Research Article

Investigating the Effects of Transcutaneous Electrical Nerve Stimulation on Lumbar Fascia Tissue and Lumbar Curvature in Healthy People

Hassan Tamartash[1], Afsaneh Dadarkhah[2], Sharif Najafi[2], Jalal Kargar Shouraki[3], Seyed Morteza Tabatabaee[2], Sirous Azizi[2]*

1. Trauma and Surgery Research Center, AJA University of Medical Sciences, Tehran, Iran.
2. Clinical Biomechanics and Ergonomics Research Center, AJA University of Medical Sciences, Tehran, Iran.
3. Radiation Sciences Research Center, AJA University of Medical Sciences, Tehran, Iran

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ABSTRACT

Introduction: Transcutaneous electrical nerve stimulation (TENS) is commonly used for pain management. Recent studies have shown that TENS can improve the condition of low back pain by influencing the elastic coefficient of the lumbar fascia and the balance status; however, the effect of TENS on the lumbar fascia of healthy people has not been investigated. Accordingly, this study examines the effect of TENS on the lumbar fascia of healthy people.

Materials and Methods: A total of 60 healthy participants in two groups, underwent 10 sessions of conventional TENS intervention. The first group (intervention group) received TENS with an intensity at the tolerance level, and the second group (control group) received sham TENS. Ultrasonography and a spinal mouse device were assessed lumbar fascia thickness and lumbar curvature before and after the TENS.

Results: Significant changes were observed after TENS in the intervention group in reducing the lumbar fascia thickness (P=0.006) and increasing the lumbar curvature (P=0.000). Between-group changes after the intervention sessions indicated a significant difference between the lumbar fascia thickness and curvature (P≤0.003).

Conclusion: TENS in healthy people can lead to a decrease in the thickness of the lumbar fascia and improve lumbar curvature. Also, a strong correlation was found between lumbar fascia thickness reduction and increased lumbar curvature.

Keywords:

Lumbar fascia; Transcutaneous electrical nerve stimulation; Ultrasonography; Lumbar region; Spinal curvatures

*** Corresponding Author:**
Sirous Azizi, Associate Professor.
Address: *Clinical Biomechanics and Ergonomics Research Center, AJA University of Medical Sciences, Tehran, Iran.*
Tel: *+98 (21) 43823476*
E-mail: *s.azizi@ajaums.ac.ir*

Introduction

Low back pain (LBP) is usually a serious problem in developing societies that threaten people's health and causes the inability to perform activities [1]. The most common symptoms following LBP are pain in the back and lower limbs and the inability to perform daily activities, which can severely affect the work efficiency of people in society [2].

LBP is a common symptom that occurs in high-income, middle-income, and low-income countries and all age groups, from children to the elderly. Globally, years lived with disability due to LBP increased by 54% between 1990 and 2015, mainly due to population growth and aging, with the greatest increase observed in low- and middle-income countries. LBP is now the leading cause of disability worldwide [3].

Many studies conducted in this field have investigated the causes of LBP and how to diagnose, prevent, and treat it [4]. Among the different causes affecting LBP, disorders of the fascia tissue and the structure of the lumbar arch are the most important non-collision causes of LBP [5]. Loss of the lumbar lordotic curve is the most distinctive finding of the aging spine, and the prevalence of LBP increases with age [6]. Accordingly, studies have shown that the presence of deformity in the sagittal parameters of the lumbar spine can cause LBP [7]. Also, among other causes of LBP, disorders of the lumbar fascia could be mentioned [8].

Studies have shown that an increase in the thickness and a decrease in the flexibility of the fascia tissue is evident in people with LBP. There are also findings on the relationship between changes in the thickness of the fascia tissue, the lumbar flexion angle, and pelvic tilts [9, 10].

According to studies, disorders caused by work environments play an important role in the occurrence of LBP. In this regard, many active protocols, including performing stretching exercises, modifying work environments, controlling physical activities in the work environment, etc., have been considered to prevent the occurrence of LBP, which in many cases is due to lack of regular execution and the absence of a passive protocol cannot prevent soft tissue injuries and spinal involvement [11, 12]. Various methods, including exercise regimes, manual treatments, corrective movements, etc., have been proposed to control the incidence of LBP and also to maintain the condition of the soft tissue and the structure of the lumbar spine [13, 14]. However, in the meantime, the use of electrical stimulation, considering the passiveness of the treatment method and the type of its effect on the tissue, can be a suitable option to prevent characteristic changes in the back area and, as a result, LBP [15].

Transcutaneous electrical nerve stimulation (TENS) has analgesic effects and segmental relaxation by selectively activating non-noxious skin afferents (Aβ fibers) without simultaneously activating noxious skin afferents (Aδ and C-fibers) [16]. Considering that muscle shortening and spasms can cause disturbances in the structure of the lumbar curve, therefore, there is a hypothesis that using TENS to reduce the load and fatigue of the muscles in the lower back [17] can cause positive changes in the structure of the fascia tissue as well as maintain the back arch.

Studies have shown that TENS can help reduce LBP through multiple mechanisms, including the pain gate theory, environmental effects, and the effect on muscle tissue and fascia [15]. Also, the studies conducted on healthy individuals showed that TENS can help improve pressure pains, muscle function, and corticospinal excitability [18, 19]. On the other hand, previous studies have shown that TENS can cause changes in healthy people. Studies have shown that TENS in healthy people can cause a distinct decrease in systolic blood pressure, diastolic blood pressure, and heart rate [20]. Local increase in blood flow in healthy people is another finding of TENS [21]. In addition, studies have shown that TENS can cause significant changes in the metabolism of skeletal muscles in healthy people [22]. So far, no study has investigated TENS's effect on healthy individuals' fascia tissue. In this regard, the current investigates the changes in fascia tissue and lumbar arch in healthy people by using the TENS in the lower back area.

Materials and Methods

Study population

The G*power software, version 3.0.10, was used to determine the sample size, and 30 participants were obtained for each group. The sample size was calculated so that statistical analysis would be supported by 80% power at $\alpha=0.05$ for pair-wise comparison of the active group to the sham TENS group. Meanwhile, 60 healthy people without LBP after being informed about the study process and signing the consent form participated in the study. The inclusion criteria were the absence of LBP in the last 12 months, minimum age of 20 years and maximum age of 50 years, and body mass index of 18.5 to 30. Also, people with a history of surgery and fractures in the spine and lower limbs, disorders, and deformities of the spine, taking anti-inflammatory drugs, as well as a history of rheumatic and infectious diseases and cardiovascular disorders were excluded.

Examinations

The participants were evaluated by ultrasound and spinal mice before and after the intervention sessions (Figure 1 and Figure 2).

To investigate the thickness of the fascia tissue, the subjects underwent an ultrasound examination using a clinical ultrasound system (S9, SonoScape Corporation, made in China) with a linear 5-14 MHz array L14-5/38. The transducer with a cross-section of 6.24 cm^2 was targeted at points that were located 2 cm lateral to the midline of the L2 and L3 vertebrae on both sides of the spine (Figure 3). The choice of this point was due to the greater parallelism of the lumbar fascia with the skin, as well as the better visibility of the fascia tissue in this area [23, 24].

All images provided by routers using monotone settings have a frequency of 14 MHz and a depth of 5 cm and can provide optimal image quality for subcutaneous structures. Images were analyzed using ImageJ version 1.50h software (National Institutes of Health, USA) and its high validity has been shown in previous studies (intraclass correlation coefficient [ICC]= 0.81-0.99) [25]. Meanwhile, during ultrasound imaging, no force was applied to the lumbar region by the probe. And, the examination of the lumbar arch from T12 to S1 was done by a spinal mouse device.

To check the lumbar spine curve, the participants were evaluated in a standard standing position using the spinal mouse device (Idiag, Voletswil Company, Switzerland). The subjects were tested in a comfortable standing position with hands hanging beside their bodies with an exposed trunk and the T12 spinous process and the top of the anal cleft were determined and marked by the examiner [26]. Then, the spinal mouse device was placed on the defined T12 spinous process and moved along the midline of the spine to the top of the anal cleft at a constant speed. The spine's topography was recorded in the sagittal plane and repeated three times. The validity of the spinal mouse device was confirmed in previous studies (ICC= 0.867-0.876) [27]. Before the main study, an intra-tester reliability study was carried out to confirm the repeatability of the spinal mouse (ICC= 0.81-0.89) and ultrasonography (ICC= 0.78-0.86) devices.

Study protocol

The participants were randomly divided into two groups (n=30). Random allocation was done using the Flip-the-Coin method. In this triple-blind study, the par-


[redacted]

Figure 1. Measuring lumbar curvature in the sagittal plane with a spinal mouse

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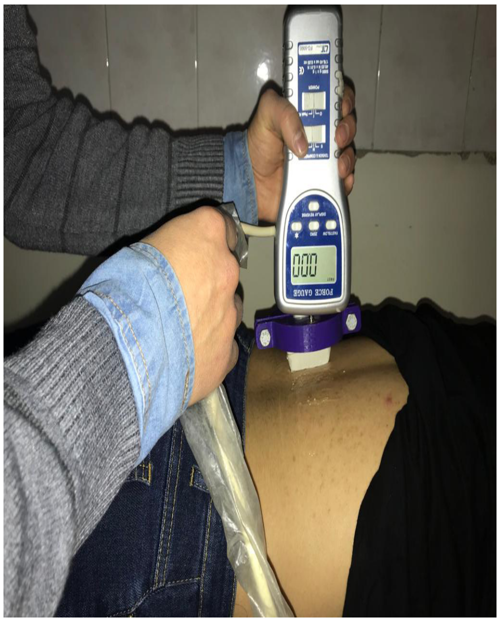

Figure 2. Examination of lumbar fascia thickness with ultrasonography

ticipants, examiners, and analysts did not know about the study groups. The participants in two groups underwent 10 electrotherapy sessions with TENS current for two weeks, each session lasting 45 min. The difference is that in the first group (intervention group [IG]) the intensity of the TENS current was increased to the tolerance limit of the participants; however, in the second group (control group-CG), the participants received sham-TENS.

Transcutaneous electrical stimulation protocol

In the intervention sessions, symmetrical conventional TENS with a triangular wave, random modulation, a frequency of 100 Hz, and a current intensity of 10-30 mA, 50 µs pulse duration were used. Therapy was performed by a 2-channel method. The participants lay prone with their heads resting on a pillow. The skin on the lumbar spine was cleaned with alcohol pads. Then, the physiotherapist put four rubber electrodes with a cross-section

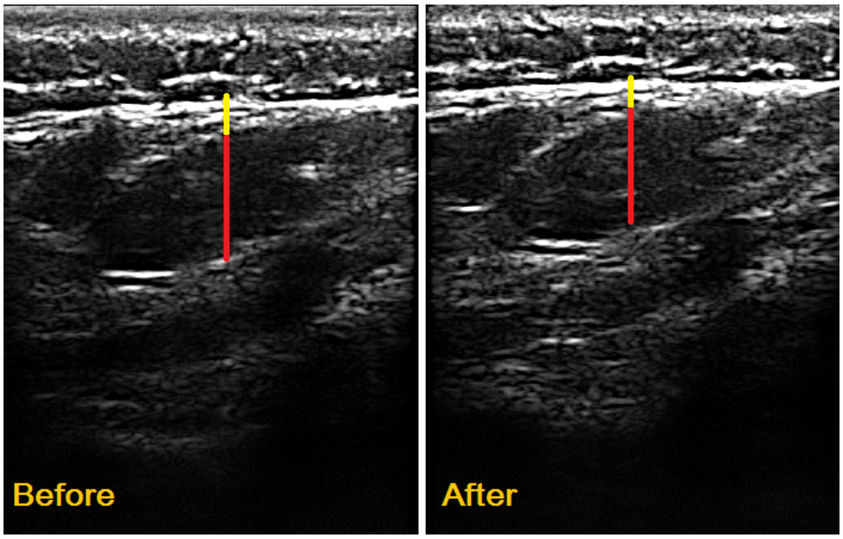

Figure 3. Ultrasonography images before and after the intervention from the lumbar fascia

Notes: Yellow lines show the thoracolumbar fascia thickness and red lines show muscle tissue.

Table 1. Baseline data of the participants

Variables	Mean±SD	
	Intervention Group (n=30)	Control Group (n=30)
Sex (men/women)	15/15	15/15
Age (y)	39.8±3.24	40.21±3.45
Body mass index (kg/m²)	24.03±2.41	24.87±2.06
Height (m)	1.74±0.42	1.75±0.50
Weight (kg)	77.54±11.63	78.12±10.42

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of 12 cm^2 on both sides of the L1-L2 and L3-L4 vertebrae [28, 29]. Specifications of the used device included Endomed 682v (Enraf Nonius Corp, Delft, The Netherlands).

Statistical analysis

Statistical analysis was conducted by SPSS software, version 16. The Kolmogorov-Smirnov test was used to determine the distribution of data. An independent sample t-test was used to compare baseline variables in both groups before the start of the study and between-group changes after the intervention sessions, a paired t-test was used to compare within-group changes, and the multiple linear regression tests were used to the relationship between the lumbar curve and fascia thickness. The statistical significance level was considered $P<0.05$ in all tests.

Results

The demographic data of the participants are shown in Table 1. The results of the Kolmogorov-Smirnov test showed a normal distribution of data. The independent t-test was used to compare the fascial thickness and lumbar curve in both groups before the intervention sessions. The results show that both groups' lumbar fascia thickness ($P\geq0.671$) and lumbar curvature ($P=0.950$) were not significantly different before the intervention sessions (Table 2). A paired t-test was used to examine the changes in lumbar curve and lumbar fascia thickness before and after intervention sessions. The results of the paired t-test showed that the lumbar fascia thickness decreased ($P\leq0.006$), and lumbar curvature increased ($P=0.000$) significantly after using TENS in IG. However, these variables did not change significantly in the CG group ($P\geq0.452$) (Table 3). An independent sample t-test was used to compare between-group changes after the intervention sessions. The results showed that the mean of lumbar fascia thickness ($P\leq0.003$) and curvature ($P=0.001$) differed significantly between groups after the interventions (Table 4). Multiple linear regression tests were used to investigate the relationship between lumbar curvature and lumbar fascia thickness changes in IG. The results showed a significant relationship between curvature increase and fascial thickness reduction ($R=-0.625$; $P=0.001$).

Table 2. Independent t-test comparing the baseline information of both groups

Variables	95% Confidence Interval of the Difference		t	P	Effect Size
	Lower	Upper			
Age (y)	-3.343	1.743	-0.630	0.841	0.52
Body mass index (kg/m²)	-2.00049	0.31611	-0.455	0.754	0.63
Lumbar curvature (degree)	-0.45866	0.30332	-0.408	0.950	0.67
Right side L2-L3 fascia thickness (mm)	-1.25678	0.85678	-0.379	0.671	0.58
Left side L2-L3 fascia thickness (mm)	-1.17301	0.75412	-0.325	0.821	0.61

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Table 3. Paired t-test to investigate within-group changes

Groups	Variables	Mean±SD		t	P	Effect Size
		Before Intervention	After Intervention			
Intervention	Lumbar curvature (degree)	17.61±0.73	19.46±0.69	2.881	0.000*	0.78
	Right side L2-L3 fascia thickness (mm)	37.48±2.07	36.08±2.14	-1.664	0.006*	0.82
	Left side L2-L3 fascia thickness (mm)	37.43±2.26	36.25±2.12	-1.421	0.005*	0.80
Control	Lumbar curvature (degree)	17.69±0.74	17.59±076	-0.117	0.452	0.62
	Right side L2-L3 fascia thickness (mm)	37.68±2.01	37.51±1.98	-0.355	0.745	0.73
	Left side L2-L3 fascia thickness (mm)	37.82±3.42	37.17±2.17	-0.317	0.652	0.69

Notes: * indicates significant difference ($P<0.05$).

Discussion

The present study investigated the effect of TENS on the thickness of the lumbar fascia and curvature. Following TENS in healthy people, significant changes are made to reduce the lumbar fascia thickness and increase the lumbar curvature. Also, statistical analyses showed a strong relationship between the decrease in the lumbar fascia thickness and the increase in the lumbar curvature. Considering that the activities of the participants did not differ much during the two weeks of the intervention, in the group that was subjected to sham-TENS, no significant changes were observed in the investigated variables.

TENS can help reduce pain and increase relaxation of the area through different mechanisms. Studies have shown TENS can have positive effects on the physical and mental components [30]. TENS inhibits pain fiber-evoked responses in the dorsal horn by influencing large-diameter fibers and involves partial inhibition using neurons located in the substantia gelatinosa in the dorsal horn of the spinal cord [29, 31]. The findings of previous studies stated that conventional TENS stimulates the thick Aβ fibers induced, activates the inhibitory neurons in the posterior horn of the spinal cord, and decreases the projective neurons' firing rate, in addition to reducing pain, this mechanism helps to improve muscle function as well as feeling more relaxed and can improve muscle function [32]. This can prevent secondary injuries by reducing muscle protective spasms and help improve the range of motion of the lower back [33]. Alternatively, Campbell and Taub stated that high-frequency TENS can conduction block or fatigue of Aδ fibers and cause optimal muscle function [34]. In this regard, the results of the present study showed a strong relationship between the decrease in the lumbar fascia thickness and the increase in the lumbar curvature.

Another theory is that TENS increases adenosine levels to improve the feeling of relaxation and optimal function of muscles. Considering that TENS affects large fibers, a theory was proposed that adenosine can play an important role [35]. In support of this theory, Marchand et al. stated that if healthy people are given caffeine (which blocks adenosine receptors) before using TENS, the ef-

Table 4. Independent t-test comparing the between-group changes

Variables	Mean±SD		95% Confidence Interval of the Difference		t	P	Effect Size
	Intervention	Control	Lower	Upper			
Lumbar curvature (degree)	19.46±0.69	17.59±076	1.48146	2.24465	0.665	0.001	0.75
Right side L2-L3 fascia thickness (mm)	36.08±2.14	37.51±1.98	-1.35671	0.79563	-0.469	0.003	0.81
Left side L2-L3 fascia thickness (mm)	36.25±2.12	37.17±2.17	-1.03254	0.82645	-0.412	0.001	0.86

fects of TENS will be significantly reduced compared to the placebo group [36].

Finally, another theory of the effect of TENS in healthy subjects is the release of endogenous opioids. There are 3 types of opioid receptors μ, δ, and k, which are located peripherally, in the spinal cord, the nucleus raphe magnus in the rostral ventral medulla, and the periaqueductal gray. Stimulation of these areas produces inhibition of dorsal horn neurons. Further, the rostral ventral medulla pathways use serotonin as a neurotransmitter. Another common inhibitory pathway is from the pontine noradrenergic cell groups, A6 (locus caeruleus) and A7 (locus subcaeruleus). These pontine neurons use the neurotransmitter noradrenaline and activate α-2 receptors spinally to produce inhibition of dorsal horn neurons. A previous study stated that the concentrations of β-endorphins increase in healthy subjects' blood and cerebrospinal fluid after TENS [37].

Increased concentrations of methionine enkephalin (a δ opioid agonist), and dynorphin A (a k opioid agonist) are observed in the lumbar cerebrospinal fluid after high-frequency TENS in subjects. Increasing the dynorphin, enkephalin, and serotonin levels can improve the motor condition of muscles, reduce fatigue, improve the optimal function of myofascial tissue, and increase the response to internal myofascial damage that may occur after daily living functions [38, 39].

According to previous studies, after reducing the thickness of the lumbar fascia, the flexibility of the lumbar region increases. These findings were expressed by increasing the elasticity of the lumbar myofascial tissue following therapeutic interventions [10, 40]. Also, with the increase in elasticity and the decrease in the lumbar fascia thickness, LBP was decreased, and the function of lumbar myofascial tissue and lumbar flexibility were improved [40]. Therefore, from the results of previous studies, it can be concluded that one of the causes of LBP is changes in the thickness and elasticity of the lumbar fascia tissue [24, 41].

Also, studies conducted on the biomechanical structures of the pelvic girdle showed a significant relationship between LBP and the reduction of lumbar curvature [9, 42]. However, there are inconsistencies between studies, and some studies show that there is no significant relationship between lower lumbar curvature and LBP, and certainty about this issue requires more comprehensive studies [43, 44]. Based on these findings, TENS can prevent the occurrence of LBP in healthy people by reducing the thickness of the lumbar fascia as well as increasing the lumbar curvature, however, more studies are needed to confirm this.

Studies have shown that TENS can help improve muscle function and relaxation by increasing blood circulation in the area [45]. In this regard, studies have shown that following TENS, the range of motion of the lower limbs increases [46]. Also, previous studies have shown that TENS can improve muscle function and be efficient in altering the distribution of muscle fibers without causing local inflammation [47, 48]. So far, there have not been many findings about the occurrence of morphological and structural changes following TENS. In this regard, the results of the present study showed that TENS in healthy people can improve the thickness of the lumbar fascia and lumbar curvature. Due to the direct effect of these variables on the occurrence of LBP, TENS can be mentioned as an assistive factor in preventing LBP, however, this issue requires more studies examining other parameters related to LBP.

Conclusion

TENS in healthy people can lead to a decrease in the thickness of the lumbar fascia and an increase in lumbar curvature. Also, a strong correlation was found between lumbar fascia thickness reduction and increased lumbar curvature. TENS in healthy people can help to increase the flexibility of the lumbar region by reducing the lumbar fascia thickness and improving the alignment of the lumbar arch. Another aspect of the present study was the introduction of TENS to improve the characteristics of the lower back, which can be considered a factor in preventing LBP, although this issue requires more future studies.

The limitations of the present study include the lack of a follow-up, and investigating the effect of TENS on other parameters related to LBP which can be considered in future studies.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of AJA University of Medical Sciences (Code: IR.AJAUMS.REC.1402.037).

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Authors' contributions

Conceptualization, Writing- reviewing and editing, and Visualization: Sirous Azizi and Hassan Tamartash; Methodology: Sirous Azizi, Hassan Tamartash, and Afsaneh Dadarkhah; Supervision: Sirous Azizi, Hassan Tamartash, Jalal Kargar Shouraki, Sharif Najafi, and Seyed Morteza Tabatabaee; Investigation, Software: Hassan Tamartash, Afsaneh Dadarkhah, Jalal Kargar Shouraki, Sharif Najafi, and Seyed Morteza Tabatabaee; Data curation, Writing- original draft preparation: Hassan Tamartash and Afsaneh Dadarkhah; Validation: Jalal Kargar Shouraki, Sharif Najafi, and Seyed Morteza Tabatabaee.

Conflict of interest

The authors declared no conflict of interest.

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