
Age (years)	67.30 ± 5.92	67.70 ± 5.37	.882
Height (cm)	160.70 ± 5.87	160.60 ± 8.08	.976
Weight (kg)	60.48 ± 11.15	58.17 ± 9.95	.648
BMI (kg/m^2)	23.31 ± 3.21	22.37 ± 2.01	.466
LBM (kg)	41.86 ± 7.73	42.40 ± 8.92	.892
BFM (kg)	18.65 ± 4.96	15.77 ± 3.51	.174
Percent body fat (%)	30.56 ± 5.58	27.29 ± 5.16	.213
Duration of pain (month)	11.70 ± 9.20	15.90 ± 7.40	.275

Data are means (± SD). Values are expressed as mean ± standard deviation. SD, standard deviation; LSE, lumbar stabilization exercise; CE, combined exercise; BMI, body mass index; LBM, lean body mass; BFM, body fat mass.

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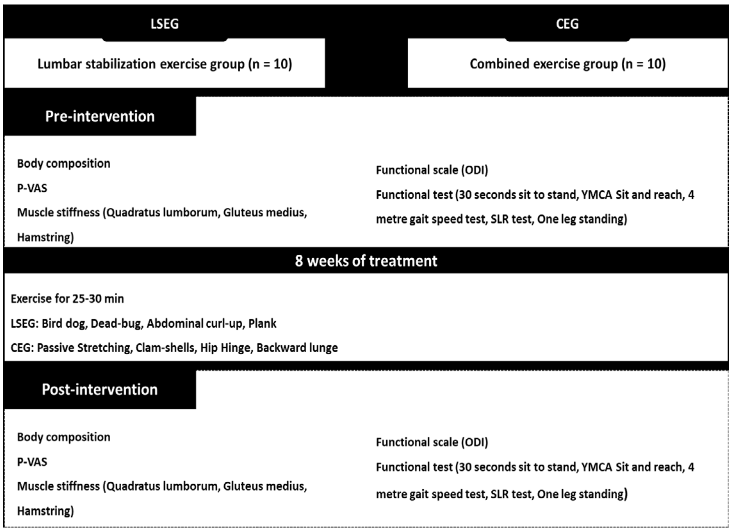

Figure 1. Study design. CE, combined exercise; LSE, lumbar stabilization exercise; BMI, body mass index; LBM, lean body mass; BFM, body fat mass; QL, quadratus lumborum; GM, gluteus medius; HAM, hamstring; P-VAS, pain visual analog scale; ODI, Oswestry disability index; SLR, straight leg raise.

Figure 2. Lumbar stabilization exercise.

Figure 3. Hip joint muscles strengthening exercise.

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Figure 4. Passive stretching.

movements, and the total exercise time was set to 25–30 min. By contrast, the LSE comprised four movements: abdominal curl-up, dead-bug, bird, dog, and plank. The LSE group performed 12–15 reps for each movement, and a total of two sets were executed for 15–30 s. The exercise intensity was set to an OMNI scale of 6–8; the rest between movements was set to 1–1.5 min, and the total LSE time was approximately 25–30 min such as in the CE group[35,36]. Previous studies have demonstrated that hip muscle strength exercise and LSE intensity can also lead to an increase in fat control, muscle strength, and muscle mass by high-intensity resistance training in the elderly[37-39]. As the OMNI scale of 6–8 indicates high intensity, the number of repetitions was adjusted to the extent that the participants did not feel pain or discomfort while performing the exercise. Thus, the intensity of the exercise was started at a scale 6 and gradually increased to 8.

In all participants, body composition (weight, body mass index [BMI], lean body mass [LBM], body fat mass [BFM], and percent body fat), muscle stiffness (quadratus lumborum [QL], gluteus medius [GM], and hamstring [HAM]), P-VAS, ODI, and physical function (30-second sit-to-stand, YMCA sit-and-reach, 4-meter gait speed, straight leg raise [SLR], and one-leg standing tests) before and after the 8-week exercise intervention were measured.

Measurements

Body composition

Weight, BMI, LBM, BFM, and percent body fat were measured using bioelectrical impedance analysis (Inbody 770, Inbody, Korea). All participants wore lightweight clothing and were asked to remove all metallic items from their bodies.

Muscle stiffness

Muscle stiffness was measured in the QL, GM, and HAM, which are regions closely related to LBP using a hand-held myometer (Myoton-Pro, Myoton, Tallinn, Estonia). For measuring muscle stiffness, a mechanical probe was positioned over each site, which delivered an impact (duration: 15 ms; force: 0.3–0.4 N), causing the tissue to briefly deform, and damped natural oscillations occurring due to the applied impact were measured by an in-built accelerometer sampling at 3,200 Hz[40]. We made three consecutive measurements in each of the left and right areas and provided the average value as the muscle stiffness score.

Pain perception and pain-related disability

Pain perception was evaluated using the P-VAS, which involves the use of a ruler marked from 0 to 10. Pain-related disability was measured using the ODI version 2.1, which is a self-administered questionnaire comprising ten items to assess the extent of the patient's back pain and difficulty in performing nine different activities of daily living. The ten evaluation items were pain intensity, personal care, lifting, walking, sitting, standing, sleeping, social life, travelling, and change in pain degree. Participants selected one of the six statements (items) according to their ability in performing the activity, with a score between 0 and 5 points for each item. Subsequently, the total score of all items was divided by the total possible score and multiplied by 100 to provide the percentage of disability. Depending on the degree of disability, 0%–20% was considered minimal, 21%–40% was moderate, and 41%-80% was severe.

Physical function

In the physical function test, the 30-second sit-to-stand test was performed to measure lower extremity muscle strength, and the YMCA sit-and-reach test was performed to measure flexibility of the lumbopelvic region. Additionally, a 4-meter gait speed test was conducted for gait evaluation. The SLR was performed to measure the flexibility of the hip joints and HAM, and the one-leg standing test was conducted to evaluate the risk of falls in the elderly. All parameters were measured twice, and the average value was used as the measured value.

Statistical analysis

Means and standard deviations were calculated for all the dependent parameters. Normality of distribution of all outcome parameters was verified using the Shapiro–Wilk W-test for the parametric tests. A two-way analysis of variance with repeated measures on the "time" factor was performed to analyze the effects of the 8-week intervention on each dependent parameter. Post-hoc Bonferroni correction was used to identify within-group changes over time. Additionally, the paired *t*-test was performed to compare the post-intervention versus pre-intervention values of the dependent parameters in each group separately. We used the Cohen's d (effect size), which reflects the value of a statistic calculated from a sample of data and standardized mean differences. Statistical differences in the means (effect size, Cohen's d) were determined with a significance level ($p < 0.05$) and 95% confidence interval (CI). Cohen's d effect size (small d = 0.2, medium d = 0.5, and large d = 0.8) was used to assess the significant effects. All analyses were performed using the Statistical Package for the Social Sciences version 25.0 (IBM, USA).

RESULTS

Body composition

As presented in Table 2, a significant interaction was identified between CE and LSE for LBM ($\eta^2 = 0.402$, $p = 0.003$) and body fat percentage ($\eta^2 = 0.222$, $p = 0.036$). The post-hoc analyses revealed a significant increase in LBM (Cohen's d: 0.06, 95% CI: − 0.78, 0.90, $p < 0.05$) and decreased percent body fat (Cohen's d: −0.17, 95% CI: −1.00, 0.68, $p < 0.05$).

Muscle stiffness, pain perception, and pain-related disability

Table 3 depicts the pre- and post-intervention data of the CE and LSE groups. No significant differences in muscle stiffness, P-VAS, and ODI were observed between the two groups; however, a significant main effect within time was observed in MS_QL ($\eta^2 = 0.770$, $p < 0.001$), MS_GM ($\eta^2 = 0.833$, $p < 0.001$), MS_HAM ($\eta^2 = 0.625$, $p < 0.001$), P-VAS ($\eta^2 = 0.917$, $p < 0.036$), and ODI ($\eta^2 = 0.835$, $p < 0.001$). The post-hoc analyses revealed significant improvement in

Table 2. Pre- and post-exercise intervention data for body composition measures with main analysis of variance results.

Variables	LSE (n = 10)			CE (n = 10)			p (η^2) value		
	Pre	Post	Cohen's d (95% CI)	Pre	Post	Cohen's d (95% CI)	Time	Group	Inter
Weight (kg)	60.48 ± 11.15	60.32 ±11.05	−0.01 (−0.85, 0.83)	58.17 ± 9.95	58.23 ± 10.58	−0.01 (−0.83, 0.84)	0.828 (0.003)	0.659 (0.011)	0.633 (0.013)
BMI (kg/m^2)	23.31 ± 3.21	23.23 ± 3.18	−0.02 (−0.86, 0.82)	23.31 ± 3.21	22.35 ± 2.19	−0.01 (−0.85, 0.83)	0.615 (0.014)	0.472 (0.029)	0.762 (0.005)
LBM (kg)	41.86 ± 7.73	41.85 ± 7.98	0.00 (−0.84, 0.84)	42.40 ± 8.92	43.03 ± 9.57	0.06* (−0.78, 0.90)	0.003# (0.387)	0.829 (0.003)	0.003# (0.402)
BFM (kg)	18.65 ± 4.96	18.47 ± 4.92	−0.03 (−0.87, 0.81)	15.77 ± 3.51	15.23 ± 3.45	−0.14 (−0.98, 0.70)	0.040# (0.215)	0.136 (0.119)	0.283 (0.064)
Percent body fat (%)	30.56 ± 5.58	30.42 ± 5.92	−0.02 (−0.86, 0.82)	27.29 ± 5.16	26.34 ± 5.08	−0.17* (−1.00, 0.68)	0.007# (0.341)	0.158 (0.108)	0.036# (0.222)

Values are expressed as mean ± standard deviation. LSE, lumbar stabilization exercise group; CE, combined exercise group; CI, confidence interval; Inter, interaction; BMI, body mass index; LBM, lean body mass; BFM, body fat mass. #Significant interaction or main effect. *p < 0.05 vs. before intervention.

Table 3. Pre- and post-exercise intervention data for muscle stiffness, VAS, and ODI with main analysis of variance results.

Variables	LSE (n = 10)			CE (n = 10)			p (η^2) value		
	Pre	Post	Cohen's d (95% CI)	Pre	Post	Cohen's d (95% CI)	Time	Group	Inter
Muscle stiffness in QL (N/m)	335.20 ± 49.87	291.60 ± 53.71	-0.83* (-1.67, 0.08)	353.70 ± 49.18	288.70 ± 36.29	-1.45* (-2.33, -0.44)	0.000# (0.770)	0.703 (0.008)	0.144 (0.115)
Muscle stiffness in GM (N/m)	330.40 ± 55.32	280.60 ± 54.44	-0.91* (-1.75, 0.01)	288.40 ± 50.79	237.13 ± 50.78	-1.01* (-1.86, -0.08)	0.000# (0.833)	0.080 (0.161)	0.869 (0.001)
Muscle stiffness in HAM (N/m)	276.70 ± 46.86	255.70 ± 39.26	-0.42* (-1.25, 0.45)	274.90 ± 46.59	239.96 ± 32.93	-0.78* (-1.62, 0.12)	0.000# (0.625)	0.632 (0.013)	0.189 (0.094)
P-VAS (scale)	5.00 ± 0.66	3.10 ± 0.74	-2.70* (-3.74, -1.42)	4.80 ± 0.78	2.80 ± 0.63	-2.67* (-3.71, -1.40)	0.000# (0.917)	0.392 (0.041)	0.722 (0.007)
ODI (score)	31.50 ± 6.99	23.70 ± 5.79	-1.04* (-1.89, -0.10)	29.70 ± 7.49	17.73 ± 5.20	-1.78* (-2.69, -0.71)	0.000# (0.835)	0.165 (0.104)	0.060 (0.183)

Values are expressed as mean ± standard deviation. LSE, lumbar stabilization exercise group; CE, combined exercise group; CI, confidence interval; Inter: interaction; QL, quadratus lumborum; GM, gluteus medius; HAM, hamstring; P-VAS, pain visual analog scale; ODI, Oswestry disability index. #Significant interaction or main effect. *p < 0.05 vs. before intervention.

Table 4. Pre- and post-exercise intervention data for physical function test with main analysis of variance results.

Variables	LSE (n = 10)			CE (n = 10)			p (η^2) value		
	Pre	Post	Cohen's d (95% CI)	Pre	Post	Cohen's d (95% CI)	Time	Group	Inter
30-second sit-to-stand test (reps)	9.20 ± 1.13	11.00 ± 1.15	1.57* (0.54, 2.47)	10.2 ± 1.31	12.47 ± 1.29	1.74* (0.68, 2.65)	0.000# (0.861)	0.027# (0.243)	0.238 (0.076)
YMCA sit-and-reach test (cm)	24.46 ± 10.95	26.72 ± 11.00	0.21* (−0.64, 1.04)	26.84 ± 8.21	30.52 ± 8.16	0.45* (−0.42, 1.28)	0.000# (0.899)	0.484 (0.028)	0.007# (0.338)
4-meter gait speed test (s)	5.78 ± 0.74	5.02 ± 0.64	−1.08* (−1.93, -0.13)	5.42 ± 0.89	4.42 ± 0.64	−1.15* (−2.01, -0.20)	0.000# (0.741)	0.136 (0.119)	0.340 (0.051)
SLR test (degree)	59.00 ± 8.29	65.30 ± 8.95	0.72* (−0.18, 1.55)	61.90 ± 11.83	71.82 ± 12.57	0.77* (−0.13, 1.61)	0.000# (0.888)	0.328 (0.053)	0.016# (0.283)
One-leg standing test (s)	4.07 ± 1.13	4.99 ± 1.43	0.63* (−0.26, 1.46)	3.70 ± 1.21	5.27 ± 1.62	0.95* (0.02, 1.80)	0.000# (0.779)	0.940 (0.000)	0.052 (0.194)

Values are expressed as mean ± standard deviation. LSE, lumbar stabilization exercise group; CE, combined exercise group; CI, confidence interval; Inter, interaction; SLR, straight leg raise. #Significant interaction or main effect. *p < 0.05 vs. before intervention.

MS_QL (CE = Cohen's d: −1.45, 95% CI: −2.33, −0.44, $p < 0.05$, LSE = Cohen's d: −0.83, 95% CI: −1.67, 0.08, $p < 0.05$), MS_GM (CE = Cohen's d: −1.01, 95% CI: −1.86, −0.08, $p < 0.05$, LSE = Cohen's d: −0.91, 95% CI: −1.75, 0.01, $p < 0.05$), MS_HAM (CE = Cohen's d: −0.78, 95% CI: −1.62, 0.12, $p < 0.05$, LSE = Cohen's d: −0.42, 95% CI: −1.25, 0.45, $p < 0.05$), P-VAS (CE = Cohen's d: −2.67, 95% CI: −3.71, −1.40, $p < 0.05$, LSE = Cohen's d: −2.70, 95% CI: −3.74, −1.42, $p < 0.05$), and ODI (CE = Cohen's d: −1.78, 95% CI: −2.69, −0.71, $p < 0.05$, LSE = Cohen's d: −1.04, 95% CI: −1.89, −0.10, $p < 0.05$).

Physical function

The physical functions of the CE and LSE groups are presented in Table 4, and significant differences in the YMCA sit-and-reach test ($\eta^2 = 0.338$, $p = 0.007$) and SLR ($\eta^2 = 0.283$, $p = 0.016$) were observed between both groups. The post-hoc analyses revealed significantly improved YMCA sit-and-reach test (CE = Cohen's d: 0.45, 95% CI: −0.42, 1.28, $p < 0.05$; LSE = Cohen's d: 0.21, 95% CI: −0.64, 1.04, $p < 0.05$) and SLR (CE = Cohen's d: 0.77, 95% CI: −0.13, 1.61, $p < 0.05$; LSE = Cohen's d: 0.72, 95% CI: −0.18, 1.55, $p < 0.05$) in the CE group than in the LSE group. Additionally, a significant main effect within time was observed in 30-second sit-to-stand ($\eta^2 = 0.861$, $p < 0.001$), 4-meter gait speed ($\eta^2 = 0.741$, $p < 0.001$), and one-leg standing ($\eta^2 = 0.779$, $p < 0.001$) tests. Both groups demonstrated significant differences in the 30-second sit-to-stand (CE = Cohen's d: 1.74, 95% CI: 0.68, 2.65, $p < 0.05$, LSE = Cohen's d: 1.57, 95% CI: 0.54, 2.47, $p < 0.05$), 4-meter gait speed (CE = Cohen's d: −1.15, 95% CI: −2.01, −0.20, $p < 0.05$, LSE = Cohen's d: −1.08, 95% CI: −1.93, −0.13, $p < 0.05$), and one-leg standing tests (CE = Cohen's d: 0.95, 95% CI: 0.02, 1.80, $p < 0.05$, LSE = Cohen's d: 0.63, 95% CI: −0.26, 1.46, $p < 0.05$).

DISCUSSION

This study hypothesized that another exercise method is effective in older adults with chronic LBP other than LSE. The results revealed that the combined hip joint muscle strengthening exercise and passive stretching program (CE) had greater improvement than LSE in the measured factors.

In this study, CE was more effective in improving body composition than LSE by increasing LBM and decreasing percent body fat; body composition improved in a relatively short-term intervention of 8 weeks. These results may be similar to those of previous studies examining the improvement effect of exercise on body composition in older adults. Ellen et al.[37] have reported that the application of resistance to older adults increased LBM. Another study[38] has reported that an increase in muscle mass or muscle strength in older adults can also be achieved by high-intensity resistance exercises for 10 days at three times a week. Meanwhile, Kryger and Andersen[39] have reported an increase in type II muscle fiber and an increase in protein synthesis of myosin heavy chain due to high-intensity resistance exercise even in older adults.

Based on previous studies[41,42] that demonstrated that multi-joint exercise has greater muscle strength and more muscle recruitment effects than single-joint exercise, the decrease in percent body fat may be due to the CE program including multiple joint exercises that use large muscles of the lower extremities, such as backward lunge and hip-hinge, compared to LSEs, which involve a high proportion of core muscles. The characteristics of the CE program may have contributed to increasing muscle mass and LBM, and to decreasing percent body fat by increasing energy and calorie consumption. However, in the present study, accurate result interpretation was difficult because of the lack of direct measurement of energy consumption during exercise in both groups, which is a limitation of the study.

In previous studies, muscle stiffness affects pain and physical activity; P-VAS and ODI have also been used to assess LBP. Back muscle stiffness is known to contribute to back pain by reducing the mobility of the spine[43], When the stiffness of the muscles is higher, resistance to contraction may occur, thus causing functional problems[44]. Patrick et al.[45] have also reported that the stiffness of the lumbar muscles causes disability in activities of daily living. Our results revealed no significant differences in muscle stiffness, P-VAS score, and ODI score between the LSE and CE groups. However, both groups demonstrated significant improvements in all factors, and the P-VAS scores tended to be higher in the CE group. These results indicated that exercise in both groups influenced the improvement in each factor. Based on the results of previous studies, the reduction in muscle stiffness and P-VAS score after 8 weeks of exercise intervention in both groups can be considered an effect of improving the structural stability of the lumbar spine by inducing strengthening of the lumbopelvic region and hip joint muscles, including the lumbar region, and reducing posture displacement. Furthermore, this improvement in muscle stiffness and P-VAS can be considered to positively affect activities of daily living and movements, resulting in a positive effect on the evaluation of ODI[45]. Moreover, the greater improvement tendency for muscle stiffness and ODI in CE may be a result of the addition of passive stretching, known to induce stiff muscle relaxation and enhance functional movements[46], and exercise such as backward lunge, hip-hinge, and clamshells are more closely related to movements and functions in activities of daily living than LSE, which can be considered to have a more positive effect on the improvement of ODI[47]. Hence, the CE program can effectively improve the muscle strength and function of the hip muscles, which are highly associated with back pain[19-23,34] and may be more effective than applying LSE by strengthening the stability of the pelvis and lumbar region, which is the most important purpose of exercise therapy.

In our study, to evaluate the flexibility of soft tissues from the lumbar region, pelvis, and HAM and the mobility of the hip joint and lumbar regions, we measured the SLR and conducted a YMCA sit-and-reach test. The data suggest that the YMCA sit-and-reach test and SLR had significant differences, while the other factors, including the 30-second sit-to-stand, 4-meter gait speed, and one-leg standing tests, had no significant differences in terms of effectiveness between the two interventions but demonstrated improvements in LBP in both the LSE and CE groups. The degree of improvement was greater in the CE group. Some researchers have sought to improve mobility by applying LSE. Standaert et al.[48] stated that the LSE is intended to improve muscle strength, endurance, and flexibility. In 2017, Sehrish et al.[49] reported that lumbar flexion, extension, and lateral flexibility were effective 2 weeks after performing LSE. Study designs that can provide better results to the CE group in improving flexibility may be advantageous, which is considered a limitation of this study. However, according to the results of previous studies, LSEs are considered effective in improving lumbar stability by strengthening the deep muscles, thereby improving flexibility. Therefore, our study was designed to identify the difference in muscle stiffness reduction effects of LSE and passive stretching and added it to the CE program, assuming that passive stretching with various advantages as an exercise therapy would have additional effects[30-33]. Our results reveal that SLR and the YMCA sit-and-reach test demonstrated greater improvement in the CE group. As we have discussed, these results can be considered an effect of the exercise program applied to CE and LSE, which improves the stability of the lumbar spine and pelvis, and it may be the result of adding a passive stretching effect.

Regarding physical functional factors, such as the 30-second sit-to-stand, 4-meter walking speed, and one-leg standing tests, the significant improvements in both groups are consistent with the results of previous studies. According to previous studies, exercise therapy helps in improving pain and functional restrictions in patients with LBP, and exercise focusing on joint function and alignment of the lower extremities demonstrated greater effects in the long and short term than exercise for strengthening trunk muscles[50,51].

In conclusion, CE is comparable to LSE as an effective and successful exercise intervention that reduces muscle stiffness and P-VAS scores, although CE is more effective in enhancing physical function than LSE in older adults with LBP. Therefore, CE is a potentially new exercise program that can be applied as an alternative to LSE for chronic LBP in clinical practice. However, the effectiveness of exercise programs with longer treatment periods in various age groups need to be verified in future studies.

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