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RESEARCH

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Effects of aerobic exercise in addition to core stabilization exercises on functional capacity, physical performance and fall risk in geriatric individuals with chronic non-specific low back pain

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Abstract

Background Geriatric individuals may frequently develop low back pain after physiological changes. The aim of our study was to compare the effects of core stabilization exercises alone and aerobic exercises in addition to core stabilization exercises on functional capacity, physical performance and fall risk in geriatric individuals with chronic non-specific low back pain (CNLBP).

Methods In this randomized controlled study, 30 participants in the core stabilization exercise group (CG) received intervention, and the mean age of this group was 70.43 ± 4.48 years. The mean age of the 30 participants in the core stabilization + aerobic exercise group (CAG) was determined as 69.60 ± 4.05 years. Sixty individuals with CNLBP were included in the study and divided into two groups: CG ($n = 30$) and CAG ($n = 30$). CG received core stabilization exercises for 8 weeks, while CAG received aerobic exercise using a treadmill in addition to core stabilization exercises for 8 weeks. Functional capacity (six-minute walk test), physical performance (Oswestry Disability Index), fall risk (Biodex Balance System), pain intensity (Visual Analogue Scale), depression status (Beck Depression Inventory) and kinesiophobia level (Tampa Kinesiophobia Scale) were evaluated before and after the treatment programmes.

Results Significant improvements were found in all parameters in both groups after the treatment programmes ($p < 0.05$). In addition, functional capacity, physical performance, fall risk, pain severity and depression scores improved more in CAG compared to CG ($p < 0.05$), but the improvement in kinesiophobia was similar ($p > 0.05$).

Conclusions The results of the study showed that both core stabilization exercises alone and core stabilization exercises combined with aerobic exercise led to improvements in patients with CNLBP. However, the group that combined aerobic and core stabilization exercises (CAG) showed greater improvements, particularly in functional capacity, physical performance, fall risk, pain intensity, and depression levels. These findings suggest that core stabilization exercises are beneficial for CNLBP, but adding aerobic exercise may enhance these positive effects.

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Therefore, incorporating aerobic exercise into rehabilitation programmes for older adults with CNLBP may provide additional clinical benefits.

Trial registration This clinical trial was registered at http://clinicaltrials.gov (Number: NCT06946758; registration date: 21/04/2025).

Keywords Geriatric, Low back pain, Functional capacity, Physical performance, Falls

Introduction

Physiological changes such as decreased muscle strength, flexibility, balance and postural control occur in geriatric individuals. This situation prepares the ground for increased loads on the musculoskeletal system, functional limitation and various pains [1]. Low back pain is one of the most important health problems that limit daily living activities, reduce quality of life and cause disability in geriatric individuals. Approximately 90–95% of low back pain in geriatric individuals is nonspecific [2]. Nonspecific low back pain occurs without any obvious pathology and its prevalence increases in parallel with age [3].

Approximately 30% of people aged 65 and over experience falls due to balance problems, postural control and proprioceptive disorders caused by low back pain [4]. Falls and related injuries that can be seen in geriatric individuals cause an increase in the level of disability, mortality and morbidity rate and a decrease in the level of physical performance. Factors that may cause low back pain in geriatric individuals include muscle imbalances, decreased trunk stabilization, degenerative changes, comorbidities, and psychosocial status [5]. At the same time, as a result of low back pain, physical activity levels of individuals decrease, atrophy may occur in the lumbar region muscles and the function of the core muscles is negatively affected [6, 7]. In the literature, it has been reported that geriatric individuals with low back pain have delayed or decreased reflex response and activation of the core muscles during functional movements [8, 9]. Losses in reflex response and core muscle strength affect functional capacity, physical performance, balance and fall risk in geriatric individuals [10, 11].

Rest, patient education, use of various medications, appropriate physical therapy modalities (ultrasound, TENS) and exercise are frequently used in the treatment of low back pain in geriatric individuals [12, 13]. It is very important to establish an appropriate exercise programme to prevent pain-related problems and reduce the risk of falls. Many studies have reported that aerobic exercise applied in addition to other treatments in the treatment of low back pain can be used to reduce pain, increase aerobic capacity and improve clinical symptoms by inhibiting the pain pathway and stimulating endorphin release [14]. It is also used to reduce the level of kinesiophobia and disability by keeping the patient more active during the rehabilitation process [14].

Both core stabilization and aerobic exercises have been found to be effective in managing low back pain. However, there are limited studies comparing the effects of these two types of exercise when used together in geriatric patients with chronic non-specific low back pain (CNLBP). Furthermore, there are differing opinions in studies examining the effectiveness of aerobic exercise in the treatment of low back pain [15, 16]. This study aims to provide a unique perspective on rehabilitation practices by investigating the contribution of adding aerobic exercise to core stabilization exercises to clinical outcomes.

Methods

Study design

This study was conducted in compliance with the CONSORT guidelines. This study is a randomized controlled trial conducted in the Spine Health Clinic of the School of Physical Therapy and Rehabilitation, Kırşehir Ahi Evran University. Ethical approval for the study was granted by the Scientific Research and Publication Ethics Committee of Muş Alparslan University (Approval No: 143804). All participants gave written and verbal informed consent before participation. The ethical principles specified in the Declaration of Helsinki were complied with in the study.

Participants

Sixty patients diagnosed with CNLBP by a specialist in physical medicine and rehabilitation with 10 years of experience were included in the study. Participants consisted of patients who consulted for treatment due to low back pain. A total of 60 patients with CNLBP were randomly divided into two groups: core stabilization + aerobic exercise group (CAG, $n = 30$) and core stabilization exercise group (CG, $n = 30$). The inclusion criteria were: Age over 65 years and low back pain lasting at least 3 months. Those with fractures, dislocations, neoplasms, inflammatory diseases, degenerative changes, discogenic disorders, scoliosis, radiculopathy, a history of spinal surgery in the spinal region, cardiac/cardiopulmonary problems, and those who participated in a physiotherapy and rehabilitation programme for back pain in the last 6 months were excluded from the study.

Interventions

Both the aerobic exercise group and the control group underwent core stabilization exercises for 8 weeks. The aerobic exercise group received an aerobic exercise programme using a stationary bicycle immediately after the core stabilization exercises. The exercises were performed three times a week for a period of 8 weeks. The interventions were performed by a spinal health physiotherapist with 5 years of experience (ŞK). Participants were instructed not to use painkillers and non-steroidal anti-inflammatory drugs during the study period.

Core stabilization exercises

Core stabilization exercises were performed in both groups. A total of 24 sessions of core stabilization exercises were performed 3 days a week (with at least 1 day of rest between each session) for a total of 8 weeks. Each exercise session was performed under the supervision of a physiotherapist. Each session was arranged as 35-minute programmes with 5 min warm-up. Before starting the exercise, it was taught to reduce the lumbar lordosis by contracting and drawing in the abdominal muscles and to find the lumbar and pelvic neutral position by moving the pelvis forwards and backwards (pelvik tilt, bridge, bird-dog and plank etc.). In each session, the neutral position was found first and attention was paid to maintain the neutral position throughout the exercise. In addition, core stability exercises including simultaneous contractions of the multifidus and pelvic floor muscles were given in different positions such as supine, prone, crawling, bridge, kneeling, sitting and standing. The exercises consisted of 3 levels (from easy to difficult). In the advanced level exercises, patients were asked to maintain the neutral curvature of the lumbar spine, resistance limb exercises were added and the exercises were completed gradually. Each exercise was performed 8–10 repetitions, depending on the patient's tolerance [17] (Fig. 1).

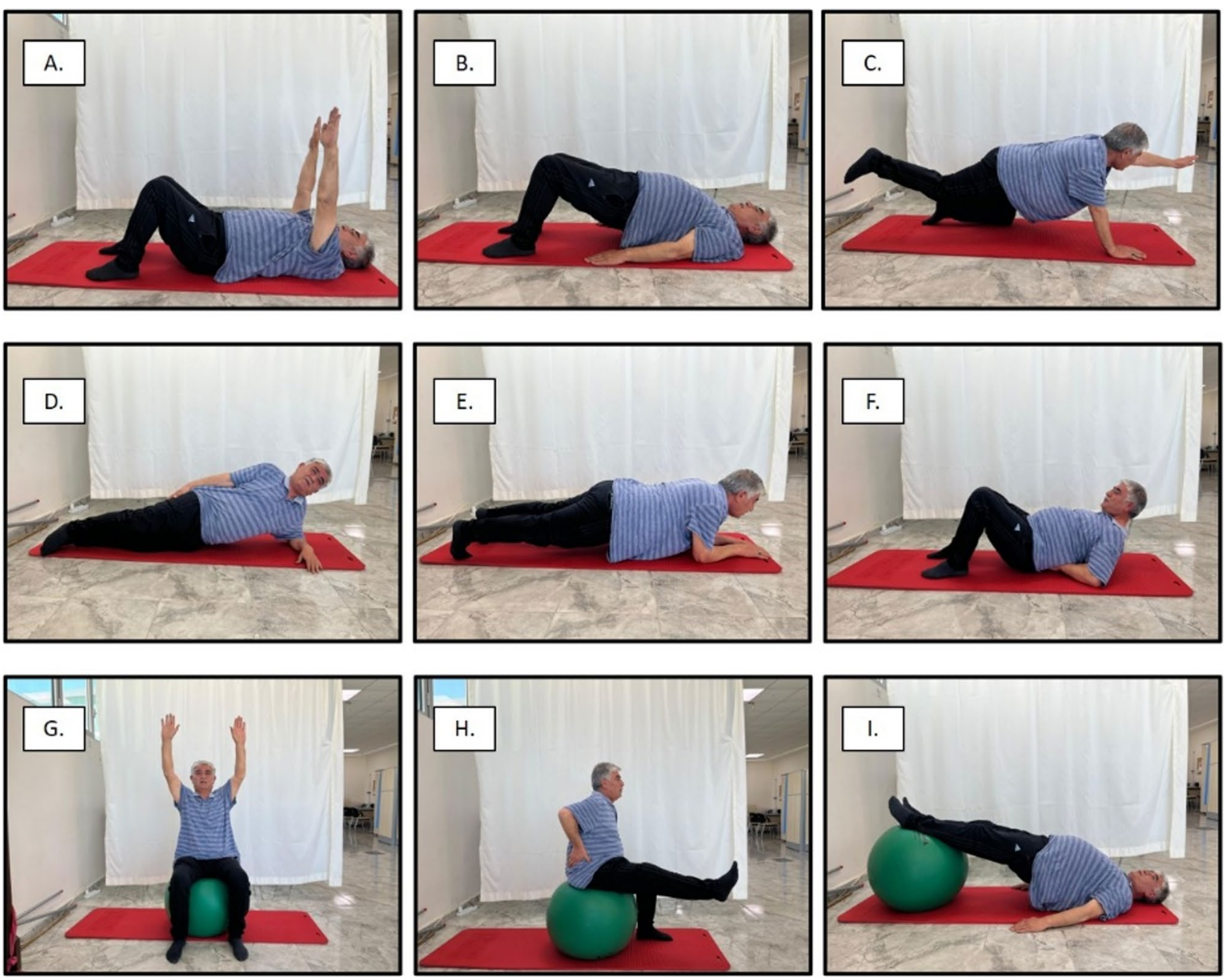

Fig. 1 Examples of exercise levels. A-B-C: beginner, D-E-F: intermediate, G-H-I: advanced

Aerobic exercises

Patients in the aerobic exercise group underwent an aerobic exercise programme using a stationary bicycle. In the first and second weeks, a total of 20 min of exercise time was performed; 5 min of warm-up (easy pedalling at a comfortable pace), 10 min of higher intensity training (60 rpm) and 5 min of cool-down (easy pedalling at a comfortable pace). In the third and fourth weeks, 25 min of exercises were performed (5 min warm-up, 15 min higher intensity training (60 rpm) and 5 min cool down. In the fifth and sixth weeks the exercise was done for 30 min: 5 min warm-up, 20 min higher intensity training (60 rpm) and 5 min cool down. Finally, in the seventh and eighth weeks, 35 min of exercise was performed: 5 min warm-up, 25 min higher intensity training (60 rpm) and 5 min cool down [18]. The intensity of aerobic exercises was adjusted according to the Borg Scale [19]. According to the Borg Scale, the target intensity was moderate, between 12 and 14. Exercise intensity was gradually increased according to each individual's starting level. Exercise was terminated when exercise termination criteria (such as dyspnoea, chest pain, cramps) were observed in the participants.

Outcome measurements

Socio-demographic data such as age, body mass index (BMI), gender and marital status were collected through face-to-face interviews. Pain severity, disability level, fall risk, cardiopulmonary capacity, depression level and kinesiophobia were assessed before and immediately after the treatment programme (8 week). Exercise compliance was assessed by participants' regular attendance at recommended sessions and application of exercises in the recommended duration and format. Compliance was monitored through diaries and researcher observations.

Primary Outcomes

Functional Capacity

The cardiopulmonary capacity of the participants was evaluated with the 6-minute walk test (6MWT). The aim of the test is to reach the maximum distance that can be covered by walking in 6 min. The test is performed on an uneven and flat track 30 m long, marked every 3 m, with the start and finish line marked with a visible line. Before starting the test, the person rests in a chair for 15 min. The participant was informed that they should walk on the track at their own pace for six minutes, that they may stop the test at any time in case of discomfort, that they are allowed to pause and rest if needed during the test, and that they should continue until instructed that the test is over. The stopwatch is started and the test is started with the 'test started' command and the test is ended with the 'test finished' command. The distances obtained at the end of the test were recorded in metres (m) [20].

Physical performance

Participants' physical performances were evaluated with the Turkish version of the Oswestry Disability Index (ODI), which has been proven valid and reliable in low back pain. In the scale, low back function impairment is evaluated in 10 sub-headings including pain status, personal care, weight lifting, walking, sitting, standing, sexual life, social life and travelling. For each sub-heading, a Likert-type score of 0–5 is given, with '0' being no disabling condition and '5' being complete disability. A minimum score of 0 and a maximum score of 50 can be obtained from the scale. Based on the total scale score, a score of 0–4 indicates no disability due to low back pain; 5–14 indicates mild disability; 15–24, moderate disability; 25–34, severe disability; and 35–50 indicates complete functional disability resulting from low back pain [21].

Risk of fall

The fall risk of the participants was assessed by tests using the Biodex Balance System [(BDS) Biodex Inc., Shirley, New York]. The BDS consists of a movable balance platform with a surface that can be tilted up to 20° and connected to a computer software that allows objective assessment of balance [22]. In this system, the amount of oscillation can be assessed for the risk of falling. High values obtained as a result of these tests indicate impaired balance and increased fall risk. Individuals were placed on the platform with bare feet, knees slightly flexed (10–15°) and in the most favourable position to ensure the balance of the individual, the foot coordinates were determined and performed on both feet and with their eyes open. Each participant was informed about the tests and the rules to be followed and three tests lasting 20 s were performed for fall risk [22, 23].

Secondary outcomes

Severity of pain

Rest and activity pain intensity were measured using the Visual Analogue Scale (VAS), a reliable tool for assessing pain levels. Participants were asked to mark their pain intensity on a 10 cm horizontal line. The VAS scores range from 0 to 10, with 0 indicating 'no pain' and 10 representing 'the most intense pain possible [24].

Depression

The Beck Depression Scale (BDS) was developed by Beck et al. [25] to assess the severity of depression. The validity and reliability of the questionnaire in Turkish language was analysed by Hisli et al. [26]. The BDS consists of a total of 21 items. Each item is scored between 0 and 3.

A high score obtained from the scale indicates severe depression. Depression levels are classified according to the total scores obtained from the scale as follows: scores between 0 and 13 indicate minimal depression, scores between 14 and 19 indicate mild depression, scores between 20 and 28 indicate moderate depression, and scores between 29 and 63 indicate severe depression [26].

Kinesiophobia

The Tampa Kinesiophobia Scale (TKS) is a 17-question questionnaire developed to assess the presence of kinesiophobia, which was developed for musculoskeletal pain and whose Turkish validity and reliability have been established [27, 28]. In the scale, a 4-point Likert scoring system (1 = Strongly disagree, 2 = Agree, 3 = Disagree, 4 = Strongly agree) is used for each question. As a result of the questionnaire, the person receives a total score between 17 and 68 according to his/her answers. A total score of 37 or above on the scale indicates a high level of kinesiophobia. Scores below this threshold are considered to indicate a low level of fear of movement. A high score on the scale indicates a high level of kinesiophobia [28].

Sample size

6MWT was selected as the primary outcome variable of the study. In determining the minimum required sample size, the data of a similar study conducted by Hicks et al. [29] were taken as reference. In this direction, according to the power analysis with 95% confidence interval and 95% statistical power, at least 26 participants were required for each group. Taking into account the possible data losses of 15-20% and the losses that may occur during the follow-up process, it was planned to include at least 60 participants in total in each group.

Randomization and blinding

A randomization process was performed for 60 geriatric individuals with CNLBP. Participants were randomly divided into two groups, aerobic exercise and control groups, using matched-pairs randomization according to their age and gender. Matched-pairs randomization was conducted using sequential numbers generated by the Research Randomizer program available at randomizer.org [30]. All assessments at study baseline and after the 8-week treatment period were performed by one investigator who remained blinded to group assignment and intervention throughout the study (MC).

Statistical analysis

All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). Prior to the inferential analyses, the assumption of normality for continuous variables was assessed through both visual (histograms, Q–Q plots) and analytical methods, including the Shapiro–Wilk and Kolmogorov–Smirnov tests. For variables demonstrating normal distribution, descriptive statistics were expressed as mean ± standard deviation (SD). Categorical (nominal) variables were presented as absolute frequencies and corresponding percentages (%).

To compare baseline differences in continuous outcome variables between the CG and the CAG, independent samples t-tests (Student's t-test) were applied. To evaluate within-group and between-group effects over time, a two-way repeated-measures Analysis of Variance (ANOVA) with a mixed design was employed. This approach allowed for the assessment of the main effects of time and group, as well as the interaction effect (group × time) on each dependent variable.

Effect sizes for the repeated-measures ANOVA were estimated using eta squared (η^2), and interpreted as small (η^2 = 0.02), moderate (η^2 = 0.13), and large (η^2 = 0.26) based on established benchmarks. All statistical tests were two-tailed, and a p-value less than 0.05 ($\alpha = 0.05$) was considered indicative of statistical significance, controlling the overall Type I error rate.

Results

Seventy individuals who were diagnosed with CNLBP and referred to the clinic were examined for eligibility; five individuals did not meet the inclusion criteria and five refused to participate in the study. All 60 participants performed the exercise program at the recommended frequency and duration. The 60 individuals with CNLBP who were eligible and agreed to participate in the study were randomly assigned to two treatment groups (Fig. 2).

Table 1 presents the demographic characteristics of the CG and CAG groups. There were no statistically significant differences between the groups with respect to demographic variables ($p > 0.05$), indicating comparability in demographic distribution.

Pre-test and post-test comparisons of VAS, ODI, BDS, TKS, fall risk, and 6MWT scores for the CAG and CG groups are presented in Table 2. According to the ANOVA, a significant Group × Time interaction was observed for all variables except TKS ($p > 0.05$), indicating statistically significant differences over time between groups for the remaining measures ($p < 0.05$). In other words, analysis of mean change scores indicated that both groups exhibited similar changes in TKS, whereas the CAG group showed greater improvements in VAS (small effect size), ODI (medium effect size), BDS (small effect size), fall risk (medium effect size), and 6MWT (large effect size) scores. Examination of the main effect of time revealed statistically significant changes across all variables ($p < 0.05$), indicating that both groups

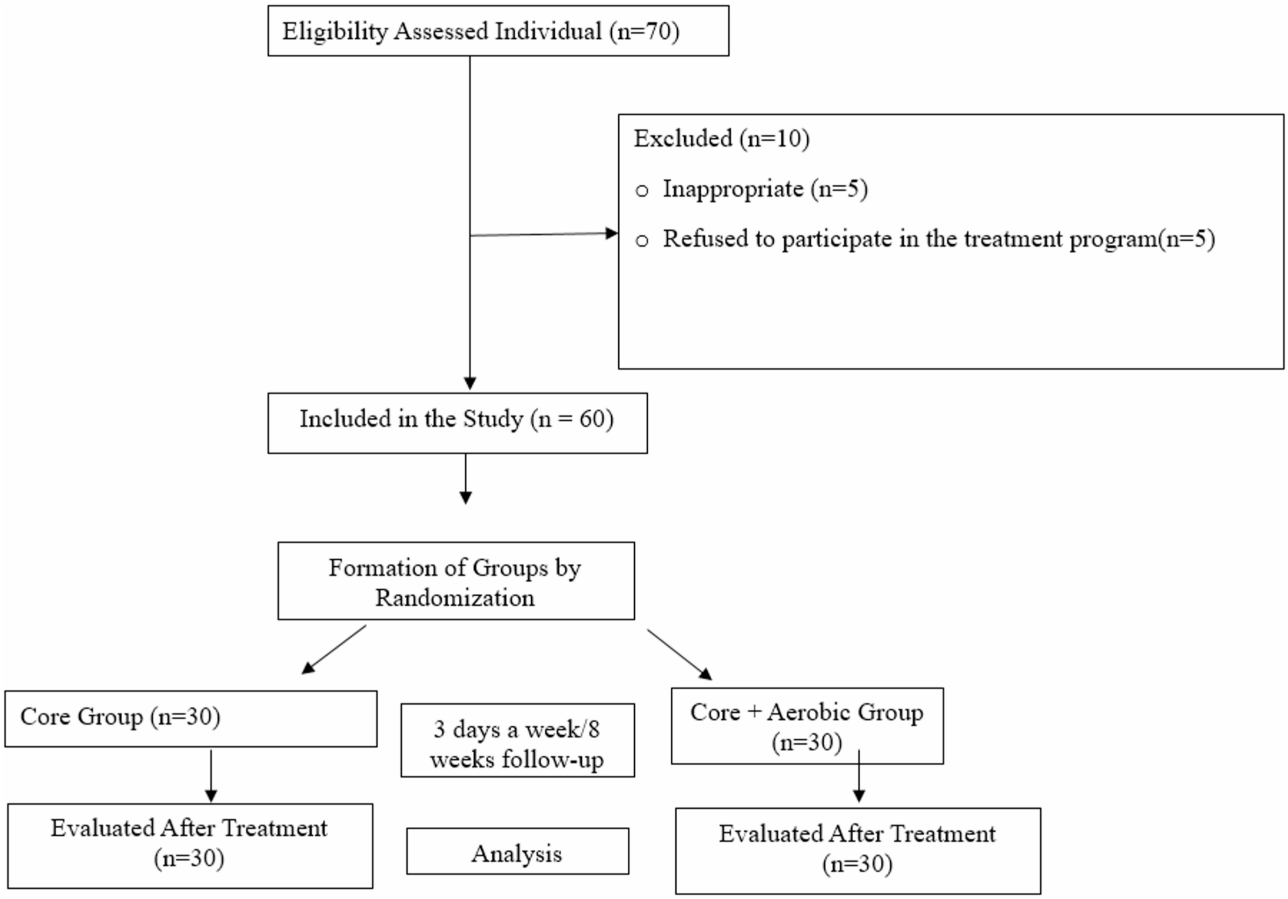

Fig. 2 Flow chart of the study

Table 1 Demographic characteristics of CG and CAG

		CAG (*n* = 30)		CG (*n* = 30)		t	*p*
		Mean	**SD**	**Mean**	**SD**		
Age (years)		70.43	4.48	69.60	4.05	0.75	0.453
BMI (kg/m^2)		26.17	2.71	25.44	1.56	1.28	0.204
		n	**(%)**	**n**	**(%)**	**X^2**	**p**
Gender	**Male**	15	50.0	14	46.7	0.06	0.706
	Female	15	50.0	16	53.3		

CAG: Core Stabilization + aerobic exercise group, CG: Core stabilization exercise group, BMI: Body Mass Index, t: Student T test, X^2: Chi-Square test, SD: Standard deviation

experienced improvements in VAS, ODI, BDS, TKS, fall risk, and 6MWT over the course of the study.

Discussion

In the present study, we investigated the effectiveness of aerobic exercises in addition to core stabilization and core stabilization exercises in geriatric individuals with CNLBP. As a result of the study, we concluded that aerobic exercises were more effective on functional capacity, physical performance, fall risk, pain severity and depression, while we observed similar effects on kinesiophobia in both groups. Additionally, no serious side effects were observed during the interventions applied to both groups.

Core stabilization exercises target the deep muscle groups around the waist to increase the mechanical stability of the spine and are considered an effective approach to managing CNLBP. The literature has repeatedly highlighted the positive effects of these exercises on pain reduction, improved postural control, and increased functional capacity [31]. Especially in geriatric individuals, core stabilization exercises contribute significantly to reducing the risk of falls and improving quality of life by increasing muscle activation around the spine [11].

Table 2 Pre-test, post-test comparison of 6MWT, ODI, risk of fall VAS BDS, and TKS values of CAG and CG

		CAG (n=30)		CG (n=30)		Mean Difference (95% CI)	Standard error	Time (Main effect)	Group*Time (Interaction)	η2
		Mean	**SD**	**Mean**	**SD**			*p value*	F/ *p value*	
6MWT	BT	419.99	68.83	424.91	62.43	38,12 (24,95/51,27)	6,57	**<0.001**	33.61/**<0.001**	0.367
	AT	486.83	53.23	453.63	53.31					
ODI	BT	35.97	6.42	35.53	8.17	-4,83 (-7,27/-2,44)	1,19	**<0.001**	16.38/**<0.001**	0.220
	AT	22.57	4.55	26.97	6.18					
Fall Risk	BT	2.45	0.53	2.41	0.56	-0,35 (-0,50/-0,19)	0,08	**<0.001**	19.90/**<0.001**	0.255
	AT	1.75	0.34	2.06	0.37					
VAS Rest	BT	5.83	1.37	5.50	1.17	-0,50 (-0,96/-0,03)	0,23	**<0.001**	4.61/**0.036**	0.074
	AT	1.63	1.13	1.80	1.19					
VAS Activity	BT	7.47	1.25	7.00	1.05	-0,97 (-1,67/-0,25)	0,35	**<0.001**	7.44/**0.008**	0.114
	AT	2.23	1.36	2.73	1.11					
BDS	BT	34.10	8.97	34.53	8.06	-2,77 (-4,66/-0,86)	0,95	**<0.001**	8.47/**0.005**	0.127
	AT	26.30	6.10	29.50	6.24					
TKS	BT	36.43	5.41	35.93	6.14	-1,10 (-3,59/1,39)	1,25	**<0.001**	0.38/0.382	0.013
	AT	26.17	3.24	26.77	3.73					

CAG: Core Stabilization + aerobic exercise group, CG: Core stabilization exercise group, CI: Confidence interval BT: Before treatment, AT: After treatment, 6MWT: 6-minute walk test, ODI: Oswestry Disability Index, BDS: Beck Depression Scale, TKS: Tampa Kinesiophobia Scale, 2-way mixed design repeated-measures analysis of variance, SD: Standard deviation, η^2: Effect size, ANOVA: A mixed-design repeated-measures two-way analysis of variance.

In this context, our study observed significant improvements in parameters such as functional capacity, physical performance, risk of fall, pain, depression, and kinesiophobia in both groups that underwent core stabilization exercises.

Low back pain and advanced age are considered to be a determining factor on walking speed and performance [32]. It is known that functional capacity is affected in elderly individuals with low back pain compared to elderly individuals without low back pain [33]. It is known that aerobic exercises improve the functional capacity of muscles by increasing circulation and oxygenation, and this is reflected in parameters affecting physical performance such as walking distance [34]. A recent review investigating the effects of various exercises on elderly individuals with chronic low back pain concluded that aerobic exercise is effective in increasing functional capacity [35, 36]. In a study investigating the effects of in-water aerobic exercises in elderly individuals with low back pain, it was found to improve aerobic capacity by improving walking speed [37]. Two studies investigating the effects of different exercises in elderly individuals reported that long-term aerobic exercise significantly improved physical capacity [38, 39]. In our study, we observed significant improvements in functional capacity in both CG and CAG, but the improvement in CAG was significantly greater in terms of large effect size. This may be explained by the fact that aerobic exercises (e.g. brisk walking, cycling, treadmill) directly increase cardiorespiratory endurance [16].

There are studies showing the positive effects of core stabilization training on the risk of falls in elderly individuals [40]. Core exercises improve postural control by increasing the stabilization of the trunk. Aerobic exercises, on the other hand, positively affect the risk of falls by improving dynamic balance and proprioceptive control. Irandoust et al. [37] found that water-based aerobic exercise had a significant effect on fall risk in elderly individuals with low back pain compared to the control group. In another study, De Oliveira et al. [41] reported that both Pilates and aerobic exercises improved balance and functionality in chronic low back pain. In our study, improvement in the risk of falling parameter was superior in CAG with a medium effect size. This may be because aerobic exercises (e.g. walking, cycling, stepping) improve dynamic balance and body awareness more. During these exercises, vestibular and proprioceptive systems are activated as continuous weight transfer and direction change are required, which may increase postural stability and reduce the risk of falls.

In individuals with low back pain, the severity of pain restricts activities of daily living. Studies have reported that aerobic exercise is an effective method that can be used to reduce low back pain. Oliveira et al. [41] reported that aerobic exercise caused a significant improvement in pain intensity in a study conducted with geriatric individuals with chronic nonspecific low back pain. Chan et al. [42] reported that aerobic exercise applied in addition to traditional physiotherapy was effective in reducing pain intensity. Murtezani et al. [43] reported that high-intensity aerobic exercise can reduce pain intensity in individuals with chronic low back pain. Adamse et al. [44] reported that aerobic exercise is an effective method to improve pain severity in individuals with chronic low back pain. Shnayderman et al. [20] reported that aerobic exercise with the help of a moderate intensity treadmill reduced pain intensity by 2.4 points. In our study, we observed significant improvements in pain intensity in both the CG and CAG groups, but the improvement in the group that performed core stabilization exercises in addition to aerobic exercises was superior with a small effect size. This result may be related to the fact that aerobic exercises decrease pain sensitivity in the central nervous system by increasing endorphin release and blood circulation.

CNLBP is an important health problem that causes more disability in the elderly population [45]. Stabilization exercises used in the treatment of low back pain have a positive effect on pain intensity and disability level [46]. In addition, Shabbir et al. [47] reported in their systematic review that different types of aerobic exercises have a positive effect on the level of disability in individuals with low back pain. Shnayderman and Katz-Leurer [20] reported that 6 weeks of aerobic exercise improved the disability score by approximately 20% in individuals with low back pain. Ram et al. [48] reported that high-intensity aerobic exercise improved disability level more than low-intensity aerobic exercise in adults with chronic low back pain. Cerini et al. [49] also reported that aerobic exercise statistically significantly reduced the level of disability in individuals with chronic low back pain. In our study, we observed significant improvements in disability levels in both CG and CAG, but the improvement in CAG was superior with a medium effect size. This result can be explained by the fact that elliptical exercise causes a decrease in the disability level of the individual with increased stability because it actively exercises the muscles of the lumbopelvic region [35].

It is often stated that individuals with low back pain have a higher prevalence of depression, anxiety, substance abuse, personality disorders, and somatization compared to the general population [36]. It is also reported that exercise causes a decrease in the severity of mood disorders and pain medication [50]. Tekin et al. [51] reported that aerobic exercise performed with the help of a treadmill for 6 weeks in individuals with chronic non-specific low back pain caused a significant improvement in the severity of depression. Mahmoudi et al. [52] concluded that aerobic, resistance, and combined exercises were effective in reducing depression symptoms in older adults. Carek et al. [53] concluded that exercise was as effective an intervention as antidepressant drugs in individuals with mild to moderate depression. Another study by Sculco et al. [54] found that 10 weeks of low to moderate aerobic exercise effectively improved general mood in individuals with low back pain. In this study, we observed significant reductions in depression severity in both the CG and CAG groups; however, the improvement in the CAG group was superior with a small effect size. This finding may be attributed to the fact that aerobic exercises, particularly continuous and rhythmic activities such as walking, cycling, and swimming, enhance the release of neurotransmitters such as endorphins, serotonin, and dopamine, thereby alleviating depression severity.

Kinesiophobia or "fear of movement" was first defined as a condition in which an individual experiences an excessive, irrational, and debilitating fear of physical movement and activity as a result of a feeling of being vulnerable to painful injury or re-injury [55]. In clinical settings, fear has been recognized as a significant element in patients' disability that must be addressed to achieve a successful outcome as it impacts rehabilitation strategies [56]. Studies have shown that geriatric individuals with low back pain exhibit high levels of kinesiophobia [57, 58]. Despite pain and fear, it may not be appropriate to advise patients to avoid painful movements or activities, as this will result in further activity restriction, leading to muscle deconditioning and disuse [59]. Jadhakhan et al. [60] reported that exercise is effective in reducing levels of kinesiophobia in individuals with chronic low back pain, but the level of evidence is low. Shakeri et al. [61] reported that core stabilization exercises reduce kinesiophobia. In another study, Pardo et al. [62] reported that a therapeutic exercise intervention including an aerobic exercise program reduced levels of kinesiophobia. In our study, kinesiophobia levels improved significantly in both groups, but we concluded that aerobic exercise had no additional benefit. This may be due to the significant improvements in postural control, muscle strength and sense of confidence that core stabilization exercises provided and thus reduced fear of movement. Since core stabilization exercises had a strong effect on kinesiophobia, aerobic exercise may not have provided additional improvement due to the “ceiling effect”.

The current study has several limitations. First, the study evaluated the effects of the exercises only in the short term. However, longer-term follow-up is needed to determine the long-term effects and sustainability of both core stabilization and aerobic exercises. Another limitation is that the extent to which participants adhered to the exercises was based solely on self-reports, which limits the reliability of the results. A methodological limitation is that exercise adherence was not measured with objective tools (e.g., activity monitors).

Conclusion

This study revealed that aerobic exercises added to CNLBP core stabilization exercises provided more significant improvements in functional capacity, physical performance, risk of falling, pain intensity and depression compared to core stabilization exercises alone. However, the fact that both groups showed similar effects on kinesiophobia suggests that physical exercise alone may not be sufficient to reduce fear of movement and that this problem may need to be addressed with more specific psycho-educational interventions. The findings suggest that aerobic exercises should be evaluated as part of a holistic approach in rehabilitation programs and should be supported by longer-term and larger sample studies. Furthermore, this study highlights the importance of multidisciplinary exercise approaches by demonstrating the additional benefits of aerobic exercise added to core stabilization exercises in geriatric patients with CNLBP. Future studies comparing different exercise types, durations and intensities and evaluating long-term effects may provide more comprehensive contributions to this field.

Abbreviations

CNLBP	Chronic non-specific low back pain
CAG	Core Stabilization + aerobic exercise group
CG	Core stabilization exercise group
BMI	Body mass index
6MWT	6-minute walk test
ODI	Oswestry disability index
VAS	Visual analogue scale
BDS	Beck depression scale bds
TKS	Tampa kinesiophobia scale
ANOVA	A mixed-design repeated-measures two-way analysis of variance
SD	Standard deviation
η2	Effect size

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Author contributions
ŞK: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. MC: Conceptualization, Data curation, Investigation, Writing - original draft, Writing - review & editing. İV: Investigation, Methodology, Writing - original draft, Writing - review & editing. AÖ: Methodology, Writing - orijinal draft, Writing - review & editing. HA: Writing - orijinal draft, Writing - review & editing. AH: Writing - orijinal draft, Writing - review & editing.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the principles of the Declaration of Helsinki. The purpose and procedures of this study were thoroughly explained to all participants both orally and in writingEthics committee approval for the study was obtained from Muş Alparslan University Scientific Research and Publication Ethics Committee (Number: 143804).

Consent for publication
Written informed consent was obtained from the participants for the publication of personal or clinical details and identification images in this study.

Competing interests
The authors declare no competing interests.

Patient consent statement
Written informed consent was obtained prior to theenrolment of every study participant. That all participants in our study were adults who provided their owninformed consent to participate. Therefore, parent orguardian consent was not applicable or required for thisstudy.

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