





The Effect of Lumbar Erector Spinae Muscle Endurance Exercise on Perceived Low-back Pain in Older Adults

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Abstract

This study investigates changes in lumbar erector spinae (LES) muscle endurance, perceived low-back pain (LBP), and perceived exercise fatigue in older adults, and analyzes the trends of these changes during a 5-week lumbar exercise. Sixteen older adults with LBP were equally and randomly divided into two groups: the experimental group with incline-standing and the control group with the level-standing positions. They were separately treated with lumbar exercise tasks and 10 seconds of muscle endurance tests using surface electromyography (sEMG). There was a trend of changes in both groups. The exercise tasks led to increase LES muscle endurance in the experimental group (53.7%) and the control group (45.4%) and decrease perceived LBP score significantly with the incline-standing position. There was no significant difference between the two groups in perceived exercise fatigue ($p>0.05$). Trunk flexion and extension with an incline-standing position can be an effective method to increase LES muscle endurance and reduce LBP in older adults.

Keywords: trunk muscle endurance; perceived low-back pain; perceived exercise fatigue

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INTRODUCTION

Physical exercises provide a wide range of interventions from aerobic exercise to flexibility-based stretching and muscle-strengthening exercise [1]. The focus of these exercises is to retrain trunk muscles against improper posture development [2] and improve muscle endurance in weak body muscles [3]. However, most older adults with low-back pain (LBP) conditions show weakened muscle endurance in the lumbar region [4, 5]. Therefore, strength exercises are difficult to be properly performed in weak body muscles because exercise that involves intensive and maximum efforts can produce trunk fatigue, and thus considered less efficient for older adults [6].

LBP is majorly associated with muscle stiffness or backache located in the lumbar region of the trunk, thus most exercise methods target lumbar erector spinae (LES) muscle for greater trunk stability. This muscle is attached to the lumbar vertebral columns and directly acts to extend the spine at the lumbar region [7]. Exercise with standing upright, squatting, and bending postures is considered as a core exercise for flexing and extending the hip, knee, and ankle joints to activate a wide range of supporting muscles of the lower trunk [8, 9]. Some studies suggest squatting posture training for the lumbar region [10, 11]; however, the methods shown in these studies cover insufficient references to the lumbar spine flexion and extension [12, 13]. Besides, bending exercises have shown a greater trunk flexion on a decline standing position while an incline standing position triggers a greater trunk extension [13]. However, it is not well established whether squatting and bending postures with the incline standing position influence trunk muscle endurance in older adults with LBP conditions. Based on this notion, this study posits that strong LES muscle endurance is vital for lumbar spine stability to minimize perceived LBP and perceived trunk fatigue.

The present study is, therefore, measured the effect of squatting and bending postures with two standing positions (level-standing and incline-standing) on the LES muscle endurance. A 5-week lumbar exercise (partial squatting, forward, and lateral bending tasks) was conducted with 16 older adults from a senior care center. During this period, sEMG was used to understand the LES muscle's level of contraction. Muscle contraction is a muscle strength that determines the amplitude and frequency measures of the EMG signal and expresses as the percentage of maximum voluntary contraction (MVC) [14]. This study, in particular, determines maximum contraction in LES muscle for its endurance, perceived LBP, and perceived fatigue associated with the exercise tasks.

MATERIALS AND METHODS

Participants

A total of 18 older adults were recruited for this study. The exclusion criteria included a history of stroke and low back, hip, or leg surgery. They were equally and randomly divided into two groups: the control and experimental groups. The control group performed the exercise tasks with the level-standing position, and the experimental group completed them with the incline-standing position. Over the course of the study, two participants withdrew from each group because of health problems ($n = 1$) or were failed to follow up ($n = 1$). Thus, 8 participants in the experimental group and 8 participants in the control group were included in the current analysis. As such, 16 older adults gave their informed consent before participation. The investigation was approved by our institutional review board (IRB) and further reviewed and approved by International Clinical Research Information Service (CRIS). The participants' anthropometric characteristics are shown in Table 1. It shows the participants' metrics (age, height, body weight, and body mass index) and baseline LBP, and their descriptive statistics values were presented as mean \pm standard deviation.

Measures

Two independent variables (lumbar exercise and time) and three dependent variables (LES muscle endurance, perceived LBP, and perceived exercise fatigue) were included. The first independent variable was a lumbar exercise with two levels: incline-standing and level-standing positions. The second independent variable was time with three levels, representing five consecutive weeks (Week 1 [W-1], Week 3 [W-3], and Week 5 [W-5]).

Table 1. Subjects' Anthropometric Characteristics

Indicator	Control	Experimental
Number of subjects	8	8
Height [cm]	151.82 ± 6.01	150.21 ± 3.62
Body weight [kg]	53.52 ± 5.21	53.33 ± 5.33
Body mass index [kg/m ²]	23.22 ± 1.81	23.61 ± 2.12
Age [years]	71.81 ± 4.51	72.21 ± 2.91
Baseline LBP [0–10]	6.32 ± 0.92	6.11 ± 1.42

†LBP, low back pain

EMG signals of the right LES muscle were captured using a PolyG-A - sEMG-4, LAXTHA system (Ulsan, South Korea). The participants' skin was prepared over the location of the muscle belly of the LES muscle. A bilateral Ag/AgCl surface electrode disks with a diameter of 11.4 mm were placed on the right of the vertebral column (L5) located in the lower lumbar region, inferior to the L4 and superior to the sacrum. A reference electrode was placed over the 7th cervical vertebrae (C7) of the spinous process in the neck region. All MVC tests were 10 seconds in length where participants were asked to ramp up to maximum effort over the first five seconds while keeping maximum force for the remaining five seconds.

The perceived LBP and perceived exercise fatigue were the ratings of subjective response measures with the LBP and discomfort scale. LBP was measured using the Wong-Baker Faces Pain Rating Scale obtained from the Wong-Baker Faces Foundation¹.

Body parts discomfort was measured using the Body Part Discomfort Scale, proposed by Corlett and Bishop [15] and modified by Li et al. [16]. Body part discomfort scores were collected as perceived exercise fatigue using a body map and numerical rating scales. The scale divides the body regions into nine parts: head and neck, shoulder, arm, middle back, low back, buttock, thigh, knee, and leg and foot.

Design and Procedure

A pretest-posttest comparison group design was used to assess changes in the LES muscle, perceived LBP, and perceived exercise fatigue during exercise training among older adult participants for five weeks. Lumbar exercise training and experiments were arranged for these participants on daily basis, except on Saturdays and Sundays, for five weeks. The total duration of the exercise training was 25 minutes that included five minutes for each of the three standing conditions (15 minutes). After a 10-minute break, the participants underwent the experimental trials. Exercise protocols (normal standing task, lateral bending tasks for flexion and extension, forward bending, and partial squatting tasks for flexion and extension) are presented in Figure 1.

The experiment used a repeated measures design. The perceived LBP and perceived discomfort scales were administered at the end of the exercise on daily basis. All the participants performed MVC tests and brief rest periods between sets to boost LES muscle endurance. The MVC tests were conducted to determine maximum contraction in LES muscle for its muscle endurance [14]. In total, two MVCs were measured and recorded for 10 seconds. There was a one-minute rest period between each MVC test and the highest MVC was selected for further analysis. To obtain a successful MVC for LES muscle, the participant was asked to lie on a therapeutic table with the trunk hanging off the edge of the table at the level of the frontal superior iliac spinal column while spreading the trunk to the resistance applied by the examiner. The MVC technique was performed according to protocols outlined by Szpala et al. [17] and Vera-Garcia et al. [18]. Before the experimental setup, all participants were taught the specified MVC technique and verbally encouraged during the maximum isometric exertions. Participants' activities during the tasks and MVC tests are presented in Figure 2.

¹Wong-Backer Faces Foundation for pain rating scale. <https://wongbakerfaces.org/>



Figure 1. Lumbar exercise tasks (normal standing, lateral bending, forward bending, and partial squatting) for five weeks of exercise training.



(a)



(b)

Figure 2. (a) Participants activities during exercise tasks and experiments (MVC tests), (b) Training subjects regarding the exercise tasks

Data Processing and Statistical Analyses

The raw EMG signals were processed in offline analysis using band-pass filtered and full-wave rectified and smoothed using a Fast Fourier Transformation (FFT) to produce a bandwidth of 8 - 240 Hz. A notch filter was used with a filter cut-off frequency of 60 Hz. The sampling rate of the EMG signals was 512 Hz and amplified using a common-mode rejection ratio of 90 dB with an overall gain of 210.084. The raw data were processed into the root mean square (RMS) with a window width of 78 milliseconds and calculated the maximum EMG amplitude for MVC of the LES muscle. The maximum EMG values were used to normalize all EMG signals collected during each MVC test and expressed as a percentage of the calculated RMS of the maximum contraction. All raw signals were digitized using Telescan 2.89 software from LAXTHA Inc. Korea and a custom program in MATLAB.

At first, a paired samples t-test was performed, respectively t with $n-(k+1)$ degrees of freedom, to observe variations in the muscle endurance of LES muscle in both groups across the weeks. Second, a two-way mixed-design analysis of variance (ANOVA) was used to determine whether there was a significant change in perceived LBP score due to the lumbar exercise with the time (within-subject factors) between the experimental and control groups (between-subject factors). Third, the same procedure was applied to overall perceived exercise fatigue scores to assess the significant main effect of the exercise with time. Besides, a one-way multivariate analysis of variance (MANOVA) was run to measure the effect of the exercise with each level of the time on body parts fatigue scores.

Finally, post hoc analyses using the least significant difference (LSD) test were performed to investigate the differences in perceived LBP score and perceived exercise fatigue score between the experimental and control groups over the levels of time (W-1 to W-5). An alpha level of .05 was considered statistically significant. All statistical analyses were performed using IBM SPSS version 22.0.

RESULTS

Changes in LES muscle endurance over time

In W-1 week, the LES muscle endurance was strongly and positively correlated ($r = 0.78$, $p < 0.005$) between the two groups. There was a significant average difference between experimental group (35.05 ± 8.89) and control group (31.78 ± 10); $t(140) = 6.21$, $p < 0.005$). On average, the muscle contraction of the experimental group was 3.27% higher than that of the control group (95% CI [2.23, 4.31]).

In W-3 week, the LES muscle endurance was weakly and positively correlated ($r = 0.29$, $p < 0.005$) between the two groups. There was a significant average difference between the experimental group (51.06 ± 6.39) and control group (45.5 ± 5.53); $t(140) = 9.08$, $p < 0.005$). On average, the muscle contraction of the experimental group was 5.4% higher than that of the control group (95% CI [4.28, 6.66]).

In W-5 week, the LES muscle endurance was strongly and positively correlated ($r = 0.63$, $p < 0.005$) between both groups. There was a significant average difference between experimental group (53.7 ± 7.81) and control group (45.4 ± 10.6); $t(140) = 11.7$, $p < 0.005$. On average, the muscle contraction of the experimental group was 8.2% higher than the control group (95% CI [6.8, 9.6]). The trend of changes in the LES muscle over time is presented in Figure 3.

Perceived LBP

A repeated measure ANOVA was performed to test the effect of the lumbar exercise with time on perceived LBP. The exercise influenced perceived LBP over time ($F[4, 56] = 28.21$, $p = 0.001$, $\eta^2 = 0.66$). However, there was no significant difference between the experimental and control groups over time ($F[4, 56] = 1.25$, $p = 0.291$, $\eta^2 = 0.08$).

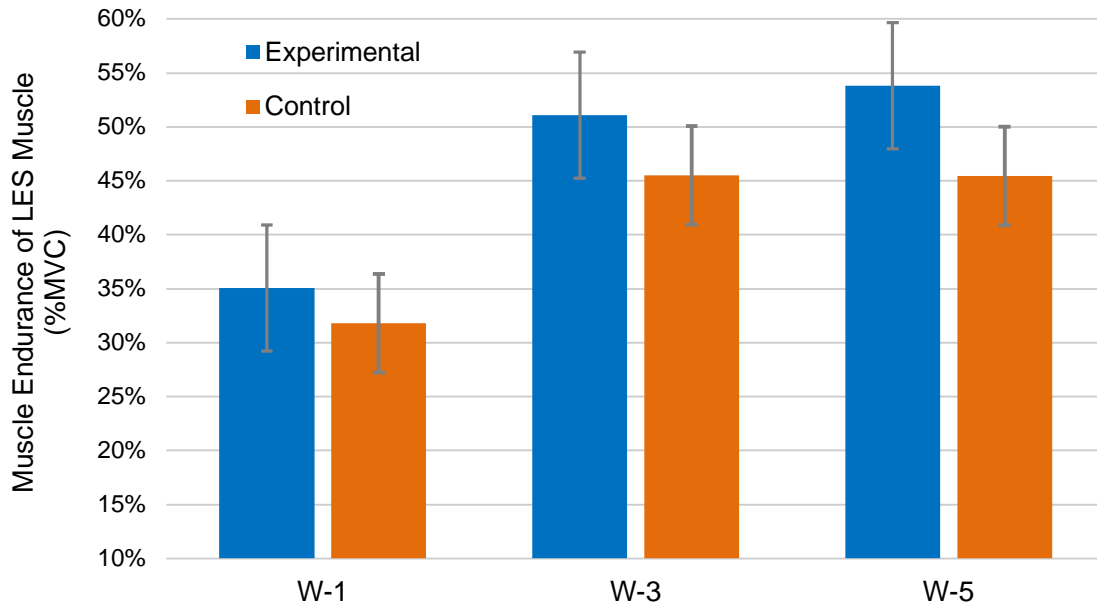


Figure 3. The trend of changes in LES muscle endurance in %MVC over a period of five weeks with three levels of time.

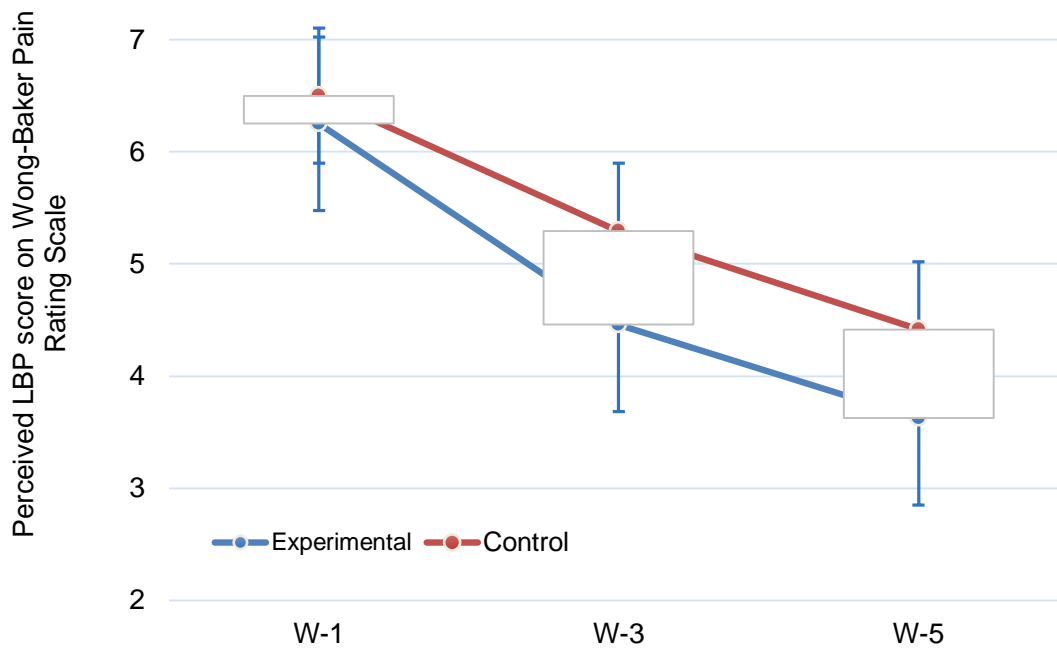


Figure 4. The trend of changes in perceived LBP represented in mean score from 0 to 10 over a period of five weeks with three levels of time.

To assess a significant difference between the LBP score in both groups over each level of the time, a post hoc analysis using the LSD test was performed. A significant difference between the experimental and control groups was observed over W-3 and W-5 weeks. However, there was no difference in W-1 week, and perceived LBP remained unchanged with both standing positions. In W-3 week, the mean LBP score in the control group (5.21 ± 0.45) was higher than that in the experimental group (4.41 ± 0.46) at a significance level of .05. The mean score of perceived LBP in the control group

(4.41 ± 0.55) was higher than that in the experimental group (3.62 ± 0.33) in W-5 week. It indicated that perceived LBP gradually decreased over time with the lumbar exercise with both incline-standing and level-standing positions. However, compared to the level-standing position, the decline ratio of the pain was higher with the incline-standing position from W-3 week, implying that enduring exercise with the incline-standing position for a longer duration will relieve LBP more effectively than the level-standing position. The trend of changes in perceived LBP is shown in Figure 4.

Perceived Exercise Fatigue

One-way MANOVA tests showed that there was no statistically significant difference in perceived exercise fatigue between the control and experimental groups in W-1 week (F [9, 38] = 2.58, $p < 0.201$; Wilk's $\Lambda = 0.62$, partial $\eta^2 = 0.38$). However, the between-subjects effects showed that the standing positions significantly influenced perceived exercise fatigue in the thigh (F [1, 46] = 11.11, $p < 0.002$, partial $\eta^2 = 0.19$).

The post hoc test showed that the mean perceived exercise fatigue score for the thigh was significantly different between the control and experimental group ($p < 0.05$), suggesting that participants in the experimental group experienced higher fatigue in their thighs than participants in the control group.

Table 2. Multivariate Analysis of Variance of Fatigue Scores in W-1, W-3, and W-5 weeks

Groups	Fatigue	Control	Experimental	F	p
W-1	Head and neck	1.58 ± 0.82	1.79 ± 1.31	0.42	0.512
	Shoulder	1.95 ± 1.45	2.50 ± 1.53	1.57	0.213
	Arm	1.70 ± 0.85	1.87 ± 1.32	0.26	0.601
	Middle back	3.87 ± 0.94	4.25 ± 1.32	1.27	0.268
	Low back	4.12 ± 1.45	4.01 ± 1.28	0.10	0.757
	Buttock	2.41 ± 1.52	1.75 ± 1.11	2.98	0.090
	Thigh	1.70 ± 0.90	2.87 ± 1.45	11.11	0.002**
	Knee	2.79 ± 1.47	2.50 ± 1.25	0.54	0.464
	Leg and foot	2.08 ± 1.31	2.20 ± 0.93	0.14	0.706
W-3	Head and neck	1.79 ± 0.88	1.62 ± 0.64	0.55	0.463
	Shoulder	2.41 ± 1.38	1.75 ± 0.73	4.35	0.042*
	Arm	2.08 ± 1.10	1.87 ± 1.39	0.33	0.561
	Middle back	3.08 ± 1.52	3.75 ± 1.07	3.05	0.082
	Low back	3.29 ± 1.51	4.01 ± 0.88	3.90	0.054
	Buttock	2.04 ± 0.85	2.45 ± 0.58	3.84	0.056
	Thigh	1.83 ± 0.86	2.16 ± 0.86	1.76	0.193
	Knee	2.45 ± 1.17	2.45 ± 1.21	0.01	1
	Leg and foot	2.37 ± 1.27	2.08 ± 1.13	0.69	0.403
W-5	Head and neck	1.62 ± 0.71	1.54 ± 0.50	0.21	0.643
	Shoulder	2.50 ± 1.44	1.79 ± 0.65	4.77	0.034*
	Arm	1.75 ± 1.03	1.58 ± 0.71	0.42	0.513
	Middle back	2.87 ± 1.39	2.01 ± 0.88	6.74	0.014*
	Low back	3.33 ± 1.34	2.25 ± 0.79	11.60	0.001**
	Buttock	1.66 ± 0.63	1.79 ± 0.65	0.44	0.508
	Thigh	1.50 ± 0.65	1.83 ± 0.70	2.87	0.091
	Knee	2.01 ± 0.72	2.01 ± 1.10	0.01	1
	Leg and foot	1.79 ± 1.14	1.70 ± 1.04	0.07	0.793

* statistically significant $p < 0.05$; ** statistically significant $p < 0.01$

In W-3 week, the results showed a statistically significant difference in perceived exercise fatigue between the control and experimental groups ($F [9, 38] = 2.34, p < 0.032$; Wilk's $\Lambda = 0.64$, partial $\eta^2 = 0.35$). As shown in Table 2, the between-subjects effects showed that the standing positions significantly influenced perceived exercise fatigue in the shoulder ($F [1, 46] = 4.35, p < 0.042$, partial $\eta^2 = 0.04$). The post hoc test showed that the mean perceived exercise fatigue score for the shoulder was significantly different between the control and experimental groups ($p < 0.05$). The participants in the control group experienced higher fatigue in the shoulder than the participants in the experimental group.

In W-5 week, there was a statistically significant difference in perceived exercise fatigue between the control and experimental groups ($F [9, 38] = 2.17, p < .046$; Wilk's $\Lambda = 0.66$, partial $\eta^2 = 0.34$). As shown in Table 2 above, the between-subjects effects showed that the standing positions significantly influenced perceived exercise fatigue in the shoulder ($F [1, 46] = 4.77, p < 0.034$, partial $\eta^2 = 0.09$), middle back ($F [1, 46] = 6.74, p < 0.013$, partial $\eta^2 = 0.12$), and low-back ($F [1, 46] = 11.6, p < 0.001$, partial $\eta^2 = 0.20$). The post hoc test showed that the mean perceived exercise fatigue scores for the shoulder, middle back, and low back were significantly different between the control and experimental groups ($p < 0.05$). The participants in the control group experienced higher perceived exercise fatigue in the shoulder, middle back, and low back than participants in the experimental group.

To understand the overall perceived exercise fatigue, repeated-measures ANOVA was performed to test the effect of the exercise tasks over time. The exercise influenced the overall perceived exercise fatigue over time ($F [4, 56] = 14.91, p = 0.001, \eta^2 = 0.51$). There was also a significant difference between the experimental and control groups over time ($F [4, 56] = 6.01, p = 0.002, \eta^2 = 0.30$). To assess the significant difference between the overall perceived exercise fatigue scores in both groups over each level of the time, a post hoc analysis using the LSD test was performed. A significant difference between the experimental and control groups was observed in W-1 week. The mean overall perceived exercise fatigue score in the control group (2.41 ± 0.56) was lower than that in the experimental group (3.31 ± 0.28) at a significance level (0.05). Both groups had no statistically significant difference in overall perceived exercise fatigue in W-3 and W-5 weeks.

DISCUSSION

Both standing positions were effective for increasing LES muscle endurance and reducing perceived LBP and perceived exercise fatigue. However, the effect size was larger in the experimental group than in the control group. The LES muscle endurance was increased by 35.1% on average in the experimental group and 31.7% in the control group in the W-1 week with a 10 second contraction time, indicating a difference of 3.27 percent. At the same time point, there was no change in the perceived LBP and perceived exercise fatigue in both groups. However, the mean perceived exercise fatigue in the control group was lower than that in the experimental group. This can be interpreted as an effect of standing on a slope inclination resulting in improved muscle contraction and reduced pain and overall body fatigue with time. The overall perceived exercise fatigue remained lower with the level-standing position than with the incline-standing position; however, the perceived LBP was higher in the level-standing position than that in the incline-standing position. The perceived exercise fatigue score was higher in the incline-standing position in W-1 week, but the LBP score was remarkably decreased with this position. It seems that exercise with the incline-standing position might cause fatigue at the beginning of the exercise with a substantial decrease in the LBP. On the contrary, the level-standing position might not influence fatigue, but its effect on LBP might be lowered. There is a possibility that the fatigue has been caused only by standing on the incline slope surface because the experimental setup for the standing exercise tasks was set to 15° slope inclination, which might be a higher slope position at the start of the exercise tasks. To avoid this fatigue, the slope inclination can be set with a minimum slope, for example, in the first week; the slope angle can be set to 5° and the second week to be 10° and so on. This gradual increase in surface inclination can reduce the fatigue ratio that is associated with the higher slope inclination.

In W-3 week, the LES muscle endurance was increased up to 51% and the control group was 45.5%, indicating a difference of 5.4 percent. The perceived LBP and perceived exercise fatigue were

decreased in the experimental group. In W-5 week, the LES muscle endurance was increased up to 53.7% in the experimental group, which was higher than that in the control group (45.4%), indicating that the LES muscle endurance was 8.2% higher than that in the control group. At this time point, the perceived LBP remained lower in the experimental group while the perceived exercise fatigue was leveled with the control group. The amount of increase in endurance is related to improved LES muscle contraction as a result of the exercise tasks, and together with a decrease in the perceived LBP and perceived exercise fatigue in W-3 and W-5 weeks in the experimental group. It has been previously shown that exercise tasks including squatting posture increase the strength of the LES muscle [19]. Another study observed a greater increase in muscle activation with an increase in the incline slope from 5° to 10° and was assumed to be effective for trunk muscle endurance [20].

Previous studies have discussed spine stability and LBP reduction through exercise interventions of the pelvic floor, transversus abdominis, oblique abdominals, and quadratus lumborum [21, 22]. Core stability exercises seem to be particularly vital in cases of spinal instability because of their links with trunk fatigue that usually causes LBP [23, 24]. These exercise interventions have become a popular fitness trend in the sports medicine field due to the widespread gains of core stabilization in increasing athletic performance and preventing sports injuries and relieving LBP [24]. For older adults with chronic LBP, studies have recommended physical exercises for improving their functional performances. Of these studies, Vincent et al. [25], Rasmussen-Barr et al. [26], Kuss et al. [27], and Hyoung [28] reported that LBP is a common complaint related to muscle weaknesses; therefore, rehabilitation through physical exercises is widely recommended to manage its prevalence among the elderly population. Other studies highlighted trunk strengthening exercises for LBP that include lumbar flexion and extension (e.g., Ilves et al. [29], Wasser et al. [30], and Hicks et al. [31]). However, another study showed that older adults may not endure maximum muscle strength exercises for a longer period due to aging and muscle weaknesses [32, 33] as well as poor motor control skills [34]. The fact that participants in our study improved LES muscle endurance due to lumbar exercise training with a positive effect on their LBP conditions, and a slightly negative impact on the exercise fatigue in the first week, however a significant reduction in the last week. Therefore, this study confirmed that lumbar exercises performed with the incline-standing position could be significantly efficient in reducing the intensity of LBP among older adults. Based on such hypotheses, the present study suggests this practice in rehabilitation centers for the effective management of LBP in the older adult population.

CONCLUSIONS

Trunk muscle endurance along with perceived LBP and perceived exercise fatigue were gradually improved with the ongoing lumbar exercise performed with the incline-standing position. Considering the 5-week study period, the incline-standing position has shown positive results; however, there can be better outcomes in longitudinal studies in months or years. Conducting further studies to increase the applicability of lumbar exercises with different standing positions for trunk muscle activation and isometric muscle strength measurements, and thus contributing to the lumbar improvement of the older adults is warranted.

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CONFLICT OF INTEREST

None to declare

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