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Review

Occupational health improvement study on lumbar paraspinal muscles via surface electromyography during several tasks – a review

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Abstract The lumbar paraspinal muscles are located next to the vertebrae responsible for lower back motion, and they are a set of muscles with distinct designs and complex features. Lower back muscles are represented by the erector spinae (ES) and multifidus (MF) muscles, which are located between the L3 and L4 vertebrae. Back pain from paraspinal muscular disorders causes muscle atrophy, tension, and poor posture. As a result, it is important to monitor muscle fatigue and the cross-sectional area (CSA) of paraspinal muscles using the EMG approach and imaging techniques. The screening of these paraspinal muscles can evidence changes related to low back pain both before and after exercise; it can be used together with CSA of the paraspinal muscles to assess muscle atrophy caused by disc herniation and spinal stenosis as well as postoperatively. This review will aid researchers in gathering information on numerous elements that influence muscle fatigue and determining the usefulness of studying muscle atrophy in connection to disc herniation and spinal disease using various imaging modalities.

Keywords Lumbar paraspinal muscles, Electromyography, Cross-sectional area (CSA), Erector spinae (ES), Multifidus (MF).

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Introduction

The paraspinal muscles include: the quadratus lumborum, psoas major, multifidus, erector spinae, interspinal, and intertransversarii. They maintain the mobility and stability of the spine [1]. The mobility of the lower back is governed by muscles of the back, such as the multifidus and erector spinae. The architecture and design of paraspinal muscles are complicated, and they differ from the architecture and design of other muscles that have been widely studied (such as appendicular muscles). Many skeletal attachments and insertions exist in the paraspinal muscles, for example, at various vertebral levels. The erector spinae muscles serve to stabilize the lower back by combining the longissimus and iliocostalis muscles. The longissimus is in the erector spinae's middle section. Both the medial portion of the transverse process and the auxiliary process supply fibers to each of the five lumbar vertebrae. The multifidus is the biggest and most medial back muscle, spanning the lumbosacral junction. Its job is to keep the trunk erect and allow for abduction and rotation[2, 3].

Back pain caused by paraspinal muscular diseases can induce muscle atrophy, muscle strain, and poor posture. With 65–85 percent of the population reporting having lower back pain at some time in their life, it is becoming more and more prevalent [4]. As a result, it is crucial to consider the factors that impact muscular exhaustion in certain muscles, as well as their cross-sectional area (CSA), because fatty infiltration is more likely to occur. Fat and fibrous tissues can occasionally replace atrophied muscle, resulting in a decrease in muscular activation. Such phenomena render assessing muscle's CSA imminent.

The paraspinal muscles can be evaluated quantitatively and qualitatively using MRI, CT, and f-MRI images to measure CSA and determine the presence of fatty infiltration. To reveal the elements that produce muscular fatigue, researchers are analyzing EMG data from people with both acute and chronic lower back pain.

Electrodes inserted in skeletal muscles are used to detect electrical impulses from motor neurons in the central nervous system (CNS). Biomechanics uses these signals to evaluate movements and diagnose medical issues and activation levels. HD-sEMG is a non-invasive technique that covers a small patch of skin with more than two evenly spaced electrodes to measure electrical muscle activity. The ability to capture both temporal and spatial EMG activity with HD-sEMG enables the identification of new muscle properties [5]. In neurogenic diseases and channelopathies, HD-sEMG can reveal pathologic MU alterations [6]. Prior to and following exercise both acute and persistent lower back pain CSA values obtained from imaging modalities are also used to evaluate paraspinal muscle atrophy in the setting of spinal stenosis and disc herniation in people who currently feel or have in the past experienced back pain. Some research studies were inspired by [7], which describes assessment of fat infiltration in lumbar paravertebral muscle for LBP, and how imaging modalities like Dual Energy CT (DECT) were more efficient here. Similarly, many literature studies have been performed by paraspinal muscles monitoring using different approaches and have been discussed throughout this manuscript. Figure 1 shows an MRI of the L3-L4 disc level revealing the default size and location of the paraspinal muscles.

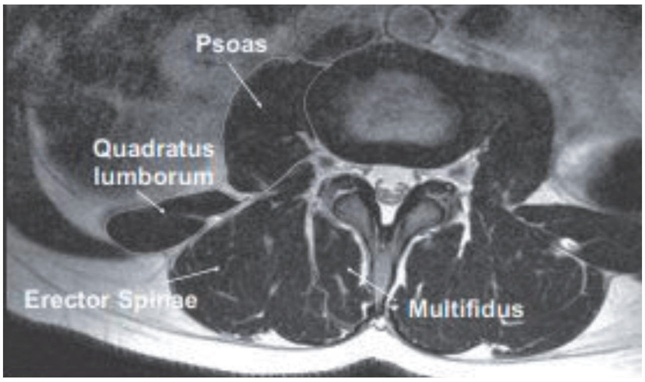

Figure 1. MRI of L3-L4 disc level showing paraspinal muscles around it.

Study Criteria

The present review analyzes the impact on paraspinal muscles during low back pain, during the flexion-relaxation phenomena, and their structural alterations that may be examined using medical images. The flow chart of studies selection according to well-defined criteria is shown in Figure 2.

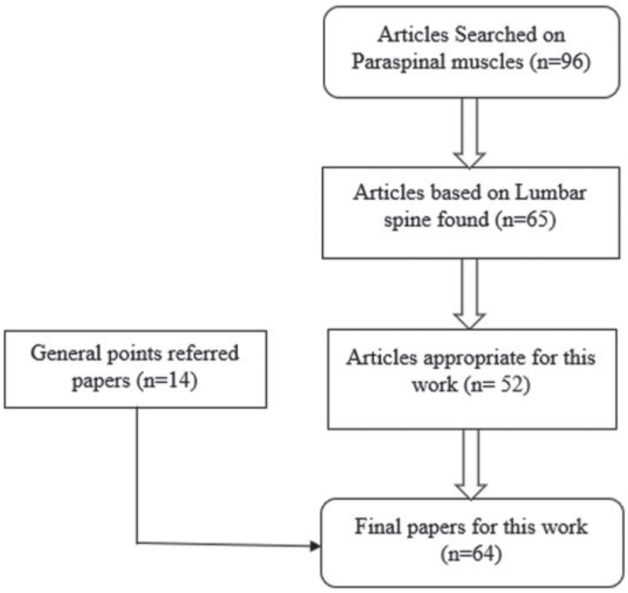

Figure 2. Flow chart of study criteria.

Need of EMG variables in the study

To compare the characteristics of those who experienced low back pain (LBP) with those who did not, as well as to determine the degree of their discomfort, EMG data from lumbar paraspinal muscles were required. Figure 3 and Table 1 describe electrode location from L1 to L5. EMG from these studies also aids in the understanding of FRP (Flexion-Relaxation Phenomenon), providing a thorough examination of lumbar muscle activity [8, 9, 10].

Table 1. Electrode placement in each channel.

Sl.No	Channel Name	Muscle
1	Channel 1	Erector spinae (ES) (left L1/L2 level)
2	Channel 2	Erector spinae (ES) (right L1/L2 level)
3	Channel 3	Multifidus (MF) (left L4/L5 level)
4	Channel 4	Multifidus (MF) (right L4/L5 level)

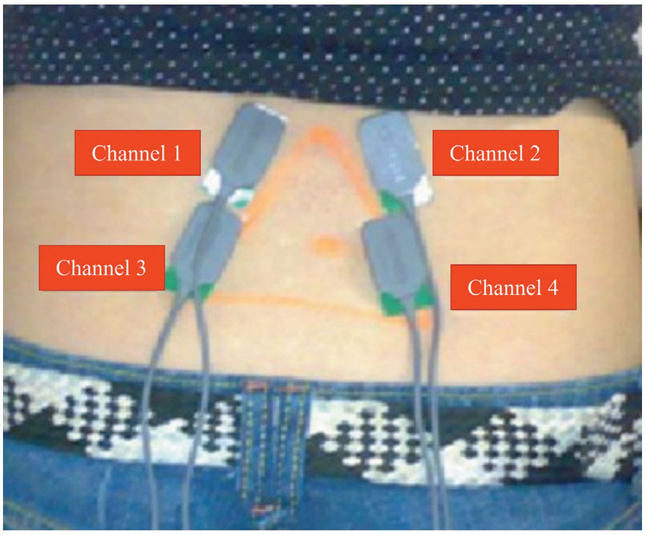

Figure 3. Electrode position at L1 to L5(S. ARJUNAN & al., 2010 [10]).

EMG Feature Extraction

The method of feature extraction emphasizes important information by removing noise from the raw signal data. An EMG-based control system must include three types of characteristics to function properly. These are the time, frequency, and time-frequency domains [11, 12].

Time domain

For EMG pattern identification, time-domain features are more typically utilized. This is due to the fact that they are simple and quick to calculate because no transformation is required. The amplitude of the input signals is used to construct time domain characteristics. The generated numbers offer an approximation of waveform amplitude, frequency, and duration within defined bounds [13]. The next subsections give complete descriptions on integrated EMG, mean absolute value, mean absolute value slope, Simple Square integral, EMG variance, root mean square, and waveform length.

(i) Integrated EMG (IEMG)

To know the pre-activity of muscles Integrated EMG (IEMG) is widely used. They are the areas under the curve of rectified EMG signals and they are also the summation of absolute EMG amplitude [14].

$$IEMG = \sum_{i=1}^{N} |x_i| \quad (1)$$

(ii) Mean Absolute Value (MAV)

The intensity of muscular contractions is found and measured using the Mean Absolute Value (MAV) technique. It is calculated as the full-wave rectified EMG signal's moving average [12, 14].

$$MAV = \frac{1}{N}\sum_{i=1}^{N} |x_i| \quad (2)$$

(iii) Mean Absolute Value Slope (MAVS)

To determine the difference in MAVs between neighboring segments, one uses the Mean Absolute Value Slope [14].

$$MAVS_i = MAV_{i+1} - MAV_i \quad (3)$$

(iv) Simple Square Integral (SSI)

The Simple Square Integral (SSI) is used to represent the EMG signal's energy into an useable characteristic [14].

$$SSI = \sum_{i=1}^{N} |{x_i}^2| \quad (4)$$

(v) Variance of EMG (VAR)

The EMG signal's strength is expressed as a usable property via the Variance of EMG (VAR) [12, 14].

$$VAR = \frac{1}{N-1}\sum_{i=1}^{N} x_i^2 \quad (5)$$

(vi) Root Mean Square (RMS)

There is a connection between the RMS and the constant force and non-fatiguing muscular contractions. For feature extraction, the RMS technique is commonly employed, because it is fast and economical in terms of computing while maintaining critical data [14].

$$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N} |x_i|^2} \quad (6)$$

(vii) Waveform Length (WL)

Waveform length is the term used to describe the length of the waveform overall (WL). The amplitude, frequency, and duration of the waveform are calculated using the WL method [14].

$$WL = \sum_{i=1}^{N} |x_{i+1} - x_i| \quad (7)$$

Frequency domain

To extract features in the frequency domains, a signal's power spectral density is employed (PSD).

(i) Autoregressive Coefficients (AR)

It consists of the previous samples added to an error term for white noise [15].

$$x_n = \sum_{i=1}^{p} a_i x_{n-i} + w_n \quad (8)$$

where x_n represents a sample of the model signal, a_i the AR coefficients, w_n is the white noise error term, and p is the order of the AR model.

(ii) Frequency Median (FMD)

Frequency Median (FMD) is a term used to describe a frequency distribution based on the power spectral density (PSD). To determine the frequency domain feature for EMG, there are two basic forms of PSD estimation: parametric and nonparametric. Parametric techniques treat the signal as the product of a linear system. The model of a system is not assumed in nonparametric techniques.

$$FMD = \frac{1}{2} \sum_{i=1}^{M} PSD \quad (9)$$

Effects on paraspinal muscles during low back pain

Lower back discomfort is caused by injury to the back muscles or tendons. It turned out to be extremely widespread. These effects will be noticed between L3 and L5 in the lumbar region of the spine. It has been demonstrated that electromyography signals are more effective than other techniques in differentiating between those with persistent low back pain and healthy individuals [16, 17]. The findings of Anthony R. Humphrey *et al*. demonstrated that EMG variables may be used to identify between patients with chronic back pain and healthy controls since the variable values differed considerably between the two groups [16].

A patient with an EMG variable half-width and an initial median frequency (IMF) above 49 Hz had back pain 5.8 times more often than others (p=0.014) and three times more often than those with a half-width greater than 56 Hz and no history of persistent LBP [18]. The activation of paraspinal muscles in persons with acute non-specific lower back pain was investigated using measurements of average EMG (AEMG), visual analogue scale (VAS), and finger-to-floor (DFTF) [19]. They discovered that paraspinal muscle activity changes after massage therapy due to variations in flexion and extension values. The EMG signal varied throughout prolonged periods of silent sitting; patients with cLBP showed less temporal variability (p=0.03), higher RPE (rating of perceived exertion), and equal spatial variation in muscle activity compared to healthy individuals. This shows cLBP patients have trouble in tolerating low levels of static muscular tension [20].

Within another study the patients' lumbar paraspinal muscle tone and stiffness were assessed using the Standard Error of Measurement (SEM), Smallest Real Difference (SRD), and Bland-Altman Analyses (BAA). The study proved that upper-level lumbar measurement was not as accurate as lower-level lumbar measurement [21]. Ultrasonic Shear-wave Elastography (USWE) can also reveal muscular stiffness. Muscle thickness and lumbar back muscle shear elastic modulus were utilised as dependent factors in a study, whereas height, age, body weight, and sex were used as independent variables [22]. During work, the soleus, vastus, and fibularis longus muscles of the lower extremities for both patients with and without a history of back pain experienced lumbar paraspinal fatiguing due to altering in the soleus muscle, where the postural reaction that keeps lower extremity function going occurs [23].

Shin-Yi Chiou *et al*. (2017) looked at the relationship between EMG frequency characteristics (derived from CWT-Continuous Wavelet Transform analysis) and patient self-reported disability ratings. The patients filled in the Roland-Morris Disability Questionnaire (RMDQ) in addition to collection of bilateral EMG activity from the erector spinae at levels L4 and T12. The back extensors underwent three brief MVICs (maximum voluntary isometric contractions) before the torque reading on the dynamometer was recorded. For 200 milliseconds, CWT was applied to the EMG signals of each muscle, focusing on the maximal torque generated during the MVICs. The findings demonstrated that peak power at T12 and L4 as well as peak power frequency were lower in patients than in healthy people. Similar correlations between RMDQ and the average energy ratio at T12 were discovered (r=0.63; p=0.012), indicating that the lower frequencies had a predominant energy distribution [24].

Zeng Ming Hao *et al*. performed the Sorensen test for soldiers with and without chronic low back pain (CLBP) and published a comparative study about muscle fatigue and asymmetry on lumbar muscles using paired and independent samples *t*-tests and spatial distribution of those by repetitive ANOVA (Analysis on Variance) during sustained contraction using HDEMG. From these data they concluded that CLBP patients featured less significant effects on muscle fatigue and asymmetry in both sides of erector spinae and also uneven spatial distribution when compared to healthy subjects [25].

Influence of paraspinal muscles during FRP

The "flexion-relaxation (F-R) phenomenon" occurs when electrical silence begins immediately in back muscles when the trunk is flexed to a certain degree. The spinal extensors relax completely in full flexion, allowing the spinal ligaments to supply the flexion torque. This happens because the tension in the spinal ligaments contributes significantly to the anterior shear stress on the lumbar vertebrae and increases the strain on the facet

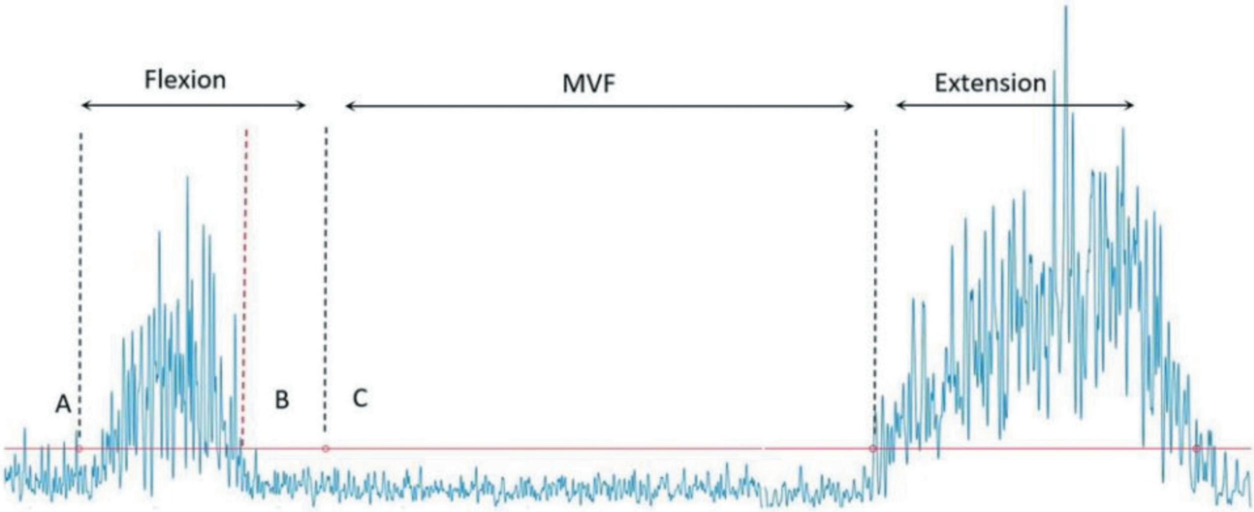

Fig 4. FRP of HDEMG

joints during weight training. Good technique is especially important when the spine is fully flexed [26].

Under spline statistical analysis, the paraspinal muscles with and without LBP had lower EMG amplitude with FRP than without FRP [19]. The erector spinae [ES] (L2, L5) muscle exhaustion caused with the Sorenson procedure was convincingly demonstrated in [9], and examination of the power spectrum suggested that it might affect FRP. They reached this conclusion by undertaking research to learn about the influence of FRP on earlier lumbar operations and their reaction to rehabilitation treatment [27].

P. Ippersiel *et al.* examined regional lumbopelvic coordination and flexion-relaxation patterns to better understand how individuals with and without low back pain perform during bending exercises. Regardless of movement duration, the hip/lower lumbar joint pair commonly moved out of phase in the low back pain group compared to the healthy group (mean difference = 24.7; 95 percent confidence interval = 3.93-45.4). The lower/upper lumbar coordination of the groups differed just a little. All muscles in the low back pain group exhibited decreased flexion-relaxation (average: 21.7%), with the multifidus showing the least relaxation after full flexion [28].

Anais Gouteron *et al.* carried out a detailed review on FRP (Figure 4) in the population with non-specific chronic low back pain (NSCLBP) in terms of prevalence, mean flexion-relaxation ratio (mFRR), mean extension-relaxation ratio (mERR), and distinction between asymptomatic and NSCLBP FRR. Their review concludes with the statement that the test was reproducible, sEMG can accurately identify an altered FRP in the NSCLBP group, and asymptomatic and NSCLBP FRP differed significantly in terms of FRR [29].

Impact of paraspinal muscles during several activities

EMG collected with surface electrodes was used to investigate the influence of paraspinal muscles owing to various activities. Experiments were conducted on paraspinal muscles to assess their atrophy, changes in CSA, and other effects of various activities such as physical exercise, massage treatment, static and dynamic training, and so on. L.A. Danneels *et al*. looked at the impact of paraspinal or paravertebral muscles during three distinct training modalities: stability, stabilization with dynamic resistance, and stabilization with static-dynamic resistance. According to the study, stabilizing exercise had no effect on muscle CSA, but rigorous lumbar resistance training was required to restore muscle size in cLBP patients with back muscles atrophy [30]. Table 2 enumerates experiments on various activities monitored to study paraspinal muscles changes.

Impact of paraspinal muscles found in imaging studies

LBP and other activities generate changes in the paraspinal muscles, which are investigated using imaging methods such as, CT, MRI and fMRI. Research exposed in Table 3 suggests that CSA and fatty infiltration in the paraspinal muscles are associated with disc herniation and spinal disorders. EMG data from people with acute and chronic lower back pain is being utilized to figure out what factors affect muscular fatigue. 3T MRI was employed in [46] to evaluate the geometric changes in CSA and contractile density following iatrogenic injury surgery. Based on changes in the atrophy of the back muscles, "stand-alone" oblique lateral interbody fusion (OLIF) and typical OLIF were compared in [47]. FCSA and Fatty Infiltration Percentage (FIP) were

Table 2. Experiments on various activities monitored to study paraspinal muscle changes.

Reference	Activity Monitored	Method	Result
[31]	Comparison of EMG features from Erector Spinae (ES) and Vastus Lateralis (VL) during bending forward and crouching down activities.	Median frequency (MNF) changes in the SEMG frequency domain index	Forward Bending: ES has higher significance than Right Vastus Lateralis Squatting down: Right Vastus Lateralis has higher Significance than ES
[32]	Monitoring myoelectric activity of paraspinal muscles for Idiopathic Scoliosis (IS) adolescents' habitual standing and sitting.	PUMC Type 1a and Type IIc subjects' root mean square (RMS) of SEMG reflects their spinal curvature state	A more consistent RMS SEMG ratio was seen in the trapezius, longissimus dorsi, and erector spinae after the physiotherapist suggested posture modification in the thoracic and lumbar areas. Thus, AIS patients were advised to use motor learning by practising recommended positions that help in balanced posture.
[33]	Alterations in the pattern of muscular activation affect spinal tissue creep when muscles are fatigued.	Surface electromyography was used to record the right and left erector spinae's large-array activity (EMG). The EMG root mean square (RMS), median frequency, and dispersion were compared on the x- and y-axes before and after the fatigue exercise.	The EMG median frequency was shown to alter significantly with muscular exhaustion.
[34]	The effect of repeated abrupt external perturbations on the trunk's neuromuscular adaptation after muscle fatigue.	A high-density EMG The activation of the erector spinal muscles was assessed using this method. A 3D motion analysis system was used to collect trunk kinematics from perturbation studies. Two-way measures were employed for baseline activity, reflex latency, reflex peak, and trunk kinematics to investigate adaptation, fatigue, and interaction effects.	Muscle activity was distributed more spatially in post-fatigue trials, compared to fatigue tasks. Values of baseline activity were higher in muscle fatigue and reduced in perturbation training.
[35]	Surface electromyography (SEMG) of the lumbar paraspinal muscles in stroke sufferers with later pulsion in a passive posture.	Correlation of Burke Lateropulsation scale during onset and duration of SEMG response.	In lateropulsion patients, paraspinal muscle activity had SEMG response length shorter on the weaker side after passive tilting at the stronger side, which implies more muscle activity during fast, passive tilting at the weaker side than controls. There is no correlation for dependent variables in BLS
[36]	Affect in lumbar reflex adaptation due to back muscle fatigue in response to fast external perturbations	Back muscular fatigue protocol (intermittent)	Erector Spinae (ES) reflex latencies were shorter by 25% (p<0.05) during expected versus unexpected conditions, To compensate for muscle weariness, a substantial external force disturbance would result in greater amplitude responses in paraspinal and even earlier activation.
[37]	The surrounding muscles of the cervical spine, thoracic spine, and lumbar spine are all affected by different designs of high heels.	The paraspinal muscles surrounding the C6, T7, and L5 vertebrae were an electrode.	Standing on wedge heels, setback heels, and French heels increased paraspinal activity in the cervical and lumbar spine as compared to bare feet. The various styles of heels, on the other hand, had no noticeable difference.

[38]	Dynamic superman contractions on stable and unstable surfaces, as well as unloaded body weight squats, activate the paraspinal muscles (longissimus and iliocostalis).	Correlation Analysis	Compared to Superman's exercise, the bodyweight squat produces equilibrium muscle activation in longissimus and iliocostalis on stable and unstable surfaces. Due to dynamic natures and daily activities, sports situation bodyweight squat was suggested, because it was better in activating paraspinal muscles than superman boat exercise.
[39]	Juchumseogi and Juchumseo Jireugi's motions affect paraspinal muscle activation.	Muscle activation was measured from C3, T7, and L3 during these motions. The movements were repeated three times, with the average results utilized in the analysis.	In comparison to simple standing, Juchumseogi and Juchumseo Jireugi movements increase paraspinal muscle activity in C3 and T7. When compared to Juchumseogi alone, Juchumseo Jireugi's motions In C3, T7, and L3, there was a considerable increase in muscular activity of paraspinal muscles. In C3, T7, and L3, the paraspinal muscular activation caused by Juchumseo Jireugi's motion was much greater than that caused by standing and Juchumseogi alone.
[40]	The effect of the bridge workout approach on rectus abdominis muscle change and paraspinal muscle activation while walking on the treadmill in high heels.	In the supine position, bridge exercise was done in a hook lying posture, whereas in the prone position, bridge exercise was done in a plank position. The rectus abdominis muscle's strength was measured by keeping the same posture for a certain amount of time. EMG (4D-MT & EMD-11, Relive, Korea) was utilized to evaluate paraspinal muscle activation.	The rectus abdominis muscle strength rises in the supine and prone groups during the bridge exercise. During bridge training, both groups' paraspinal muscular activation in the thoracic and lumbar portions diminishes.
[41]	During back bridge training, EMG was measured in the time and frequency domains from the Lumbar Multifidus (MF) and Erector Spinae (ES).	Between the first and last epochs of the test, the normalized Root Mean Square (RMS) value and the spectral Median Frequency (MF) were compared. Throughout the test, the dynamics of MF were acquired using the Short-Time Fourier Transform (STFT)	The LM muscle exhibited a bigger MF than the ES muscle towards the conclusion of the exercise, which remained constant. The slope of MF, on the other hand, was crucial for LM.
2009 [42]	The lumbar muscles react by creating tension-relaxation of viscoelastic tissue when undergoing extended passive cyclic trunk flexion and extension.	Passive exercise session	Decrease in posterior viscoelastic tissue over time due to supply of tension when muscle activity remains constant. After a passive flexion session, active flexion results in a rise in paraspinal muscle EMG and an increase in median frequency.
[43]	Lumbar Muscle Activation During Resistant and Non-Resistant Core Strength Exercises: EMG Analysis (Trunk extension exercise, superman boat exercise, Quadruped exercise)	To normalize EMG, the Root Mean Square (RMS) and Maximum Voluntary Contraction (MVC) methods were applied (per cent MVC)	Muscle activation during manually resisted and unresisted tasks is identical, according to the findings. During resistive training, the muscles were not certainly overused or strained. As a result, specialized muscle group resistance training can be used to develop target muscles.

[44]	Myofascial release	(1) superficial myofascial release; (2) deep myofascial release; 10 sessions, each lasting 40 minutes were employed in a ten-session, twice-weekly myofascial release technique intervention regimen. The Toe-Touch Test and electromyography activity were used to gauge the lumbar erector spinae muscle's flexibility and activity during trunk extension-flexion motion (EMG).	EMG activity in the right iliocostalis (p = 0.179; r = 0.43), right longissimus (p = 0.877; r = 0.05), left iliocostalis (p = 0.386; r = 0.29), and left longissimus (p = 0.418; r = 0.27) muscles was unaffected by myofascial release methods.
[45]	After lumbar spine surgery, patients may experience spinal muscular atrophy (PMA).	The search for research that documented PMA after spine surgery was conducted in the literature. The amount of PMA released following surgery was compared in three groups: lumbar fusion vs. nonfusion procedures, posterior vs. anterior lumbar fusion, and minimally invasive (MIS) posterior lumbar decompression and/or fusion vs. non-MIS equivalent therapy.	The mean postoperative volumetric PMA following fusion procedures was significantly higher than the mean postoperative volumetric PMA following non-fusion procedures (p=.0001), the mean postoperative volumetric PMA following posterior fusion procedures was significantly higher than the mean postoperative volumetric PMA following anterior fusion procedures (p=.0001), and the mean postoperative volumetric PMA following conventional fusions was significantly higher than the mean postoperative volumetric PMA following MIS fusions (p=.001). The mean volumetric lumbar PMA did not differ statistically between MIS and non-MIS decompression (p=.56). Postoperative PMA was shown to be higher following non-MIS fusions, posterior surgeries, and lumbar spine fusions.

measured using computed tomography (CT) before and after multifidus and erector spinae surgery. The automated threshold technique was also employed in research of paraspinal muscles morphology and fatty infiltration, with the results comparing the automatic approach to a novel thresholding method leading to the conclusion that the automatic method is more reliable [7].

Discussion

EMG characteristics in LBP

A subset of persons who are more prone to experience future low back pain can be identified using the lumbar paraspinal muscles' EMG features. We can notice that to varying degrees, all the EMG variables were able to discriminate between low back pain patients and healthy controls. The previous history of patients could not be distinguished from that of healthy controls or patients with persistent low back pain due to the small sample size of the history group or the wide range of the prior history group's variables. Back pain risk rose 5.8-fold when IMF was higher than 49 Hz (p = 0.014) [18]. Reduced peak power (T12 and L4) and decreased peak frequency may be seen in the patient's EMG signal characteristics at the L4-T12 levels (T12) [24]. It was shown that those with acute non-specific lower back

Table 3. CSA and fatty infiltration in the paraspinal muscles are associated with disc herniation and spinal disorders.

Reference	Objective	Materials And Methods	Inference
[48]	The link between spinal stenosis, lumbar paraspinal muscle atrophy, and lumbar disc herniation	Materials: Pattern of disc herniation and degree of spinal stenosis. Method: Investigation of Muscle atrophy grade (Multifidus, Longissimus, and Iliocostalis) and laterality.	79% of individuals with disc herniation had multifidus atrophy and they had no relationship between paraspinal muscle atrophy with disc herniation (p=0.15) and with any grade of spinal stenosis (p<0.01). Paraspinal muscle atrophy was found in 90% of individuals with spinal stenosis.

[49]	Functional magnetic resonance imaging [blood oxygen level-dependent (BOLD) imaging and T2 mapping] was used to examine the excitation of the lumbar paraspinal muscles before and after exercise.	Simple Roman Chair made of wood. CSA, R2*, and T2 values were measured in the iliocostalis, longissimus, and multifidus anatomical portions of the lower back during an upper-body flexion and extension exercise in that chair. The data was analyzed using SPSS 2.0 statistical software.	R2* was reduced ($p<0.01$), although CSA and T2 were higher after exercise. Although there was no statistical difference, males and females had substantially different R2*, CSA, and T2 values in the iliocostalis ($p<0.05$). In comparison to the multifidus and longissimus, the iliocostalis exhibited a higher overall CSA ($p<0.05$).
[50]	The goal of this study was to determine the skeletal muscle mass index (SMI) and paraspinal muscle composition in patients who had spinal surgery for lumbar spinal stenosis (LSS) or adult spinal deformity (ASD), as well as to evaluate if paraspinal muscles influence low back pain in ASD patients. (3) Determine which ASD spinal metrics are substantially impacted by paraspinal muscles on radiographs.	Dual Energy Absorptiometry was used to perform T2-weighted MRIs at the L3/L4 level. Methods: Paraspinal muscle rm CSAs were measured using preoperative T2w MRIs at the L3/4 level. Using dual-energy x-ray absorptiometry, the body's total bone mineral density and lean, soft tissue mass were calculated. The quantity of lean soft tissue in the appendix (kg/m^2) was used to compute the SMI (upper and lower limbs). For 110 consecutive patients with ASD and 50 consecutive patients with LSS who had spinal surgery, the Roland-Morris Disability Questionnaire, Oswestry Disability Index, spinopelvic characteristics, and rmCSA were assessed.	The overall SMI and sarcopenia morbidity rates were not different between LSS and ASD patients. The multifidus/erector muscles' CSA and rmCSA are negatively correlated with the Oswestry Disability Index, but the multifidus/erector muscles' CSA and sacral slope are positively correlated.
[51]	Using digital data from lumbar spine MRIs of patients with both acute and chronic low back pain, researchers looked at changes in the cross-sectional area (CSA) and composition of the paraspinal muscles (LBP)	The amount of fat infiltration was assessed using CSAs and the mean signal intensities of the bilateral paraspinal muscles (psoas major, PM, quadratus lumborum, QL, multifidus, MF, and erector spinae, ES). Results were contrasted between painful and non-painful groups as well as between different groups. The CSA and mean signal intensity of the MF muscle were evaluated in 42 patients with chronic unilateral LBP at three distinct levels: problem, above issue, and below issue.	In terms of pain, the chronic LBP group had considerably lower CSAs of MF and ES muscles compared to the acute LBP group, which had significantly lower CSAs of PM and ES muscles. In the chronic LBP group, measurements were made of the mean signal intensity and the amount of fat in the ES muscle on the afflicted side.
[52]	A complete muscle measuring procedure the worth able quality and agreement of related paraspinal muscle composition metrics were also discussed and acquired using OsiriX and ImageJ, two widely used image processing tools.	Materials: Researchers used axial T2-weighted magnetic resonance scans of the multifidus muscle, the erector spinae muscle, and the two muscles united at L4–L5, as well as lumbar magnetic resonance imaging on 30 patients at L4–L5. Method: Measurement of muscle CSA and composition. Each software package was used twice, at least 5 days apart, to duplicate all measurements. All prior measurements were hidden from the subject.	OsiriX or ImageJ was used to determine interrater reliability and standard error of measurement (SEM), with coefficients of reliability (intraclass correlation coefficients [ICCs]) ranging from .77 to .99 for OsiriX and .78 to .99 for ImageJ, respectively. The two software tools had comparable high levels of agreement when measuring muscle composition (inter-software ICCs of .81– .99).

[53]	Evaluating the postoperative lumbar spine	Materials: X-rays, flexion-extension x-rays, CT scans, myelography, and MRI scans were used. Methods: Most patients get one or more imaging tests, depending on the kind of first surgery and symptoms.	For adequate evaluation and selection of the radiological approach to be employed, knowledge of different types of surgical operations, instruments, typical postoperative changes, and probable problems was required.
[54]	Intra- and inter-measurement errors in paraspinal muscle parameters of functional cross-sectional area (FCSA), density, and T2 signal intensity were assessed using computed tomography (CT) and magnetic resonance imaging (MRI) (MRI).	Materials: In 29 patients with incessant low back pain, CT scan density and MRI T2 signal intensity of paraspinal muscles at L3-L4, L4-L5, and L5-S1 were compared. Methods: To assess intra- and interobserver reliability, two professionals. In three weeks, musculoskeletal radiologists and one superior spine surgeon tracked the area of interest twice.	FCSA has a reasonable to outstanding intraclass correlation value, while fatty infiltration has a good to the excellent intraclass correlation coefficient. Similarly, the inter-reliability ICCs are FCSA-fair to excellent and fatty infiltration-good to outstanding. Poor to excellent ICCs for CT and MRI scans The fatty infiltration measurement's relative standard error varied.
[55]	Quantitative and qualitative assessment of paraspinal muscles composition measurement (CSA) in association with maximum isokinetic lifting performance from routine lumbar spine MRI	Materials: MRI of paraspinal muscles at L3-L levels. Methods: The major outcome variables for isokinetic lifting power and effort, as well as body fat percentage, was relative and evaluative muscle constitutions analyses.	The CSAs and relative muscle constitution values based on cerebrospinal fluid adjusted signal intensity at the L3-L4 level were excellent (ICC = 0.95-0.99 and 0.96-0.99, respectively), while the evaluative muscle constitution evaluations (Kappa = 0.54-0.76) were only fair. According to the weak correlations between isokinetic lifting power and work and the relative and evaluative assessments of muscle constitution (r = 0.02-0.41), the evaluative estimations were preferred.

pain (ANLP) have different paraspinal muscle myoelectric activity signal amplitudes than healthy individuals. Consequently, the ANLP patients' myoelectric activity was recovered. In order to determine if patients with cLBP had a lower tolerance for low-level static muscular strain, the lumbar muscles alterations in the right and left side of patients were compared with healthy controls [20]. The study on Myo tonometer concluded that utilizing it in the clinical environment in young people with persistent LBP was useful. Upper lumbar level measurements were not as accurate as those performed at lower lumbar level [21]. Some studies concluded that HDEMG, Ultrasound Elastography (SWE) may help in understanding changes in stiffness and muscle mass [22, 23].

FRP impact on paraspinal muscles

The FRP was studied using HDEMG and Sorenson protocol, leading to the conclusion that people with LBP and FRP had a delayed onset. The presence of erector spinae muscle exhaustion also changes the FRP [26]. The changed FRP is frequently detected in the NSCLP population, and the test is quite repeatable. All muscles of the group of lumbar muscles showed decreased flexion-relaxation during complete flexion in the low back pain [9, 27] indicates FRP helps in knowing the conditions of the tissue due to excessive loading conditions (i.e. LBP).

Paraspinal muscles during several activities

LSS (Lumbar Spinal Stenosis) has previously been linked to impairments in lumbar movement perception. Recent studies validate the earlier conclusions using new patient data and controls that are matched for age. The disparity between the present LSS (Lumbar Spinal Stenosis) outcomes and the past disruption of local nervous and muscular tissues that resembled CLBP but was frequently more vigorous in LSS than CLPB may be explained by a variety of factors. Furthermore, stenotic patients reported leg and back pain, but CLBP patients often just experienced back pain. It was necessary to consider things like sensory loss that resulted in erroneous input, an information processing impairment, or a combination of the two to understand the variables that led to impaired lumbar movement perception. In order to achieve the proper lumbosacral spine alignment, muscle spindles appear to be essential, because lumbar discomfort reduces muscle spindle input [56, 57]. As lumbar paraspinal muscle denervation and lumbar degeneration develop, proprioceptive information is likely to be lost [58]. LBP sufferers have reportedly trouble with their ability to fine-tune their postural balance regulation [59]. Reduced lumbar proprioception was previously demonstrated to be a reversible feature in sciatica patients who were followed for three months [60]. As a result (Figure 5), looking at the paraspinal muscles during various activities can aid to assess CSA, muscular atrophy, and fatty infiltration.

Paraspinal muscles examination by imaging

The MRI data aid in determining the pattern of disc herniation and the degree of spinal stenosis, both of which contribute to the development of lumbar paraspinal muscular atrophy. 90 percent of individuals with spinal stenosis had paraspinal muscle atrophy [31, 37]. To ascertain the activation of the lumbar paraspinal muscles before and after training, the SPSS 2.0 statistical tool was used in the screening of movement activities, such as upper body flexion and extension in a simple roman chair. Values for the cross-sectional area (CSA), R2* (rate of darkening), and T2 (rate of tranverse relaxation) of were calculated [32]. It was discovered that the ODI (Oswestry Disability Index) significantly correlated negatively with the multifidus and erector muscles rmCSA [33]. Bilateral paraspinal muscles' fat infiltration ratio, CSA, and mean signal intensity were all assessed to compare the painful and non-painful sides [34]. Paraspinal muscles features may be quantified using the software packages Osirix and Image J [35]. Imaging can also aid with postoperative lumbar spine assessment [38]. The fatty degeneration extent in [61] aided in determining the mean densities of all paraspinal muscles for all age groups, which led to a better knowledge of fatty infiltration. Researchers in [62] used kinematic MRI analysis to examine the relationship between lumbar muscle deterioration and spinal degenerative diseases utilizing the

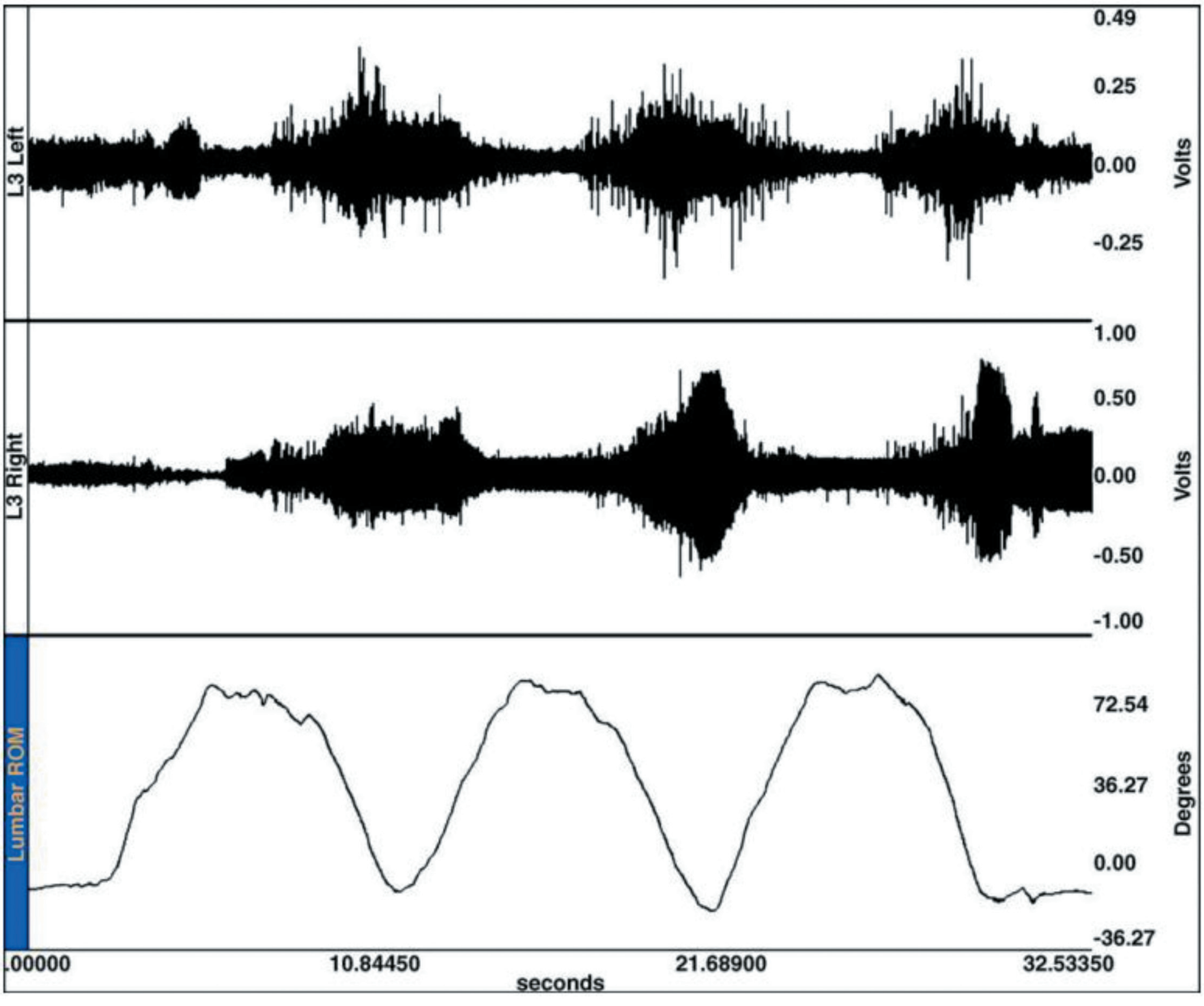

Figure 5. Flexion-extension phenomenon (C. J. COLLOCA & al., 2005 [27]).

Lumbar Indentation Value (LIV) as a quantitative variable and the Gout Allier classification as a qualitative variable. The authors of [63] conducted research on paraspinal muscle atrophy with or without internal screw fixation, using multivariate analysis to link age and fixation group. Fixation surgery was connected to higher muscle atrophy than non-fixation surgery [64]. Figure 6 shows the mean density of MF, ES, PS.

Conclusion

sEMG helps in acquiring a more precise knowledge of muscle activity variances. According to the data, CLBP atrophy was identified in the multifidus and paraspinal muscles, but not in the erector spinae. There was no evidence of atrophy in RLBP or ALBP. Fat infiltration was not observed in RLBP, however the results in CLBP were equivocal. In the paraspinal muscles, CLBP indicated no changes in fiber type. In individuals with any type of degenerative disc herniation, paraspinal muscular atrophy, which has a strong link to spinal stenosis, is prevalent. Because people with LBP seldom display signs of nerve or muscle damage, SEMG might provide essential information on evolution of the disease. Whether these metrics are practical and easy to gather in clinical settings, as well as which measurement combination is best for detecting LBP, requires more study. To better understand the causes of SEMG abnormalities in LBP and how to treat them, as well as to understand the significance of the association between the side of the disc herniation and unilateral or dominant paraspinal muscle atrophy on the same side, also requires further inquiry. This will enable these patients' therapeutic therapy to concentrate on workouts for unilateral muscle strengthening. Regional variations in the lumbar spine and the potential for subgroups with varied movement styles should both be considered when analyzing coordination in people with low back pain. Multifidus had the most flexion-relaxation changes; hence it should be considered while evaluating this construct.

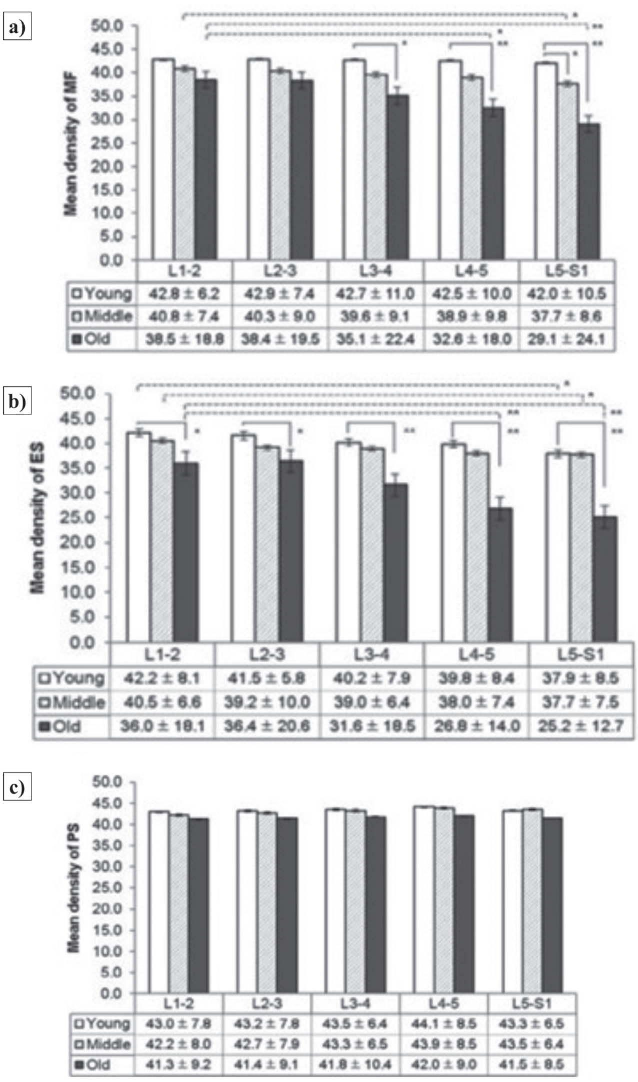

Figure 6. Mean density of (a) multifidus (MF) (b) erector spinae (ES) (c) psoas major (PS) (S.-H. LEE & al., 2015 [61])

Conflict of Interest

The authors have no conflict of interest to declare.

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Not Applicable

Abbreviations

ANOVA	Analysis of Variance
AR	Autoregressive Coefficients
ASD	Adult Spinal Deformity
BAA	Bland-Altmann Analysis
BOLD	Blood Oxygen Level Dependent
cLBP	Chronic Low Back Pain
CNS	Central Nervous System
CSA	Cross Section Area
CT	Computer Tomography
CWT	Continuous Wavelet Transform
DECT	Dual Energy Computer Tomography
DFTF	Finger to Floor
EMG	Electromyography
ES	Erector Spinae
FCSA	Functional Cross-Sectional Area
FIP	Fatty Infiltration Package
FMD	Frequency Median
f-MRI	Functional Magnetic Resonance Imaging
FRP	Flexion-Relaxation Phenomenon
FRR	Flexion-Relaxation Ratio
HD-sEMG	High Density surface Electromyography
ICC	Intra Class Correlation
IEMG	Integrated Electromyography
IMF	Initial Median Frequency
IS	Idiopathic Scoliosis
L3-L4	3rd and 4th level of lumbar region in spine
LBP	Low Back Pain
LSS	Lumbar Spinal Stenosis
MAV	Mean Absolute Value
ODI	Oswestry Disability Index
MAVS	Mean Absolute Value Slope
mERR	Mean Extension-Relaxation Ratio
MF	Multifidus
mFRR	Mean Flexion-Relaxation Ratio

MIS	Minimally Invasive Surgery
MNF	Median Frequency
MRI	Magnetic Resonance Imaging
MU	Motor Units
MVF	Maximum Voluntary Force
MVIC	Maximum Voluntary Isometric Contraction
NSCLBP	Non-Specific Chronic Low Back Pain
OLIF	Oblique Lateral Interbody Fusion
PMA	Peroneal Muscle Atrophy
PSD	Power Spectral Density
PUMC	Peking Union Medical College
RMDQ	Roland-Morris Disability Questionnaire
RMS	Root Mean Square
SEM	Standard Error of Measurement
SMI	Skeletal Muscle Mass Index
SPSS	Statistical Package of Social Science
SRD	Smallest Real Difference
SSI	Simple Square Integral
STFT	Short Time Fourier Transform
USWE	Ultrasonic Shear-Wave Elastography
VAR	Variance
VAS	Visual Analogue Scale
VL	Vastus Lateralis
WL	Waveform length

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