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Effects of Kinesthetic Imagery, Active and Combined Exercises on the Electromyographic Pattern of Hip Hyperextension and Tests of Relation with Lumbar Hyperlordosis

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ABSTRACT

Background: Mental exercise uses the same neuronal pathways involved in physical exercise to modify the pattern and function without the stress caused by physical exercise. This study investigated the effects of the three methods of kinesthetic imagery, active, and combined exercise (imagery and active) on the pattern of hip hyperextension and the strength of selected muscle of lumbo-pelvic in women with lumbar hyperlordosis.
Method: In this semi-experimental study, 36 women with lumbar hyperlordosis (age: 34.47±3.79, height: 160.48±12.63, weight: 64.46±18.26) were sorted into three groups. The groups practiced three sessions per week for six weeks. The degree of lumbar lordosis using flexible ruler, electromyographic activity of the lumbo-pelvic muscles during hip hyperextension in the prone position using surface electromyogram, the strength of the gluteus maximus during hip hyperextention using dynamometer, the strength of abdominal muscles during lowering two legs test using goniometer, flexibility of hip flexor muscles during the Thomas test using goniometer, and flexibility of erector spine muscles during the Schober test using a meter were measured before and after the intervention. The Shapiro-Wilk test was used for normality of data, and the repeated measures variance test was used for the statistical analysis of data at a significance level of 0.05.
Results: The results showed a significant difference between the three methods of kinesthetic imagery, active and combined (P=0.001). There was a significant difference between the method of imagery exercise and the methods of active and combined exercise, but no significant difference was observed between the methods of active and combined exercise.
Conclusion: Imagery exercises were effective in modifying the electromyographic activity of some lumbo-pelvic muscles (gluteus maximus and rectus femoris muscles); however, they did not have a significant effect on the strength, flexibility, or degree of lumbar lordosis. Combined exercise was as effective as active exercise in modifying the electromyographic activity of the lumbo-pelvic muscles, the strength of the abdominal and gluteus maximus muscles, and the flexibility of erector spine and hip flexor muscles.

Introduction

Repeated movement and sustained posture alter muscle tissue properties [1], so that the musculoskeletal system cannot provide the necessary support for optimal movement with stability [2]. It appears that the stress and strain on different body structures, if they go beyond tissue tolerance, can lead to pathology [1]. Therefore, motor pattern abnormalities can be an important factor

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in musculoskeletal disorders [3-5]. In this regard, Janda stated that the normal pattern of muscle activation during hip extension in the prone position is the gluteus maximus, followed by the hamstring and the spin erectors, respectively [2]. Disruptions to this natural pattern cause mechanical and compressive stresses on the lumbar spine [2]. One of the most common patterns of disorder seen clinically during the prone hip extension (PHE) test is excessive delay in applying the gluteus maximus [1]. In these cases, hip extension is caused by the activity of the hamstring muscles, which causes anterior pelvic tilt and lumbar hyperlordosis to compensate [6]. In lower crossed syndrome (LCS) (also referred to as distal or pelvic crossed syndrome) (Janda, 1987), tightness of the thoracolumbar extensors on the dorsal side crosses with tightness of the iliopsoas and rectus femoris. Weakness of the deep abdominal muscles ventrally crosses with weakness of the gluteus maximus and medius. The balance of the agonist and antagonist in lumbo-pelvic muscles is disturbed, such that erector spine muscle overactive with iliopsoas, rectus femoris muscle overactive, and deep abdominal muscles underactive with gluteus maximus muscle underactive are associated [2]. This pattern of muscle imbalance increases lumbar-pelvic mobility [7]. Particularly in activities such as gait, the stability of the pelvic is reduced, thus impeding the body's mechanical efficiency [6]. This is why it is used as a criterion in examining movement patterns, activity levels, or sequences and the order in which muscles are activated [2, 3]. If the lumbo-pelvic muscles act in a normal pattern, they provide sufficient stability to prevent excessive lumbar curvature and cause a normal movement pattern in the lumbo-pelvic [4, 5].

Oh et al. investigated the effect of inward abdominal maneuvering on erector spine and hip electromyographic activity and anterior pelvic tilt angle during hip extension in the prone position. Their results showed that inward abdominal maneuvering during hip extension caused a significant decrease in erector spine amplitudes and a significant increase in internal hamstring and gluteus maximus amplitudes. Park et al. examined the effect of inward abdominal maneuver on muscle activity, pelvic movement during knee flexion in patients with extension lumbar rotation syndrome. Their results showed that the activity of both left and right erector spine muscles was significantly reduced during the abdominal maneuver. Internal and external hamstring electromyography activity was significantly increased. Pelvic tilt, knee flexion, and pain during abdominal maneuver decreased in the prone position during knee flexion. The results of these studies show that by increasing abdominal activity, pelvic tilt is reduced [7, 8].

The muscles are a window to the function of the central nervous system (CNS), and any dysfunction in the central nervous system or sensory-motor system exhibits adaptive and compensatory manifestations in the motor system [2, 4, 5]. Research findings have shown that physical exercise is an effective intervention to correct imbalances and muscle function. However, the use of mental training methods that increase cerebral cortex activity and attention [9] and thus provide better cognition has not been sufficiently addressed. It seems that in mental practice, more repetition can be achieved in less time and achieve results to those with similar physical exercise [9-12]. Lebanon et al. examined the increase in muscle activation following intervention with mental imagery exercises during anterior cruciate ligament rehabilitation. Their findings showed that imagery exercise increased muscle activation [13]. Kristico et al. used mental imagery exercises along with physiotherapy for ankle rehabilitation. Although the researchers used mental intervention to help subjects, the results showed that there were no significant changes in pain, swelling, or range of motion in athletes [14]. In another attempt, Hoyek et al. examined the effect of mental imagery on functional rehabilitation in impingement syndrome of the shoulder. The results showed that mental imagery exercise increased joint mobility [15]. Findings from these studies suggest that mental exercise along with physical exercise can be used to modify muscle activity patterns [1], but the use of mental imagery exercises as an effective intervention in correcting motor pattern and musculoskeletal disorders functionality requires further study. The aim of the present study was to compare the efficacy of active, imagery, and combined exercise on movement patterns of hip hyperextension, strength of gluteus and abdominal muscles, and flexibility of hip flexor and erector spine muscles in women with lumbar hyperlordosis.

Methods

The semi-experimental study has the clinical trial code number IRCT20130109012078N4 from the Iranian Registry of Clinical Trials. To provide no alternative explanation for the observed differences between interventions, all subjects were selected from a single cohort (non-athlete women with no history of injury, age: 34.47±3.79, height: 160.48±12.63, weight: 64.46±18.26) [16]. Screening was first performed using observational evaluation of the sagittal and frontal plates. The lumbar lordosis angle was measured using a flexible ruler. Women whose lordosis angle was above 45 degrees [17] were included in the study after completing the consent and motion imagery questionnaire. Those who achieved the quota [18] were placed in the group of kinesthetic imagery and combined exercises (active and imagery), and the rest were placed in the active exercise group. To avoid spreading the effects of the intervention from one group to another, attempts were made to separate the exercise groups as much as possible. Each group's training time was set at a distance from the other training group, so that participants would not meet and become aware of each other's work [16].

Samples were calculated using G Power software (analysis of variance with repeated measures within and between interactions); with an effect size $f^2=0.3$ (moderate effect size); number of groups=3; measurement numbers=2; significance level=0.05; and statistical power of 0.85, the total number of 36 subjects was estimated (Active exercise group: 12, kinesthetic imagery exercise group: 12, and Combined exercises group: 12). Subjects signed a written consent form and entered the study (Appendix 1).

A flexible ruler, which has been described as validity (0.88) and reliability (0.82), was used to measure lumbar lordosis degree [19]. The spinous process of the twelfth thoracic vertebrae (T_{12}) was used as the starting point of the arch, and the spinous process of the second sacral vertebra (S_2) was used as the end point of the arch (Youdas, 2006) [17]. The ruler was then placed on the desired points and they were marked on the ruler. The ruler was applied to paper with no changes, and the curvature formed on the ruler was drawn by a pencil on the paper. After removing the ruler from the paper, two distinct points were connected to the straight line, and a straight line was drawn on the deepest part of the perpendicular arc. The lumbar arch size was calculated using the 4Arctg H / L2 formula [17, 19].

To measure the strength of a gluteus maximus muscle using a dynamometer, the subject lay in the prone position on the bed and bent the knee 90 degrees. Next, the leather interface was attached to the middle of the thigh, and the subject was asked to apply maximum force to the leather interface. Each subject repeated this test twice with a one-minute interval, and the best obtained number was considered as the maximum isometric strength of the gluteus maximus muscle [17, 20-22].

Abdominal muscle strength was measured using the double leg-lowering test (DLLT) [23]. All measurements were completed by a team of 2 examiners. Subjects wore shorts and removed their shoes to avoid additional external loads. The examiners explained the testing procedure to the subjects, who then were allowed to practice the procedure only once to demonstrate their understanding of the DLLT. When performing the test, each subject lay supine on a wooden table with a 1-cm–thick felt pad with the arms folded across the chest. Two trials were performed with a 1-minute rest between trials. The test began with an examiner helping the subject place her legs in a vertical position with the knees extended to the terminal range as allowed by the flexibility of the hamstrings. Each subject was instructed to keep the pelvis posteriorly rotated, so the lumbar spine was held firm to the table, while slowly lowering the legs to a horizontal position. Examiner 1 monitored the position of the low back from the subject's right side by placing fingers between the low back (L4-5 area) and the table. Examiner 1 verbally signaled Examiner 2 when the subject's back began to lift from the monitoring fingers; this represented the end of the test. Examiner 2 recorded the subject's performance with the goniometer. The goniometer was placed on the greater femoral trochanter; then one axis of the goniometer was placed along the long axis of the femur and the other along the trunk. The axis of the goniometer remained parallel to the long axis of the femur while the test was being done. At the signal to end the test, a stop to measure with goniometer occurred [17, 20, 21].

Flexibility of the hip flexor muscles was measured using the modified Thomas test. The subjects were instructed to sit as close to the edge of the examination table as possible. Subjects supported their left thigh and, with the assistance of the examiner, slowly rolled backward onto the table. The left hip was flexed to the point that the lumbar lordosis was flattened, and the right limb was allowed to hang unsupported off the table. The examiner palpated the lumbar spine to confirm that it remained in contact with the table. Thigh position was also monitored to prevent abduction of the thigh, because abduction of the thigh during hip extension would indicate tightness of the tensor fasciae latae. When the final test position was achieved, the examiner placed the measurement device (goniometer) on the subject. For the goniometer, the fulcrum was placed over the lateral aspect of the greater trochanter. The proximal arm was aligned with the lateral midline of the pelvis, and the distal arm was aligned with the lateral midline of the femur using the lateral epicondyle for reference. When the examiner was satisfied with the placement of the goniometer, the range shown with the goniometer was recorded [17, 20, 21].

Flexibility of the erector spine muscles was measured using the Schober method (1937); the subject stood erect and the lumbosacral junction was identified and marked. Another skin mark was made 10 cm above this. The subject then bent forward as far as possible and the distance between the marks was measured [17, 20, 21]. All tests were performed on participants' right leg.

The electromyography activity of abdominal, hip extensors, lumbar extensors, and hip flexor muscles was measured using surface electromyography in the prone position [3]: The participant was asked to perform hip hyperextension in the prone position. To record the electrical activity of the muscles, a 16-channel electromyogram of the ME model from Flanders and dipole electrodes were used. Four channels were used for muscle examination. Superficial disposable electrodes and FRG rectangular electromyography (SKINTACT, Austria) were also used. Electromyographic data was collected at a sampling rate of 1000 Hz/s. These signals were initially 10 x preamplified and filtered in the band-pass filter between 20 and 500 Hz. The distance between the electrodes was 2 cm, and the electrodes were positioned on the midline of the muscles according to SENIAM instructions. Then the electrodes were connected to the target points (gluteus maximus muscle: 1.2 distance of S_2 to greater trochanter; lumbar erector spine muscle: 3 cm apart from L_3 lumbar; transfers abdominis muscle: 2 cm distal to upper anterior superior iliac spine to downward and inward; and rectus femoris muscle: 1/2 distance anterior superior iliac spine to under patella) (Appendix 2). Electromyographic parameters were recorded in a computer. Motion speed was controlled using a metronome, and data was analyzed using the RMS algorithm (Root Mean Square) and megavine software designed by Mega Electronics of Finland. The electromyography of hip hyperextension for a period of six seconds was recorded, and 1.5 seconds were eliminated from the beginning and the end. The maximum voluntary contraction method was used to normalize the electromyographic data, with each muscle being tested three times, and the maximal voluntary contraction and the electromyographic activity of the muscles in six seconds was recorded. To process the information, 1.5 seconds of the first and last were deleted and three middle seconds were selected. The maximum value of the three measurements was used for analysis. Finally, the amount of electromyographic activity of each muscle during hyperextension of the femur was divided to the maximum voluntary contraction of the same muscle until the numbers were presented as normal and a percentage of maximal voluntary contraction [3, 4].

Sahrmann exercises were used for the active exercise group [1]. Active exercises were performed for a duration of 60-75 min three sessions per week for six weeks, including 5 min of warm up, the main training program for 45 to 60 min, and cool down for 5 min (Appendix 3). The group of kinesthetic imagery exercises performed the same Sahrmann exercise mentally (kinesthetic imagery including sense of motion and sensation of power or effort during imagery). The imagery exercise was performed for 60-75 min, three sessions per week, for six weeks, including 5 min of warm up, kinesthetic imagery program for 45 to 60 min, and cool down for 5 min. The combined exercise group (imagery and active) carried out the program by blocking active exercises and kinesthetic imagery. Initially, they performed the exercises mentally, followed by actively, and the process was repeated until the end of the exercise (half the exercise as active and half of the exercise as mental). The combined exercises were performed for a duration of 60-75 minutes, three sessions per week for six weeks, including 5 min of warm up, the main exercise program for 45 to 60 min, and cool down for 5 min. Exercises from one set with six replications in the first session were increased to three sets with eight replications in the last session. All exercises were designed to observe the principle of gradual overload in the number of iterations (from a set with six replications, to three sets of eight repetitions in the sixth week) and the maintenance period of each movement (from six seconds maintenance of contraction to ten seconds in the sixth week). The duration of exercises in all three groups was equal (Appendix 3).

All information is provided as average and standard deviation. Data was analyzed using the repeated measure ANOVA test. Before analysis of variance with repeated measures, M Box and Mauchly tests were used to predict the assumptions, and after the fitting of data, normal distribution of errors was investigated. Since the M Box test was not significant for any of the research variables, the homogenous condition of the variance matrix was properly observed. Moreover, there was no significant lack of variables in the Leven test, indicating that the condition of equality between group variance, observance, and variance of error of dependent variables was equal in all groups. Finally, the results of the Mauchly test showed no significance for any of the variables, so the equality of variance in the subjects was observed. The results of normal distribution of errors was $P \geq 0.05$, indicating normal distribution of error. The significance level for all calculations was considered to be 0.05. The post-hoc Bonferroni test was performed to compare the groups. All statistical calculations were performed using SPSS software (Version 24).

Results

The general characteristics of the subjects by group are presented in Table 1. Considering the significance of the stage effect, Table 2 shows the pre-test and post-test on variables of lumbar lordosis degree, electromyographic activity of gluteus maximus, lumbar erector spine, transfer abdominis and rectus femoris muscles, and strength of gluteus and abdominal muscles in each group. A significant difference was observed between the pre-test and post-test scores of the exercise groups. Moreover, the significant interaction of group-stage and group on the variable of lumbar lordosis degree showed a significant difference between exercise groups. The Bonferroni post hoc test was also used to compare the groups in the pre-test, post-test, and stages in the exercise groups (Tables 3-5).

Discussion

The current study purposed to investigate the effect of the three methods of kinesthetic imagery, active, and combined exercises on the electromyographic pattern of hip hyperextension, muscle strength of the gluteus maximus and abdominal muscles, and flexibility of the hip flexor and erector spine muscles in women with lumbar hyperlordosis. In lower crossed syndrome, the pattern of movement changes due to stiffness and shortness of flexure of the hip muscles, erector spinal muscles, and weakness of abdominal and gluteus muscles. This muscle imbalance has detrimental effects on the static and dynamic state of the body, especially when walking. This syndrome causes anterior pelvic tilt, increased lumbar lordosis, and slight flexion of the hip joints [1-3]. This syndrome alters the transverse of forces in both the lumbar and pelvic areas [1], so correction of lumbar hyperlordosis functional abnormalities is necessary.

One of the objectives of the current study was to investigate the effect of mental imagery exercises on electromyography activity of the transverse abdominis, gluteus maximus, and rectus femoris muscles. The results showed that imagery exercises had an impact on increasing gluteus maximus activity and reducing rectus femoris muscle activity. In mental imagery, movement

Table 1: General characteristics of the subjects

Groups	Age (years) Mean±SD	P value	Height (cm) Mean±SD	P value	Weight (kg) Mean±SD	P value
Active exercise	34.06± 3.15	0.93	160.60±14.21	0.87	65.73±16.06	0.81
Imagery exercise	34.27±4.17		159.54±10.62		63.52±15.93	
Combined exercise	35.08±4.06		161.32±13.08		64.34±22.81	

One-way ANOVA test to investigate intergroup differences in age, height, and weight; P *value* ≥ 0.05: There is no significant difference between groups.

Table 2: Repeated Measures Analysis of Variance for Comparison of Pre-test and Post-Test on the Variables of Lordosis Degree, Activity of Gluteus Maximus Muscle, Lumbar Erector Spine, Transfer Abdominis, and Rectus Femoris

Variables	Source	Sum of squares	Df	Mean square	P value	Partial Eta squared
Lordosis degree	Time	606.391	1	606.391	0.001	0.883
	Groups*time	114.384	2	57.192	0.001	0.586
	Error	80.725	29	2.784	-	-
	Groups	103.084	2	51.542	0.013	0.260
	Error	293.525	29	10.122	-	-
Activity of gluteus maximus	Time	218.116	1	218.116	0.001	0.414
	Groups*time	5.314	2	2.657	0.781	0.17
	Error	309.039	29	10.657	-	-
	Groups	14.331	2	7.166	0.925	0.005
	Error	2668.887	29	92.031	-	-
Activity of erector spine	Time	1001.710	1	1001.710	0.001	0.395
	Groups*time	30.372	2	15.186	0.753	0.019
	Error	1535.078	29	52.934	-	-
	Groups	43.184	2	21.592	0.827	0.013
	Error	3276.082	29	112.968	-	-
Activity of transfer abdominis	Time	86.578	1	86.578	0.021	0.171
	Groups*time	12.630	2	6.315	0.651	0.029
	Error	420.910	29	14.514	-	-
	Groups	66.454	2	33.27	0.877	0.009
	Error	7302.291	29	251.803	-	-
Activity of rectos femoris	Time	615.471	1	615.471	0.001	0.584
	Groups*time	108.082	2	54.041	0.041	0.198
	Error	438.706	29	15.128	-	-
	Groups	106.205	2	53.102	0.774	0.018
	Error	5957.654	29	205.436	-	-
Strength of gluteus maximus	Time	197.659	1	197.659	0.001	0.531
	Groups*time	26.629	2	13.315	0.127	0.133
	Error	174.308	29	6.011	-	-
	Groups	55.229	2	27.615	0.628	0.032
	Error	1696.708	29	58.507	-	-
Strength of abdominal	Time	1467.108	1	1467.108	0.001	0.729
	Groups*time	342.526	2	171.263	0.001	0.386
	Error	544.583	29	18.779	-	-
	Groups	415.159	2	207.580	0.204	0.104
	Error	3585.950	29	123.653	-	-
Thomas test	Time	467.641	1	467.641	0.00	0.751
	Groups*time	87.109	2	43.555	0.002	0.360
	Error	154.750	29	5.336	-	-
	Groups	230.284	2	115.142	0.086	0.156
	Error	1245.950	29	42.964	-	-
Schober test	Time	10.810	1	10.810	0.00	0.606
	Groups*time	1.621	2	0.811	0.049	0.187
	Error	7.031	29	0.242	-	-
	Groups	1.475	2	0.738	0.570	0.038
	Error	37.365	29	1.288	-	-

P value≥0.05: There is no significant difference. P value≤0.05: There is a significant difference.

is activated by the brain structures that are involved in cognitive control and motor planning; in other words, all cognitive stages of motion control including projection, planning, and readiness of motion are similar to real moves [11, 12]. In the executive phase the movement is controlled, but the same neural pathway that is activated in active activity results in increased activity of motor units [12], and the activity of the gluteus maximus is increased. Conversely, the activity of the opposite muscle, the rectus femoris, is reduced. The increase in electromyography activity following imagery exercises may be related to the activation of the central nervous system. Based on equivalence and functional equality between mental imagery and motor activity, because mental imagery results in reorganization of the cortex for the same physical exercise, and followed by an increase in the cortex output signals, the muscle tends to increase the level of higher surface activation [11, 12]. Lebon et al. investigated the increase in the activation of muscles following mental imagery during the rehabilitation of the anterior cruciate ligament. Their findings showed that mental imagery increased muscle tone, although imagery exercises resulted in a decrease in pain [13]. The fact that mental imagery exercises did not affect the transverse abdominis muscle is probably due to the fact that it is a deep muscle that needs more intense and longer training to change the rate of muscle activity. Moreover, the exercises did not affect the activity rate of the transverse

Table 3: Intergroup effects in pre-test and post-test stages

Variables	Stages	Beta	Standard error	T	P value
Lordosis degree	Pre-test	-0.200	0.966	-0.207	0.837
	Post-test	5.350	1.197	4.468	0.001
Activity of gluteus maximus	Pre-test	-0.722	3.534	-0.204	0.840
	Post-test	-1.084	2.518	-0.430	0.670
Activity of erector spine	Pre-test	-1.787	2.647	-0.675	0.505
	Post-test	0.809	4.838	0.167	0.868
Activity of transfer abdominis	Pre-test	1.905	5.008	0.380	0.706
	Post-test	1.618	4.873	0.332	0.742
Activity of rectos femoris	Pre-test	-4.434	3.900	-1.137	0.265
	Post-test	-0.774	5.023	-0.154	0.879
Strength of gluteus maximus	Pre-test	2.383	2.549	0.935	0.357
	Post-test	5.551	2.309	0.346	0.732
Strength of abdominal	Pre-test	3.717	4.017	0.925	0.363
	Post-test	-6.617	3.158	-2.095	0.045
Thomas test	Pre-test	3.500	1.427	1.525	0.286
	Post-test	1.50	1.410	1.06	0.060
Schober test	Pre-test	4.708	0.263	5.821	0.627
	Post-test	5.583	0.241	4.61	0.435

P value≥0.05: There is no significant difference. P value≤0.05: There is a significant difference.

Table 4: Bonferroni post hoc test results for phase effect on variables

Variable	Imagery		Active		Combined	
	Stages	P	Stages	P	Stages	P
Lordosis degree	Pre-test: 48.30±2.21	0.21	Pre-test: 48.40±2.31	0.001	Pre-test: 48.50±2.23	0.001
	Post-test: 46.10±4.06		Post-test: 40.20±2.39		Post-test: 40.75±2.34	
Activity of gluteus maximus	Pre-test: 79.66±6.3	0.04	Pre-test: 78.82	0.03	Pre-test: 80.38±8.01	0.01
	Post-test: 82.78±4.01		Post-test: 83.34±6.15		Post-test: 83.86±6.85	
Activity of erector spine	Pre-test: 82.41±5.30	0.10	Pre-test: 84.17±8.55	0.02	Pre-test: 84.20±4.22	0.001
	Post-test: 75.33±11.75		Post-test: 77.54±11.25		Post-test: 74.52±10.95	
Activity of transfer abdominis	Pre-test: 79.87±7.63	0.16	Pre-test: 78.24±15.21	0.6	Pre-test: 77.96±10.94	0.02
	Post-test: 82.63±11.18		Post-test: 79.26±12.91		Post-test: 81.01±10.13	
Activity of rectos femoris	Pre-test: 75.11±9.02	0.02	Pre-test: 78.28±11.14	0.001	Pre-test: 79.54±7.09	0.01
	Post-test: 72.33±12.04		Post-test: 68.94±12.38		Post-test: 73.10±10.88	
Strength of gluteus maximus	Pre-test: 23.80±5.88	0.07	Pre-test: 19.90±6.00	0.03	Pre-test: 21.41±5.96	0.01
	Post-test: 25.50±5.58		Post-test: 24.70±4.76		Post-test: 25.50±5.71	
Strength of abdominal	Pre-test: 118.30±11.73	0.11	Pre-test: 109.00±8.43	0/001	Pre-test: 114.58±7.82	0.001
	Post-test: 121.30±9.14		Post-test: 121.50±6.25		Post-test: 127.91±6.55	
Thomas test	Pre-test: 141.20±3.15	0.10	Pre-test: 141.50±3.37	0/001	Pre-test: 143.00±6/.85	0.001
	Post-test: 143.20±4.10		Post-test: 149.00±3.16		Post-test: 150.00±6/39	
Schober test	Pre-test: 14/90±0/61	0.16	Pre-test: 14.85±1.02	0/001	Pre-test: 14.70±1.01	0.001
	Post-test: 15.30±0.85		Post-test: 16.05±0.72		Post-test: 15.58±0.90	

P value≥0.05: There is no significant difference. P value≤0.05: There is a significant difference.

Table 5: Bonferroni post hoc test results for group effect on pretest and posttest on lumbar lordosis degree variable

Variable	Groups	P value
Lumbar lordosis Pre-test	Imagery – active	0.837
	Imagery – combined	0.918
	Active – combined	0.872
Lumbar lordosis Post-test	Imagery – active	0.022
	Imagery – combined	0.037
	Active – combined	1.00

P value≥0.05: There is no significant difference. P value≤0.05: There is a significant difference.

abdominis muscle; thus, it could not reduce the activity rate of the lumbar erector spine.

The other aim of the present study was to investigate the effects of active corrective exercises on the electromyography activity of transverse abdominis, gluteus maximus, erector spine, and rectus femoris muscles. The results were in agreement with the results of Oh et al. and Park et al. showing that corrective exercises affected an increase in electromyography activity of the gluteus maximus and a reduction in the electromyography activity of the erector spine and rectus femoris muscles [7, 8]. Therefore, it is used in corrective exercises (Sahrmann exercises) to enhance the gluteus maximus and abdominal muscles, which results in a reduction in erector spine activity. Also, the exercises used to increase gluteus maximus strength lead to a reduction in the rectus femoris strength [2]. In spite of this, there was no significant effect on the rate of activity of the transverse abdominis muscle, probably because it is a deep muscle and probably needs more intense and longer training to change its rate of activity. Therefore, according to the objectives of the research, the effects of combined exercise on the electromyography activity of the transverse abdominis, gluteus maximus, erector spine, and rectus femoris muscles were investigated. The results showed that the combined exercises increased the activity of the gluteus maximus and transverse abdominal muscles and had a significant effect in decreasing the activity of the rectus femoris and erector spine muscles. With imaging exercises, the rate of muscle activity can be altered [22, 15], and when followed up by active exercise, the nerve and muscle coordination is stabilized [15]. Mental practice also increases the activity of the cerebral cortex and increases attention, thus providing better cognitive power. The most important neuromuscular compatibility code, which is cognition, is caused by mental exercise without fatigue, and with active exercises the cognition created is stable [22, 23].

The other aim of the present study was to investigate the effect of imaging exercises on the strength of the gluteus and abdominal muscles. The results showed that imaging exercises had no significant effect on the strength of the gluteus and abdominal muscles, which was not consistent with the study of Yao et al. Although imaging exercises had an effect on muscle activity rate, they did not affect muscle strength, because the exercises were repeated three times per week. In the study of Yao et al., however, five sessions of exercise per week were found to have an effect on muscle strength [23].

The third aim of the present study was to investigate the effects of active exercises on abdominal muscle strength. The results showed that active exercises had a significant effect on increasing abdominal muscle strength, which was consistent with the studies of Levine et al. and Ferreira et al. By increasing the activity of the abdominal muscles and changing the time of activation of the abdominal muscles, which plays an important role in the function of the lumbo-pelvic structure, the created muscle imbalances can be eliminated [24, 25]. The results also showed that combined exercises had a significant effect on increasing the strength of abdominal muscles. As in the study of Lebon et al. who examined the benefits of mental imagery training on muscle strength, the findings showed that the strength of the leg press was significantly higher in the MVC (maximum voluntary contraction) mental imagery group than the control group [26], because mental training alters the central command of the muscular nervous system. Studies have shown that the brain is activated to produce stronger signals through repeated mental efforts to activate the muscle. As a result, a stronger command in the central nervous system may use inactive motor units, resulting in more force generation [9, 12, 26]. Furthermore, when mental imagery exercises are combined with active exercises, proper neuromuscular coordination is created and as a result, abdominal strength is increased.

The present study also aimed to investigate the effect of active exercises on the strength of gluteus maximus muscles. The results showed that active exercises had a significant effect on increasing the strength of gluteus maximus muscles, consistent with the findings of Alvim et al. and Arab et al. [27, 28]. As mentioned in these studies, the gluteus maximus muscle plays an important role in controlling the pelvis and prevents pelvic tilt and subsequent increase in lumbar hyperlordosis. Therefore, with active exercises, positive changes can be made in reducing lumbar hyperlordosis by changing the rate of activity and activity pattern of the gluteus maximus. The results showed that combined exercises had a significant effect on increasing the strength of the gluteus maximus muscles. The results of the study were consistent with the study of Kumar et al, who examined imagery exercises on muscle strength and gait performance in people with stroke. In this study, strength and performance were improved in the control (active exercises) and experiment (active and imagery exercises) groups, and there was a significant difference between the two groups [29]. Therefore, studies showing that due to their physiological and psychological effects, imagery exercises can be used as a complementary therapy in rehabilitation and movement pattern modification [29, 30].

Another aim of the current study was to investigate the effects of imagery exercises on the flexibility of the lumbar erector spine and hip flexor muscles. The results showed that imagery exercises did not affect the flexibility of the lumbar erector spine or hip flexor muscles, which is inconsistent with the study of Vergeer et al. who examined the effect of movement and stretching imagery on increasing the flexibility of volunteers in four weeks of flexibility training [31]. This difference may be explained by the fact that in Vergeer's study, participants only illustrated flexibility exercises, but the present study emphasized improving movement patterns and relieving muscle imbalances, and the participants did not perform flexibility exercises. As a result, adequate mobility may not have been provided to the lumbar spine joints.

The current study also investigated the effects of active corrective exercises on the flexibility of the lumbar extensor and hip flexor muscles. The results showed that corrective exercises were effective in increasing the flexibility of the lumbar extensor spine and hip flexor muscles, consistent with the results of Rowena et al. and Masuda et al. Improving and modifying the movement pattern in the lumbo-pelvic area causes a decrease in the amount of tension in the lumbar spine muscles, followed by an increase in mobility in the lumbar spine joints [32, 33]. Also according to the aim of the study, the effects of combined exercises on the flexibility of the lumbar extensor spine and flexor hip muscles were investigated. The results showed that combined exercises had a significant effect on the flexibility of the lumbar extensor spine and hip flexor muscles. The results were consistent with those obtained by Williams et al. who examined the effects of mental imagery on the range of motion of the hip joint. It has also been observed that more favorable results occur when active exercises are accompanied by motor imagery [21], because imaging exercises probably facilitate the neuromuscular system of proprioceptors and, as a result, are effective in achieving and maintaining range of motion in the joints [21]. Such neuromuscular facilitation helps improve the movement pattern more effectively, and it is stabilized with active exercises. This result indicates the auxiliary role of imaging exercises along with active exercises to improve joint mobility [21].

Because both active and combined exercise methods are effective in changing the activity of the muscles of the lumbo-pelvic and the function of the selected muscles has changed, more coordination has been established between the selected muscles. As a result, the movement pattern changes and more stability is provided in this area. As the results showed, this method reduced the degree of lumbar lordosis in women with lumbar hyperlordosis [1-5].

Conclusion

The results of the study showed that combined and active exercises are effective in decreasing the degree of lumbar lordosis and altering the electrical activity of the lumbo-pelvic muscles. There was no significant difference between the two active and combined methods of exercise. Therefore, it is recommended that in addition to physical training, mental training be used to improve the motor pattern in people with functional disorders.

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Appendix 1:

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F tests - ANOVA: Repeated measures, within-between interaction
Analysis:  A priori: Compute required sample size
Input:     Effect size f              =          0.3
           α err prob  =          0.05
           Power (1-β err prob)  =          0.80
           Number of groups      =          3
           Number of measurements          =          2
           Corr among rep measures         =          0.5
           Nonsphericity correction ε      =          1
Output:    Noncentrality parameter λ       =          10.8000000
           Critical F  =          3.3541308
           Numerator df          =          2.0000000
           Denominator df        =          27.0000000
           Total sample size     =          30
           Actual power          =          0.8004441
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Appendix 2:

Muscles	Electrode position
Gluteus maximus muscle	1.2 distance of S_2 to greater trochanter
Lumbar erector spine muscle	3 cm apart of L_3 Lumbar
Transverse abdominis muscle	2 cm distal to upper anterior superior iliac spine to downward and inward
Rectus femoris muscle	1.2 distance of anterior superior iliac spine to under patella

Appendix 3:

Protocol of corrective exercises for the subjects in the active group

Training period: six weeks
Number of practice sessions per week: three sessions
Duration of each training session: 60-75 minutes
Warm-up exercises include walking and stretching movement for five minutes.
The main program of exercises was performed for 45 to 60 minutes.
Cool down program for five minutes.

Corrective exercises for lumbar lordosis

Exercise number	How to perform the exercises
1	Hip and knee extensions: The person lies in a supine position and extends the hip and knee by sliding the heel, which helps to increase the activation of the abdominal muscles to maintain the position of the pelvis.
2	Knee flexion in the prone position: The person lies on the prone position and bends the knee, and to prevent anterior pelvic tilt, it contracts the abdominal muscles, which helps to reduce the activity of the rectus femoris and tensor fascialatae muscles**.**
3	Posterior rocking: The person is in a quadrate limbs position and then tries to fill the lower back with a contraction of the abdomen and the spine is in one direction. This exercise increases the activation of the abdominal muscles and decreases the activity of the lumbar extensor muscles.
4	Pulsing up in the prone position: The person lies on the prone position and then bends the knee and pulses upwards, this movement helps to increase the activation of the gluteal muscles.
5	Hip Abduction: Hip abduction in a side position improves pelvic control through the lateral abdominal muscles. When the muscles of the tensor fascialatae, anterior gluteus medius, and gluteus minmus are short, improving the performance of the posterior gluteus medius muscle is important to counteract the activity of these hip flexor muscles**.**
6	Femoral extension and shoulder flexion in a quadrate limbs position: The person is placed on a quadrate limbs and then tries to do the opposite femoral extension and flexion of the shoulder. This movement helps to improve abdominal activity and improves pelvic control and increases balance.
7	Sitting posture: Correction of sitting posture defects is the most important treatment criterion.
8	Standing Exercise: Standing and leaning against the wall of the lumbar vertebrae, bend the knees and hips, and contract the abdominal muscles. This exercise is the best exercise to improve the control of the abdominal muscles while avoiding the activity of the hip flexor muscles.

Table of set and number of repetitions of exercises

Week	Set	Repetition
1	1	6
2	1	8
3	2	6
4	2	7
5	2	8
6	3	8

Protocol of corrective exercises for the subjects in the kinesthetic imagery group
Training period: six weeks
Number of practice sessions per week: three sessions
Duration of each training session: 60-75 minutes
Warm-up exercises include walking and stretching movement for five minutes.
The main program of exercises was performed for 45 to 60 minutes.
Cool down program for five minutes.
It includes corrective exercises in which the person was asked to imagine the exercise in mind and then hold mentally the contraction for fifteen seconds and do mentally each exercise between 6-8 repetitions like active corrective exercises.

Table of set and number of repetitions of exercises

Week	Set	Repetition
1	1	6
2	1	8
3	2	6
4	2	7
5	2	8
6	3	8

Protocol of corrective exercises for the subjects in the combined group
Training period: six weeks
Number of practice sessions per week: three sessions
Duration of each training session: 60-75 minutes
Warm-up exercises include walking and stretching movement for five minutes.
The main program of exercises was performed for 45 to 60 minutes.
Cool down program for five minutes.
Combined group exercises including active exercises and kinesthetic imagery that were performed in a blocked form and included active and imagery until the end of the exercise, respectively.

Table of set and number of repetitions of exercises

Week	Set	Repetition
1	1	6
2	1	8
3	2	6
4	2	7
5	2	8
6	3	8