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The effectiveness of kinesio taping in addition to conventional treatment in patients with chronic low back pain: a randomized controlled trial

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ABSTRACT

Aims: This study aimed to compare the effects of kinesio taping in combination with conventional treatment on pain intensity, lumbar range of motion (ROM) and flexibility, disability, and depression levels in patients with chronic low back pain (CLBP) with conventional treatment alone.

Methods: The 48 individuals with CLBP included in the trial were randomized into the control group (CG, n=24) and the kinesio taping group (KTG, n=24). The CG received only conventional treatment for four weeks, while the KTG received kinesio taping for four weeks in addition to conventional treatment. Before and after the four-week treatment periods, patients were assessed with respect to pain intensity (visual analogue scale), lumbar ROM (goniometric measurement), flexibility (hand-ground distance), disability (Oswestry disability index), and depression (Beck depression inventory).

Results: After the treatment programs, there were significant improvements in pain intensity, lumbar ROM and flexibility, disability, and depression levels in both the CG and KTG groups ($p<0.05$). Furthermore, improvements in pain intensity, lumbar ROM and flexibility, disability, and depression levels were significantly higher in CTG compared to CG ($p<0.05$).

Conclusion: Conventional treatment of CLBP is effective in improving pain, lumbar ROM and flexibility, disability, and depression levels, but further improvement can be achieved with the additional application of kinesio taping.

Keywords: Kinesio taping, low back pain, flexibility, disability, depression

INTRODUCTION

Low back pain (LBP) is a musculoskeletal system disease that affects approximately 80% of adults. LBP causes disability and impairment and is a major burden on government health expenditures.[1] Factors such as smoking, high body mass index, heavy working conditions, and weak abdominal and back muscles can cause LBP.[2] LBP decreases the quality of life by affecting many activities of the individual, including social life, lifting weights, walking, bending, standing, traveling, dressing, and sexuality.[3] In the treatment of LBP, various methods are used, including educational programs, chiropractic treatment, exercise (such as yoga, stretching, hydrotherapy, tai chi, and McKenzie), manipulative treatment techniques, electrotherapy, and medication. Some of these treatments are recommended by the European guidelines for the management of chronic nonspecific LBP to promote physical activity.[4]

Kinesio taping (KT) is another technique that is commonly used to assist in the treatment of various musculoskeletal disorders.[5] It is based on the principle of applying special elastic bands to the skin with special methods. The tape used in KT is latex-free, adhesive, and can stretch to approximately 120% to 140% of its initial length.[6] It is reported that this technique is effective in reducing pain and abnormal muscle tension, improving muscle function and blood circulation, repositioning the joint, and supporting joint function.[7] The use of the KT technique is quite prevalent in sports and clinical practices.[8] Recently, this technique has also been utilized in the management of LBP.[9] Studies in the literature have pointed out that KT can be used for the treatment of patients with CLBP either alone or in combination with physiotherapy applications.[3,10-14]

Although studies have documented that KT may be effective in the management of CLBP,[12,14] some of these studies have conflicting results suggesting that KT is not superior to other interventions.[9,11,13,15] For instance, Castro-Sánchez et al.[9] investigated the efficacy of one week of KT in chronic non-specific LBP and observed improvements in pain intensity, trunk flexion movement, disability, and trunk muscle

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endurance one week after treatment. After four weeks, the researchers found that improvements in pain and trunk muscle endurance were maintained, while improvements in disability and trunk flexion movement were not preserved. Moreover, they suggested that short-term application of KT in LBP, such as one week, may provide too small effects to be clinically valuable, so further controlled trials with longer-term KT applications should be performed to obtain better and clearer results.[9] The non-standardization of the treatment methods applied in some of the studies, the wide age range of the included patient groups, the examination of the immediate effects of KT in some studies and the relatively short treatment periods (one or two weeks) in some studies may have been effective in the emergence of these conflicting results. For more precise results in CLBP, further high-level evidence studies with better methodology comparing the effectiveness of KT, which is reported to be effective in reducing pain and abnormal muscle tension and improving blood circulation and muscle and joint function[7] with conventional therapies using approved standardized procedures, are needed. Determining whether KT application is effective in CLBP with more precise results may help clinicians working in this field to establish treatment programs. Taking these into account, this study aimed to compare the effects of KT application in combination with conventional treatment on pain intensity, lumbar lumbar range of motion (ROM), flexibility, disability, and depression levels in patients with CLBP with conventional treatment alone, using verified standardized methods by the literature.

METHODS

Study Design and Ethical Approval

Ethical approval for this randomized, controlled, single-blind study was granted by the Muş Alparslan University Scientific Researches and Publication Ethics Committee (Date: 03.06.2024, Decision No: 8-2024/72). In the study, all stages of which were carried out in compliance with the Declaration of Helsinki, verbal and written informed consent was taken from all participants.

Participants

This study was conducted with 48 patients diagnosed with CLBP. Patients aged between 18-65 years with non-specific LBP for more than three months who had not received previous treatment and were not currently included in an active treatment program, who did not have neurological deficits such as radicular pain, loss of muscle strength, or loss of reflexes, and who had no indication for surgery, were recruited to the study. Exclusion criteria were history of pregnancy, psychiatric or neurological diseases, severe osteoporosis, spinal surgery, infectious or malignant diseases in the vertebrae, or findings indicating pathology known as red flags, scoliosis, visceral pain, and medication. Patients who fulfilled the inclusion criteria were randomized into two groups: the control group (CG), in which only conventional treatment was applied, and the KT group (KTG), in which conventional treatment was combined with KT.

Interventions

An experienced specialist physiotherapist (NTY) applied both the traditional treatment program and the KT to the patients. Both groups received the treatment programs three days a week for four weeks.

Conventional Treatment

Patients in both groups underwent lumbar flexion and extension exercises, stretching exercises for iliopsoas, quadriceps, and hamstring muscles, strengthening exercises for lumbar and abdominal muscles, along with a 20-minute hot pack (25x40 cm), 20-minute conventional TENS, and an 8-minute therapeutic ultrasound (1,2 w/cm^2) for four weeks by the same physiotherapist (NTY).[15,16] Exercises were performed in 3 sets and 10 repetitions in each session under the supervision of a physiotherapist.

Kinesio Taping Application

At the end of each treatment session, the patients in KTG applied KT with a 5 cm × 5 m kinesio tape material using a special 'muscle technique'.[3] The patient who was standing was asked to bend forward. The lower end of the tape was first applied 7 cm below the sacroiliac joint at the level of the paravertebral muscles, then the patient was asked to make a slight rotation to the left, and in this position, the tape was applied upwards on the paravertebral muscles without any tension. When taping the left paravertebral region, the same procedure was performed in reverse as on the right, and the tape was not stretched. The third tape was applied to the patient, who was standing upright and leaning slightly forward, with the tape stretched by 25%, passing over the sacroiliac joints and parallel to the ground. When the patients were in upright posture, folds formed on the bands. It was observed that the folds were compatible with the patient's body movements and remained until the day the bands were removed (Figure 1).[3] The tapes usually remained on the patient's body until the patient came for the next taping. When the patients came to each treatment session, the previous tape was removed from the skin by the physiotherapist, and the taping was reapplied. No itching, redness, or allergic reactions were observed in any patient.

Figure 1. Kinesio taping application to the lumbar region

Outcome Measures

Age, duration of complaint, gender, and body-mass index (BMI) were noted for all participants. Clinic assessments were performed before and immediately after four weeks of treatment programs.

Pain intensity: The pain intensity during activity (dynamic positions of the head, neck, and trunk such as backward and forward bending and rotation) was assessed utilising a visual analogue scale (VAS). Participants were instructed to indicate the intensity of their pain on a 10-cm line, where 0 represents no pain and 10 represents severe pain. The measured value was noted in centimeters.[17]

Range of motion: Trunk flexion, extension, and right-left lateral flexion as ROM of the lumbar region were measured using a goniometer. For the lumbar region flexion ROM assessment, the participants were asked to maintain an upright standing posture. The projection on the lateral line of the lumbosacral joint was determined as the pivot point, and the goniometer was positioned on the projection. The movable arm of the goniometer was positioned parallel to the lateral line of the trunk in a free position for trunk flexion. The fixed arm was aligned parallel to the midpoint of the femur. The participants were asked to perform trunk flexion, and the value at the last position they could reach was recorded.[18] For the extension assessment, a goniometer was placed on the projection of the lumbosacral joint at the lateral level of the lumbosacral joint, similar to the lumbar region flexion measurement, and the movable arm and fixed arm were positioned in the relevant places. The participants were asked to perform a trunk extension, and the moving arm followed them to the last position they could reach. The final value was recorded.[18] For lateral flexion measurement in the lumbar region, the movable arm of the goniometer was placed pointing to the C7 spinous process by determining the midpoint of the lumbosacral joint as the pivot point, and the fixed arm was positioned parallel to the ground. The participants were asked to start the movement in a neutral position without trunk flexion or extension. The participants were then asked to maintain their posture in this position and perform trunk lateral flexion to one side, and the movable arm of the goniometer followed the trunk lateral flexion to the end point. The measurement was repeated on the other side, and the values were recorded. The values obtained from ROM measurements were recorded in degrees.[18]

Flexibility: Flexibility was assessed by measuring hand-ground distance. In the hand-ground distance measurements, the standing patient was instructed to bend forward at the waist with both legs together and without bending at the knees, to bring the fingers of the hands closer to the toes, and to reach towards the ground. The distance between the tip of the third finger of the patient's hand and the ground was measured with a tape measure and recorded in cm.[3]

Disability: The Oswestry disability index (ODI) was employed to evaluate the disability level of the participants before and after treatment. ODI is a measurement tool to determine the degree of functional disability in activities of daily living caused by LBP. The lowest score is 0, and the highest score is 50. High scores on the instrument indicate a high level of disability. The Turkish version of the scale is valid and reliable in patients with LBP.[19]

Depression: The beck depression inventory (BDI) was applied to evaluate the depression levels of the participants.[20] The revised version of the scale consists of 21 items. On the instrument with a maximum score of 63 points, a higher score indicates more depressive symptoms. The Turkish version of the scale was found to be valid and reliable.[21]

Randomization and Blinding

The 48 patients with CLBP included in the study were randomised into CG (n=24) and KTG (n=24) groups utilizing age-and gender-matched pairs randomization. Utilizing the Research Randomizer program available on the website www.randomizer.org, matched-pairs randomization was carried out.[22] All evaluations before and after the four-week treatment programs were conducted by the same researcher (HK), who was blinded to the treatment groups. On the other hand, patients in the groups were not blinded to the treatment methodologies in the trial.

Sample Size

According to the pilot study conducted with five patients in both groups, considering the VAS score, the sample size was determined to be a total of 40 individuals with a power of 0.95 and $\alpha = 0.05$ and an effect size of 0.294 based on repeated measures analysis of variance (ANOVA) within and between interactions. A total of 48 individuals, 24 in each group, were included in the study, taking into account the 15% dropout rate of the patients.

Statistical Analysis

The SPSS version 24.0 software was utilized for statistical analyses. Descriptive analyses were presented as mean and standard deviation for numerical variables, with normal distribution assessed through visual (histograms, probability plots) and analytical methods (Kolmogorov-Smirnov and Shapiro-Wilk tests). Nominal variables were expressed as counts and percentages. To compare the numerical demographic and clinical properties of the groups, an independent sample t-test was conducted, and to compare the categorical data, a chi-square test was employed. A two-way mixed design repeated measures ANOVA was performed to assess the effects of treatments on pain intensity, lumbar ROM and flexibility, disability, and depression levels, with group (CG, KTG) as the between-patient variable and time (before-treatment, after-treatment) as the within-patient variable. Furthermore, to analyze the significant between-group differences in the change scores from the initial to the final treatment intervention, pairwise comparisons were carried out applying the Bonferroni correction. Statistical significance level was taken as $p<0.05$.

RESULTS

Of the 67 CLBP patients referred to our clinic, 48 included in the study, while 19 were excluded from the study. Participants who fulfilled the inclusion criteria were randomly allocated to

the CG and KTG groups, with 24 patients in each group. The trial was completed with 100% participation and compliance from the patients. The flow diagram of the study is presented in Figure 2.

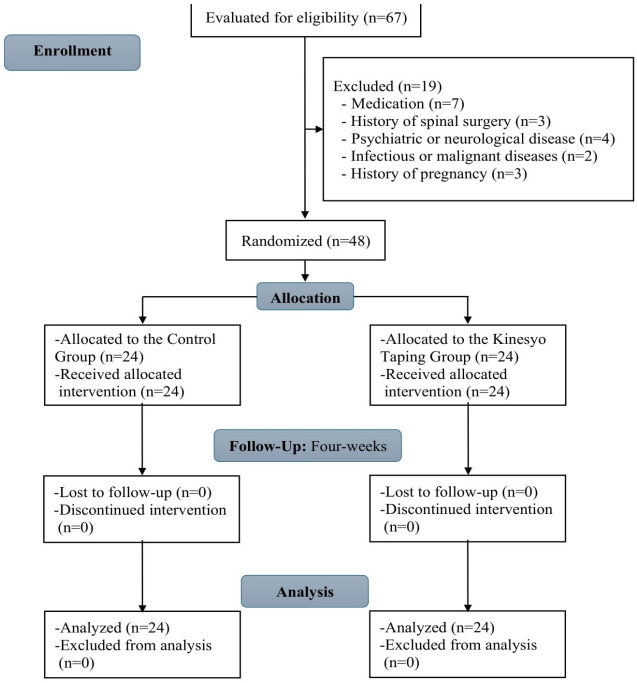

Figure 2. Flow diagram of the study

Table 1 provides the demographic and clinical properties of the participants before treatment. Accordingly, there were no significant differences between participants in the groups with regard to age (p=0.332), gender distribution (p=0.569), BMI (p=0.639), and duration of complaint (p=0.426).

Table 1. Baseline demographic and clinical properties of the groups

		CG (n=24)	KTG (n=24)	
Variables		**Mean±SD**	**Mean±SD**	**p**
Age (year)		42.60±6.23	44.40±5.48	0.332[a]
BMI (kg/m²)		24.38±2.22	23.77±2.10	0.639[a]
Duration of complaint (month)		6.72±1.18	6.27±1.06	0.426[a]
		n (%)	n (%)	
Gender	Male	13 (54.2)	14 (58.3)	0.569[b]
	Female	11 (45.8)	10 (41.7)	

CG: Control group, KTG: Kinesio Taping group, SD: Standard deviation, BMI: Body-mass index, p[a]: Independent sample t test, p[b]: Chi-square test

Table 2 demonstrated the comparison of before and after treatment scores for VAS, ODI, and BDI within and between groups. In both groups, the decreases in VAS, ODI, and BDI scores after interventions were statistically significant (p<0.05). Regarding group-time interactions, it was determined that the decreases in VAS, ODI, and BDI scores were significantly higher in KTG than in CG (p<0.05).

The comparison of before and after treatment lumbar region flexion, extension, right and left lateral flexion ROM values, and hand-ground distance measurements within and between groups is given in Table 3. In both groups, increases in all lumbar region ROM values and decreases in hand-ground distance measurements were statistically significant after treatment (p<0.05). When group-time interactions were considered, it was revealed that the increases in all lumbar region ROM values and decreases in hand-ground distance measurements were significantly higher in KTG than in CG (p<0.05).

Table 2. Comparison of pre- and post-treatment scores for VAS, ODI, and BDI within and between groups

		CG (n=24)	KTG (n=24)	MD values between groups	Time	Group* time		
		Mean±SD	**Mean±SD**	**Mean±SE**	**p**	**f**	**p**	**η²**
VAS (cm)	BT	5.32±1.07	5.44±1.04	1.80±0.21	<0.001*	75.00	<0.001*	0.61
	AT	2.68±0.69	1.00±0.65					
ODI (score)	BT	32.20±11.46	32.00±10.90	13.20±1.82	<0.001*	52.80	<0.001*	0.52
	AT	21.60±9.32	8.20±3.50					
BDI (score)	BT	29.68±7.68	29.60±7.39	9.72±1.17	<0.001*	69.47	<0.001*	0.59
	AT	19.52±5.61	9.72±3.16					

CG: Control group, KTG: Kinesio Taping group, MD: Mean difference, SD: Standard deviation, SE: Standard error, VAS: Visual analogue scale, BT: Before treatment, AT: After treatment, ODI: Oswestry disability index, BDI: Beck depression inventory, p: Two-way mixed design repeated measures ANOVA, *p:0.05, η²: Effect size

Table 3. Comparison of lumbar region ROM and hand-ground distance values within and between groups pre- and post-treatment

			CG (n=24)	KTG (n=24)	MD values between groups	Time	Group* time		
			Mean±SD	**Mean±SD**	**Mean±SE**	**p**	**f**	**p**	**η²**
ROM (°)	Flexion	BT	61.92±5.83	61.64±3.77	-17.72±1.08	<0.001*	270.86	<0.001*	0.85
		AT	73.76±5.94	91.20±2.96					
	Extension	BT	12.48±3.97	11.22±3.24	-7.64±0.50	<0.001*	237.28	<0.001*	0.83
		AT	17.82±3.90	24.20±4.02					
	Right lateral flexion	BT	19.42±5.45	18.06±3.87	-11.30±0.72	<0.001*	247.54	<0.001*	0.82
		AT	25.52±6.27	35.46±2.86					
	Left lateral flexion	BT	19.24±5.26	17.92±3.82	-12.20±0.76	<0.001*	257.57	<0.001*	0.84
		AT	24.80±5.45	35.68±3.28					
Hand-ground distance (cm)		BT	17.80±5.45	18.12±5.08	6.60±0.68	<0.001*	272.25	<0.001*	0.66
		AT	12.28±4.69	6.00±2.08					

CG: Control group, KTG: Kinesio Taping group, MD: Mean difference, SD: Standard deviation, SE: Standard error, BT: Before treatment, AT: After treatment, ROM: Range of motion, p: Two-way mixed design repeated measures ANOVA, *p:0.05, η²: Effect size

DISCUSSION

This study compared the effects of KT in addition to conventional treatment on pain intensity, lumbar ROM values, flexibility, disability, and depression in patients with CLBP compared to conventional treatment alone. As a result of the study, significant improvements were observed in all parameters evaluated in both groups. In addition, it was determined that the improvements in participants who received KT in addition to conventional treatment were significantly superior to those in the other group.

Kumar et al.[23] reported that conventional treatment was effective in reducing pain in patients with CLBP. Similarly, Yılmaz et al.[24] concluded that conventional treatment was effective in reducing pain in patients with chronic mechanical LBP. In another study, Atılgan and Erbahçeci[25] indicated that conventional treatment had a decreasing effect on pain in patients with CLBP. In our study, in accordance with the literature, we concluded that pain severity was significantly reduced in both groups treated with conventional treatment. Studies in the literature have documented that KT is effective in improving blood and lymph circulation and reducing pain severity.[26] Köroğlu et al.[27] suggested that KT may be effective in reducing pain in patients with CLBP. Sun et al.[10] reported that KT combined with physiotherapy applications in patients with CLBP may provide better therapeutic effects in reducing pain intensity compared with physiotherapy applications alone. In another study, Castro-Sánchez et al.[9] noted that KT was effective on pain improvement compared with placebo taping, but the clinical value of the effect was small. In this study, similar to the literature, significant improvements in pain intensity were observed in both CG and KTG groups. On the other hand, the improvement in pain intensity was greater in KTG. In this result, we consider that KT may have had a greater reducing effect on pain by increasing blood circulation more and decreasing muscle tension more.

In LBP, loss of spinal flexibility occurs due to pain. Loss of flexibility causes postural tension, leading to increased muscle fatigue, which in this situation leads to an increase in the load on the joint.[28] Modalities and techniques including exercises within the conventional treatment programs have an essential position in the management of LBP due to their positive effects on flexibility and functionality.[29,30] A review of the studies shows that conventional physiotherapy interventions have positive effects on lumbar region flexibility in LBP. Erdoğanoğlu et al.[31] suggested that conventional physiotherapy applications improved flexibility in patients with CLBP. Similarly, in this study, flexibility improved significantly in both groups of CLBP patients who received conventional physiotherapy. Inanoglu and Baltacı[3] concluded that kinesio taping may increase lumbar region flexibility in patients with LBP without neurologic deficits. In another study investigating the changes in trunk flexion, extension and lateral flexion before and after KT application, it was found that KT increased trunk flexion ROM. The researchers added that KT can be used to increase trunk flexion flexibility and promote tissue healing.[11] In the present study, spinal flexibility improved significantly in both groups, but the improvement was higher in the KTG. The greater improvement in flexibility in the KTG may be explained by the fact that KT may provide a greater increase in blood circulation and tissue elasticity. It has been indicated that the ROM of the lumbar region is negatively affected in LBP.[32] Kachanathu et al.[33] observed significant increases in lumbar region flexion and extension values of non-specific LBP patients included in a traditional physiotherapy program. Pointing out that the traditional physiotherapy program was effective in improving lumbar ROM in CLBP patients, Sharma et al.[34] concluded that the addition of manual therapy to the traditional physiotherapy program provided further improvement in ROM. It has been demonstrated that KT may provide significant increases in lumbar region flexion in CLBP patients.[12] Ciosek et al.[35] mentioned that KT may provide an increase in lumbar region flexion, extension, and right rotation degrees in CLBP patients. In another study investigating the application of lumbar region KT in healthy individuals, it was revealed that an increase in lumbar region flexion, extension, and lateral flexion degrees was obtained with KT.[11] In the current study, there were significant increases in lumbar ROM values in both groups. Furthermore, it was determined that the improvements in lumbar ROM values were significantly greater in KTG with additional KT. The application of KT may have stimulated the receptors in the joints more and created a mobilizing effect on the fascia, resulting in a greater increase in ROM values in KTG.

Disability is another prevalent adverse impact in patients with CLBP due to pain and/or decreased ROM and flexibility. Studies have pointed out that physiotherapy interventions can have a reducing effect on disability in patients with CLBP. After dividing CLBP patients into three groups, Durmuş et al.[36] applied only exercise to the first group, ultrasound treatment in addition to exercise to the second group, and phonopheresis in addition to exercise to the third group. They concluded that substantial improvements were observed in the level of disability in all three groups.[36] Altinbilek et al.[16] noted that conventional physiotherapy applications can improve the level of disability in patients with mechanical CLBP. In another study, Şahin et al.[37] proposed that traditional physiotherapy practices may reduce the level of disability in CLBP patients. In this study, in parallel with the literature, significant improvements in the level of disability were observed in both groups of patients with CLBP who received conventional physiotherapy. When the literature is examined, it is seen that the application of KT may have improving effects on disability in patients with CLBP.[9,15] Castro-Sanchez et al.[9] suggested that KT with the star technique may reduce disability in patients with CLBP for more than three months. Al-Shareef et al.[12] showed that, compared with placebo taping, KT was more effective in reducing pain and disability and improving trunk flexion ROM after 2 weeks of therapy.[38] In another study, it was concluded that KT provided significant improvements in pain and disability in LBP, but KT and exercise were similar in terms of efficacy.[15] In the present study, while there were significant improvements in disability level in both groups, the reduction in disability was greater in the KTG with additional application of KT. The application of KT in patients with KTG may have contributed to a greater reduction in disability level by providing a greater reduction

in pain and a greater improvement in lumbar ROM and flexibility.

The distress and anxiety that patients with LBP experience as a result of pain and mobility limitations constrain their daily living and social activities, lead to psychological problems such as depression, and consequently negatively affect their quality of life. There is some evidence that the level of depression in LBP can be improved by reducing the complaints of the patients with physiotherapy applications. Dogan et al.[39] observed significant decreases in depression levels in LBP patients who were included in a traditional physiotherapy program. Similarly, in this study, considerable decreases in the level of depression were detected in both groups in which conventional physiotherapy was applied. Çakmak et al.[13], who divided patients with CLBP into two groups, applied istrument-assisted soft tissue mobilization combined with a traditional physiotherapy program to one group and KT combined with a traditional physiotherapy program to the other group. The authors determined that both methods had positive effects on pain, functionality, and depression at the end of the study and stated that the two methods were not superior to each other. Ogunniran et al.[14] recommended that the application of CT in addition to stabilization exercises may be effective in reducing anxiety and depression levels in patients with non-specific LBP. In another study, it was highlighted that the application of CT in addition to exercise may provide positive effects on depression.[40] In the current study, where we have observed considerable decreases in depression levels in both CG and KTG groups, the reductions in the KTG group were higher. It can be hypothesized that the KT assisted in further improvement in the psychological status of the patients in the KTG, as it resulted in greater improvement in pain, flexibility, and disability.

Studies in the literature investigating the efficiency of KT in patients with CLBP have shown some conflicting results due to the application of non-standardized treatment methods, the relatively short duration of treatment periods, such as one or two weeks, and the reporting of immediate effects of KT in some studies.[9,11,13,15] However, compared to the studies in the literature, the fact that more standardized methods approved by the literature were used in both KT application and conventional treatment could be regarded as the strong aspect of the current study. In this respect, we believe that this study may provide clinicians and researchers with more clear results regarding the effectiveness of KT in CLBP.

Limitations

This study's basic limitation was that the treatment periods were comparatively short, and a long-term follow-up after treatment could not be carried out. Future studies with longer treatment and follow-up periods may provide more precise results.

CONCLUSION

In patients with CLBP, standardized conventional treatment is effective in improving pain intensity, lumbar ROM, flexibility, disability, and depression levels. On the other hand, further improvement in pain intensity, lumbar ROM and flexibility, disability, and depression levels can be achieved by applying KT in addition to conventional treatment. This study, which used more standardized methods approved by the literature in both KT application and conventional treatment compared to the studies in the literature, we think that this study can provide clinicians and researchers who are studying in the field of CLBP with clearer results regarding the efficiency of KT in CLBP.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of the Muş Alparslan University Scientific Researches and Publication Ethics Committee (Date: 03.06.2024, Decision No: 8-2024/72).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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