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Lapse of coactivation as reference for prevention of nonspecific low back pain. A Pilot study

Lapso de coactivación paravertebral como referencia para la prevención del dolor lumbar inespecífico. Estudio piloto

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Abstract

Nonspecific low back pain, affecting 70% of the population, is linked to sedentary behaviors and presents a disconnect between structural abnormalities and the pain experience. Currently, exercise is considered the first line of treatment, improving biomechanics and pain self-management. The primary objective of this pilot study was to measure, before and after an exercise program, the activation of the core muscles responsible for global and local trunk stabilization, using surface electromyography during trunk hyperflexion. A prospective, quasi-experimental study design was implemented, including an intervention group with two evaluation points (pre-intervention and 4 weeks post-intervention). A significant reduction in activation time was observed in all muscles studied after completing the program: right and left CL under load (p = .015 and p = .0003, respectively) and right and left MT without load (p = .028 and p = .036, respectively), with a strong correlation between this value and the reduction in low back pain (rho = .07). The reduction in coactivation time, as an indicator of improved and more efficient muscle response to disturbances, could be an alternative in the prevention of nonspecific low back pain.

Keywords: activation lapse; electromyography; low back pain; spinal stability.

Resumen

El dolor lumbar inespecífico, que afecta al 70% de la población, está vinculado a conductas sedentarias y presenta una desconexión entre anomalías estructurales y la experiencia dolorosa. Actualmente el ejercicio es considerado la primera línea de tratamiento, mejorando la biomecánica y la autogestión del dolor. El objetivo principal de este estudio piloto fue medir antes, y tras un programa de ejercicios, la activación de la musculatura central encargada de la estabilización global y local del tronco, empleando electromiografía de superficie en una hiperflexión de tronco. Se realizó un diseño de estudio prospectivo, cuasi-experimental, incluyendo un grupo de intervención con dos momentos de evaluación (pre-intervención y tras 4 semanas post-intervención). Se observó un descenso significativo del lapso de activación en todos los músculos estudiados tras la finalización del programa: CL derecho e izquierdo con carga (*p*= .015 y *p*= .0003 respectivamente) y MT derecho e izquierdo sin carga (*p*= .028 y *p*= .036 respectivamente), y una alta correlación de este valor con el descenso del dolor lumbar (rho= .07). El descenso del lapso de coactivación, como indicador de mayor y mejor respuesta muscular ante perturbaciones, podría ser una alternativa en la prevención del dolor lumbar inespecífico.

Palabras clave: dolor lumbar, electromiografía, estabilidad raquídea, lapso de activación.

1 .Introduction

Nonspecific low back pain is a multicomponent (Boussaid et al., 2023) with a direct relationship between sedentary behavior and increased low back pain in all age groups (Baradaran Mahdavi, Riahi, Vahdatpour & Kelishadi, 2021; Ogunlana, Govender & Oyewole, 2021). Additionally, 70% of the population may experience an episode of pain (Sirbu, Onofrei, Szasz & Susan, 2023) which in 90% of cases cannot be attributed to any specific anatomopathological cause. Currently, chronic low back pain is characterized by a discrepancy between structural abnormalities and the multidimensional pain experience described by subjects (Othman et al., 2020). Therefore, the clinical profile is highly variable when considering the pain mechanisms (Wu et al., 2020) and biomechanical characteristics of the subjects. Exercise treatment not only impacts the biomechanical component but also improves self-management and injury recovery (Hutting, Oswald, Staal, & Heerkens, 2020) because of the significance of the biopsychosocial component (Gibbs, Last, Marshall, & Jones, 2023). Despite this, recent publications emphasize the importance of multifidus muscle function, considering its loss of function as a crucial trigger in subjects with chronic low back pain (Tieppo Francio, Westerhaus, Carayannopoulos & Sayed, 2023).

To identify the existence of pain, it is necessary to open more lines of research regarding the critical load that distinguishes between acute and chronic pain (Zemková, Kováčiková & Zapletalová, 2020) and which are the joint actions that trigger the symptoms. One of them is the link between large flexion of the spine and acute low back pain, which needs to be further studied (Saraceni et al., 2020), as its evidence is not sufficiently clear and needs more supporting evidence despite establishing protocols with peak flexion torques between 175.1 and 89.7 Nm at 60º. They concluded that the evidence is very low, and further work is needed to establish predetermined reference values (Reyes-Ferrada, Chirosa-Rios, Rodriguez-Perea, Jerez-Mayorga & Chirosa-Rios, 2021).

Focusing on injury prevention, work on the well-known synergy between the transversus abdominis and multifidus, with diaphragm involvement, is crucial for central trunk stabilization (Sannasi et al., 2023). In positions with certain complexity, there tends to be greater muscle activation and poorer postural control (Salamat et al., 2024), however, there is a gap in whether there is a temporal or proportional delay between the muscles executing the action and their coactivation, which could increase the risk of injury. The background of this issue was first addressed by (Hodges & Richardson, 1996), who indicated a 50ms delay in transversus abdominis action during unilateral upper limb movements. Later, Allison and Morris (Allison & Morris, 2008) clarified that this delay was due to mechanical factors, such as rotation, which occurs in contrast to bilateral action, where this angular movement is not necessary. Greater synchrony in bilateral exercises may help to reprogram the deep musculature and condition it for daily functional tasks. Considering this context, the primary objective of this pilot study was to measure, before and after an exercise program, the activation of the core muscles responsible for global and local trunk stabilization using surface electromyography during trunk hyperflexion. Additionally, this study aimed to calculate the activation time lapses of each muscle group bilaterally to correlate them with the level of low back pain perceived before and after the conditioning program. These records could be useful in identifying the activation reference times necessary for the effective prevention of nonspecific low back pain and in differentiating individual needs in exercise prescription.

2. Material and Methods

2.1 Study design and experimental approach to the problem

A prospective, quasi-experimental study was conducted, including an intervention group with two assessment times (pre-intervention and 4 weeks post-intervention). The individuals who collected the data and analyzed the results were blinded to the sequence implemented in the interventions. This study adhered to the CONSORT guidelines (Bennett, 2005) and was designed based on the Declaration of Helsinki to ensure the fundamental rights of human research 35. This project was approved by the Ethics Committee of the Catholic University of Valencia (reference number: UCV UCV/2022-

2023/076). All participants who were included in the study signed the informed consent form.

2.2 Participants and data collection

The sample consisted of eight men and two women between the ages of 20 and 25 university graduate students. All participants were diagnosed with nonspecific chronic lower back pain by a clinical traumatologist and recruited through informative posters in Valencia from January 2022 to April 2023. The inclusion criteria were as follows: (i) sedentary subjects, (ii) sporadic non-specific low back pain, (iii) not performing physical activity during the last 48 h, and (iv) signed informed consent provided by the person in charge of the research. Table 1 presents the descriptive data of the sample. All participants were randomized in the first session and guided by an experienced professional performing the exercises.

Table 1. *Descriptive data of the sample (N=10)*

	Global	Man	Woman
N	10	7	3
Age	23.20 ± 1.40	23.14 ± 1.46	23.33 ± 1.53
Weight	82.55 ± 23.42	94.5 ± 16.46	54.67 ± 1.53
Height	1.75 ±0.10	1.80 ± 0.07	1.63 ± 0.06
Wingspan	178 ± 0.12	1.84 ± 0.08	1.64 ± 0.04

2.3 Procedure

2.3.1 Evaluation of electromyographic activity

Two measurement sessions were performed at an interval of four weeks during which a preventive exercise program was conducted autonomously. The participants were asked to perform the task with a weekly frequency of at least three days. In the first measurement session, informed consent for the research was obtained, and anthropometric weight measurements were obtained (Seca 750, Hamburg, Germany), height (Seca 213, Hamburg, Germany), and wingspan using a centimeter-measured template.

The assessment tests were as follows: 1) functional test of trunk flexion with and without load, 2) assessment of perceived low back pain in each variant of the functional test, and 3) maximum isometric contraction test of the thoracic and lumbar musculature. Surface electromyography (sEMG) was used to evaluate each test.

With the subject in a standing position, the area marked at the beginning of the session for electrode placement was wiped dry of any possible perspiration, using absorbent cotton. With alcohol impregnated into another portion of this material, the area was cleaned and shaved with a disposable razor to avoid possible interference with the electrode adhesive and impedance distortions of the electrical signal. The area was cleaned with alcohol and dried using cotton to ensure that the skin was clean and dry. The electrode placement was performed as follows.

- Lumbar square: At the height of the 3rd lumbar vertebra, 2 cm outwards and parallel.
- Thoracic multifidus: At the height of the 7th thoracic vertebra, in line with the scapular vertex, the first electrode was placed 2 cm outwards from the height of the seventh thoracic vertebra. The second electrode was obliquely outwards below the electrode.

In all cases, two electrodes were placed with a maximum separation of 2 cm on the muscle belly and a third (grounding) electrode was placed perpendicular to the previous electrode. Placement was bilateral, and the order by canal number was as follows: canal 1, right lumbar quadrate; canal 2, left lumbar quadrate; canal 3, right thoracic multifidus; canal 4, left thoracic multifidus. The electrodes used were a Lessa Pediatric Electrode model, 30 mm in diameter. They were placed according to SENIAM (SENIAM, 2017) and Criswell (Crisswell, 2010).

For electromyographic recording, we used a Megawin ME6000-T8 device (Bittium Corporation, Oulu, Finland) with eight channels weighing 344 g. The sampling frequency was 1Khz, and each stored record had a duration of 5 s. The data were converted from analog to digital (12-bit; DAQCard–700; National Instrument, Austin, USA) using the Biomonitor Megawin ME6000-T8 software, saved on a hard disk for protection, and analyzed in files using the file extension.ASC. A specific program was used to analyze the signals using MATLAB (R2023a) (MathWorks Inc., Natick, USA).

First, a fourth-order Butterworth bandpass filter between 20 Hz and 400 Hz was applied to filter the signal, discarding non-specific frequencies. Signal rectification or Root Mean Square (RMS) analysis was performed by dividing the measurement section into 100 points. Finally, segmentation was performed by collecting the central 3s of the signal and complete spectrum.

The measurement test consisted of four exercises, two dynamic (Figure 1) and two isometrics. The usual order of exercise is to first perform the maximum isometric part, followed by the dynamic part. In the present study, we performed this procedure in reverse to avoid conditioning functional exercises after previous maximal activation.

In the first exercise, the subjects stood in a bipedal position with their feet separated by a biacromial distance. Trunk flexion was performed without knee flexion, until the participant touched the floor. In cases of inability to do so due to stiffness of the lumbar-crural musculature, slight flexion of the knees was allowed. The second was a replica of the first, although in this case a 3.5 kg weight had to be picked up from the floor 50 cm in front of the feet. Both exercises were repeated three times, and the repetition of each exercise was stored for the shortest period between the analyzed muscles. After each exercise, the subject was asked to indicate his or her assessment of pain using the Analogical Assessment Scale (AAS).

Figure 1

Representation of the evaluation exercises

Note: Trunk hyperflexion without load (left) and load (right).

The smoothed mean signal amplitude data were collected with the smoothdata function, the peaks of each of the muscles, and the respective activation times to differentiate the time lapse between the first and last.

The following two exercises consisted of the execution of the Biering-Sorensen isometric test. Bilateral maximum voluntary isometric contraction (MVIC) was used to differentiate thoracic and lumbar quadriceps musculature. Each test was performed twice to avoid measurement errors due to the logical inexperience of beginners, and the maximum result was collected to normalize the dynamic exercise data, with a two-minute pause between each exercise to avoid fatigue, in line with similar studies (Koumantakis & Oldham, 2021).

In the case of thoracic multifidus, the participant was placed in the prone position on a stretcher occupying the surface of the body until the rib cage was free against gravity, crossing the arms until the hand touched the opposite shoulder. The legs were held with two straps (one under the buttocks and the other at leg height) to increase the strength. Under the resistance of a locked bar, extension of the spine was requested by the contraction of the dorsal musculature.

With the lumbar square, body position varied until the trunk was free of hip support. Under the resistance of the bar, as in the previous case, extension of the spine was performed by contracting the lumbar musculature. In both exercises, a possible force was exerted for five seconds.

2.3.2 Exercise protocol

The program between the two assessments consisted of a battery of five exercises for stabilization and strengthening of the lumbar spine, performed three days a week for four weeks. The exercises were based on the protocol by Falla et al. (2017), specifically in phase 2A, which consisted of posture and alignment exercises, the description of which is shown (Fig. 2).

1) Cat-camel: From quadruped, perform gradual extension of the spine, hold the position for 2-3 sec and flex, and hold the position for 2-3 sec.

2) Bird-dog: From the quadruped, flex one shoulder aligned with the rachis, rotate it on the longitudinal axis, and extend the knee of the opposite leg.

3) Abdominal bridge. The hips were lifted off the floor with the spine aligned from the prone position with forearm support and feet together, and the position was maintained.

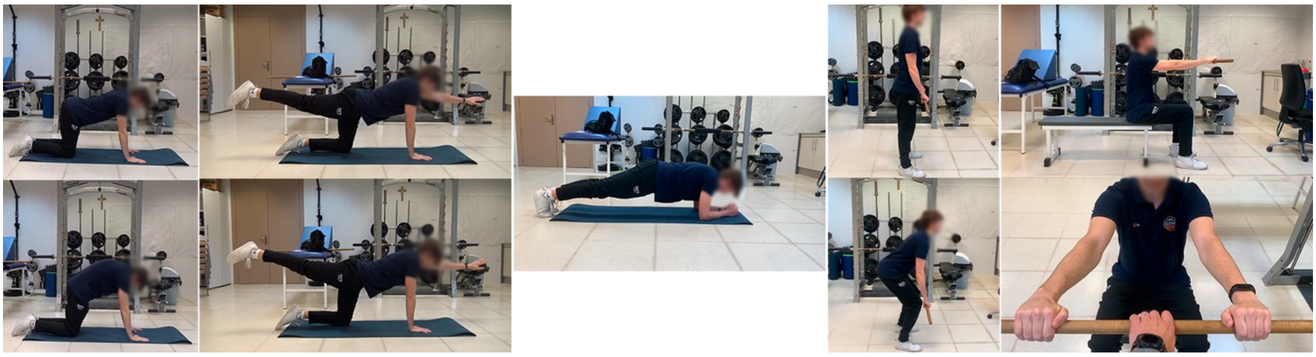
4*) Dead-lift:* From a bipedal stance, perform knee flexion-extension at 120º carrying the load close to the body.

5) *Progressive isometric lumbar:* From a seated position with a grip on a fixed support, extend the spine in the direction opposite to the support (the photograph is a reference).

In all cases, 3 × 10 repetitions were performed, except for the plank with 3 × 20 seconds of holding the position.

Figure 2

Representation of the program exercises



Note: From left to right: 1) Cat-camel 2) Bird-dog 3) Prone plank 4) Dead-lift 5) Isometrics.

2.4 Randomization and Blinding

All participants were randomized by two exercise professionals with more than 10 years of experience. One was responsible for administering the exercise program, while the other conducted evaluations and data collection, ensuring that they were completely blinded to the intervention received by the participants. Statistical analysis was performed by an independent researcher using a list of random numbers generated through an Excel formula, which allowed blinding of both the data collectors and the analysts. A block sequence of two participants was used for sample randomization. Due to the impossibility of blinding both the participants and professional administering the exercise protocol, a single-blind design was implemented, blinding the responsible for data collection.

2.5 Statistical analysis

2.5.1 Calculation of symmetry and synergy variables

To calculate the symmetry and synergy indices of the exercises, formulas have been used whose indices vary from 0 to infinity, with zero being perfect symmetry or synergy, and the higher the value, the further away from symmetry or synergy.

$$simetrySL = \log\left(\frac{LSright}{LSleft}\right); simetryTM = \log\left(\frac{TMright}{TMleft}\right)$$

$$sinergy = \log\left(\frac{LSright + LSleft}{TMright + TMleft}\right)$$

Where LS is the lumbar square and TM is the thoracic multifidus.

2.5.2 *Descriptive analysis*

Data are presented as means and standard deviations, medians and interquartile ranges for continuous quantitative variables, and proportions for qualitative variables.

2.5.3 Multiple comparisons

To determine the changes in the analyzed variables related to span, muscle activation, muscle symmetries in the same areas, muscle synergies, and perceived pain during exercise before and after the sessions, multiple comparisons were performed using Wilcoxon tests.

2.5.4 Correlation analysis

The difference in the lapses and AAS scale in the pre-measurement with respect to the post-measurement, both in the exercises without load and with load, was defined as follows:

$$LapseU = total\ LapseUpost - total\ LapseUpre$$

$$LapseL = total\ LapseLpost - total.LapseLpre$$

$$AAS\ U = ASS\ Upost - AAS\ Upre$$

$$AAS\ L = AAS\ Lpost - AAS\ Lpre$$

where U. is without load (unloaded), L. is with load (loaded), and pre. = Before the program, post. =after program.

In all analyses, the following were used α=0.05.

All analyses were performed using the R (R Core Team, 2022) v.4.2.2. Data tables were read using Openxlsx (Schauberger, Walker & Braglia, 2020) v. 4.2.5 (for xlsx files) and/or with haven (Wickham & Miller, 2019) v.2.5.0 (for xlsx files). The graphs were created using ggplot2 (Wickham, 2016) v.3.3.6 ggpubr (Kassambara, 2020) v.0.4.0, and other functions were integrated into the packages.

3. Results

Table 2 shows multiple comparisons. No significant variations were found in muscle activation, symmetry, synergy, and pain perception after the application of the program.

Table 2

Means, standard deviation and p-value in muscle activation, symmetry, synergy before and after the program

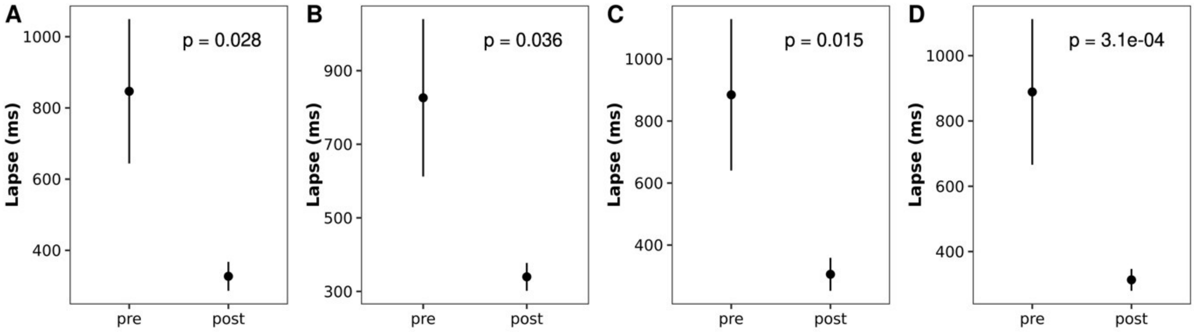
	Pre	**Post**	***p*-value**
Lumbar square right U	72.36 ± 115.53	69.81 ± 104.43	1.000
Lumbar square right L	121.25 ± 173.59	70.23 ± 69.17	0.878
Lumbar square left U	96.30 ± 158.98	41.28 ± 37.73	0.382
Lumbar square left L	195.20 ± 339.87	47.30 ± 31.48	0.065
AAS Scale U	0.88 ± 0.83	0.88 ± 1.36	0.651
AAS Scale L	1.20 ± 1.03	0.62 ± 0.74	0.241
Thoracic Multifidus right U	25.06 ± 20.35	23.49 ± 8.1	0.645
Thoracic Multifidus right L	77.46 ± 64.91	63.75 ± 50.81	0.959
Thoracic Multifidus left U	37.83 ± 40.28	24.16 ± 17.48	0.878
Thoracic Multifidus left L	54.06 ± 37.68	65.28 ± 54.47	1.000
Simetry LS U	0.14 ± 0.14	0.14 ± 0.16	1.000

Simetry LS L	0.24 ± 0.18	0.16 ± 0.16	0.382
Simetry TM U	0.23 ± 0.14	0.19 ± 0.15	0.382
Simetry TM L	0.23 ± 0.18	0.17 ± 0.12	0.645
Sinergy U	0.39 ± 0.42	0.31 ± 0.24	0.645
Sinergy L	0.33 ± 0.43	0.25 ± 0.19	1.000

Note: LS.= Lumbar square. TM.= Thoracic multifidus. U.=Unloaded. L.=Loaded.

Figure 3 shows the significant changes in the four muscle groups studied (TM*right* unloaded *p*= .028, TM*left* unloaded *p*= .036, LS*right* loaded *p*= .015, LS*left* loaded *p*= .000), which decreased the coactivation period after the exercise program.

Figure 3
Time lapse of TMright, TMleft, LSright y LSleft before and after program implementation



Note: (A) right unloaded thoracic multifidus; (B) left unloaded thoracic multifidus; (C) right loaded lumbar square; (D) left loaded lumbar square. Mean and standard errors are shown.

Table 3 shows that there were no significant correlations between the maximum voluntary isometric contraction and the time span of coactivation with no load (U) or with load (L).

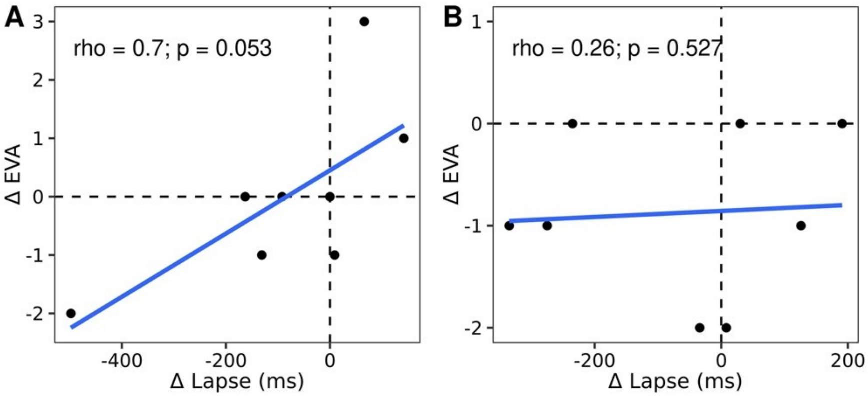
Table 3
Correlations between MVIC and coactivation lapse with and without load

Variable	Difference lapse U	*p*-value U	Difference lapse L	*p*-value L
MVIC Lumbar square right	-0.332 [-0.84 - 0.486]	0.422	-0.179 [-0.785 - 0.601]	0.671
MVIC Lumbar square left	-0.318 [-0.835 - 0.499]	0.443	-0.208 [-0.796 - 0.582]	0.620
MVIC Thoracic Multifidus right	-0.106 [-0.754 - 0.647]	0.802	-0.153 [-0.774 - 0.618]	0.718
MVIC Thoracic Multifidus left	-0.354 [-0.847 - 0.467]	0.390	-0.114 [-0.758 - 0.642]	0.787

Note: U.= unloaded. L.= loaded. MVIC.= Maximum voluntary isometric contraction. right.=right. left.=left. Lapse difference.= Difference between the mean and 95% confidence intervals.

Figure 4 shows the positive correlation between the lumbar span and AAS score.(rho = 0.7 *p*-valor = .05) The results showed that those participants with greater improvement also obtained greater improvement in pain.

Figure 4
Time lapse of MTright, MTleft, CLright and CLleft before and after program implementation



Note: Correlation between pain difference and lapse difference (A) with and (B) without load. The blue line indicates the regression line, and the dashed lines represent no change in the AAS and lapse. Spearman's correlation coefficient and *p*-value are indicated.

4. Discussion

Functional assessments, particularly those including surface electromyography, provide an objective measure to establish both baseline levels and predict improvements in variables such as strength (Martín-Ruiz et al., 2024) in nonspecific low back pain. The goal was to analyze spinal neutrality, as indicated by (Brown, Vera-Garcia &

McGill, 2006), which can be identified by the level of symmetry between muscle groups. In this study, no significant changes were observed in symmetry, either with or without load, in bilateral exercises (range, *p* = .382 to *p* = 1.000), consistent with the findings of (Hodges & Richardson, 1996) and (Allison & Morris, 2008). Regarding symmetry, no significant changes were found in muscle activation (range, *p* = .279 to *p* = .574) or muscle synergies (range, p = .645 to *p* = 1.000). However, a significant change was noted in the muscle coactivation time. Following the program, the time of force application decreased in each muscle group and in different contexts: right and left quadratus lumborum with load (*p* = .015 and *p* = .0003, respectively), and right and left thoracic multifidus without load (*p* = .028 and p = .036, respectively). This change is highly relevant, aligning with Ippersiel et al. (2021), who measured differentiated muscle activation in the dorsal muscles, highlighting the multifidus as an important local stabilizer in symmetry/asymmetry studies.

An isolated decrease in pain was observed without any notable changes (*p* = .0241). However, there were significant correlations with the coactivation time, indicating that shorter coactivation times were associated with reduced pain (rho = .07, *p*-value = .05). Recent studies have shown that age, pain, cognitive resource capacity, attentional demands, and the external environment affect coordination patterns. As discussed above, a non-significant change in the trend of muscle symmetry and activation was observed, and the determining factor influencing this variable was the difficulty or complexity of the cognitive tasks (Pourahmadi et al., 2023). Cognitive demand can negatively impact postural control by competing with attentional resources required for sensorimotor processing (Pourahmadi et al., 2023). The synergistic strategy in the trunk of individuals with nonspecific low back pain is well known (Saito, Yokoyama, Sasaki & Nakazawa, 2023), causing global stabilizers to show less variation than local stabilizers. This indicates that when the task is more demanding, motor complexity increases, as Viggiani et al. (2020) noted, with individuals experiencing lower coactivation in the trunk extensors. Therefore, the focus of prescription should be on these muscles, as observed in this study.

In terms of pain, the literature suggests that physical activity can enhance pain adaptations potentially driven by the central nervous system and immune system factors (Song et al., 2022). Subjective pain perception helps determine symptom levels, primarily through the pain visual analog scale, which is widely used in physical activity practice for low back pain (Roren et al., 2023), is capable of testing isometric or dynamic contractions without difference (Alarab, Shameh & Ahmad, 2023), and is commonly found in intervention programs for chronic nonspecific low back pain (Mirshahi, Najafi, Golbakhsh, Mirshahi & Pishkuhi, 2023). Several authors state that muscle activation can compromise motor control and trunk stability, leading to injuries such as low back pain (Sepiddar, Barati & Yarahmadi, 2024). However, this study did not find notable changes in pain reduction, although significant correlations with the coactivation time were observed. Reducing coactivation time may improve pain perception, particularly central sensitization (McKune, Murrell, Nolan, White & Wright, 2015). Although the ideal muscle response threshold could not be identified, the significant decrease in coactivation time reflects a better response to disturbances, as discussed by Cholewiki et al. (2000), and an increased ability to recruit within a unit of time (Mesfar et al., 2022), which is increasingly valued for muscle fitness improvement (Pethick, Taylor & Harridge, 2022).

The use of surface electromyography is crucial, as it allows the observation of muscle compensations occurring with low back pain (Puranik & Shenoy, 2023) or potential risks during load mobilization (Varrecchia et al., 2023), as well as during differentiated assessment of each muscle group (Ylinen et al., 2024). In trunk flexion, performing posterior chain flexibility exercises improves hamstring extensibility and correct thoracic alignment, which promotes greater pelvic curvature during maximal trunk flexion (Muyor, López-Miñarro & Casimiro, 2012). Exercise programs typically focus on both global and local stabilizers, with the latter particularly noted for their significant impact on transversus abdominis hypertrophy (Niewiadomy et al., 2021). Adding pelvic floor strengthening exercises could also contribute to reducing low back pain and should be an important part of physical conditioning programs (Kazeminia, Rajati & Rajati, 2023).This aspect has been observed in educational settings (Ito et al., 2023), essential for preventive habit acquisition, showing positive effects on ROM after consistent static stretching (Santonja, Sainz De Baranda, Rodríguez, López & Canteras, 2007), and confirms that physical activity is the most effective method for acquiring muscular and joint safety and reducing pain perception (González, Ubago-Jiménez, Castro-Sánchez, García-Martínez & Sánchez-Zafra, 2019).

Limitations and Future Research Directions

Understanding the diversity within populations affected by chronic lower back pain (CLBP) is crucial for tailoring interventions and improving subjects outcomes. Clinicians and researchers should consider the findings of this study in order to offer personalized care and optimize prescriptive effectiveness, considering demographic variability and clinical heterogeneity. The main limitation of this study was the small, homogeneous sample size. Additionally, considering sample heterogeneity, there is consistent evidence that differences in expectations and treatments can arise due to various factors such as individual preferences, cultural beliefs, previous medical experiences, pain severity, and underlying psychosocial factors, which were not included in this study. Regarding the preliminary results, surface electromyography may be very useful in future studies, specifically high-density electromyography employed to locate lumbar pain topography and variations across different types of movement (Jiang, Xue & Li, 2019).

5. Conclusions

Preliminary results showed a decrease in coactivation time, indicating a better and more effective muscle response to disturbances following extensive conditioning of the paravertebral muscles, which is linked to a reduction in pain perception despite the inability to pinpoint the ideal activation time threshold. The increased tendency towards muscle symmetry and synergy after a brief conditioning program determines the effectiveness of providing continuity of an accessible and easily reproducible exercise program to achieve preventive objectives.

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