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Acute Effect of Static Stretching Duration for Paravertebral Muscles on Lumbar Multifidus Myoelectric Activity: A Crossover Clinical Trial

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SUMMARY

Introduction. Considering that stretching can reduce neural impulses, this study aimed to verify whether stretching to paravertebral muscles changes the electromyographic activity characteristics of the lumbar multifidus.

Methods. The volunteers (n = 46) were randomly allocated to four experimental conditions performed in 4 visits: control and three paravertebral stretching interventions sustained for 10, 30, and 60 s. At each visit, the electromyographic activity of the multifidus was collected in the following sequence: a) pre-intervention in the neutral orthostatic position; b) during the intervention targeted by the visit; c) post intervention in the neutral orthostatic position. Outcomes were analyzed by MatLab codes using wavelet methodology. In addition to the inferential statistics generated by the generalized estimation equation model, it presented reproducibility and responsiveness metrics.

Results. Only the median frequency difference between the sustained stretches for 10 and 60 s was found. However, responsiveness measures indicated that such a difference was due to measurement variability rather than the actual change caused by the intervention.

Conclusions. Stretching duration did not influence the electrical activity of the lumbar multifidus.

Study registration. This study was registered at Brazilian Registry of Clinical Trials - REBEC (number: RBR-7bvg7p): http://www.ensaiosclinicos.gov.br/.

KEY WORDS

Electromyography; paraspinal muscles; skeletal muscle.

INTRODUCTION

Static stretching is often used to reverse adaptive muscle shortening (1, 2), and even to prevent lower back pain (3). However, it is suggested that prolonged maintenance of stretching promotes changes in muscle function, such as a decrease in the ability to produce strength and power in the period after immediate stretching (1, 4).

Although the strength or power production and muscle activity relationship may be controversial, studies suggest that one effect of stretching is a reduction in the neural impulse to the muscle, which can produce changes in muscle stiffness (5, 6). It is believed that, once the neural impulse can be reduced by stretching (1), the recruitment of motor units (MU) will be reduced, with a consequent reduction in myoelectric activity. This reduction is because the neural activation directed to the muscle comes from a motoneuron pool, and this neural signal is the sum of the activities of the action potentials of the motoneurons, generated by the transformation of synaptic inputs from the motoneurons into output pulse trains (7). Corroborating, passive stretching induced the suppression of the excitability of the monosynaptic spinal reflex and that afferent information produced by the stretching, probably coming from the muscle spindles and the Golgi tendon organ, inhibited the spinal reflex motor response (8). It is assumed, then, that the input produced by stretching modifies the neural drive.

Surface electromyography (EMG) is a tool to estimate the level of muscle activation (9, 10), as it carries amplitude and frequency contents related to depolarization. Signal's amplitude information works as an indirect measure of muscle activation level, while the signal's frequency spectrum is related to the depolarization frequencies of the MU (11). The EMG analysis allows us to quantify the level and duration of muscle activity and fatigue rate (12, 13), including in response to interventions such as lengthening. However, observations on electromyographic activity in poststretching are not conclusive (1).

The Williams series exercises are used when restoring lumbar spinal mobility is desired (14-16). However, little is known if stretching aimed at paravertebral muscles by these exercises can generate neurophysiological responses in them. Only one study found that performing flexion exercises in this series, with maintenance of the posterior tilt, minimizes electromyographic activity at time domain, in the lumbosacral region (17). Even less is known if changes in the frequency domain occur in the paravertebral muscles because of stretching induced by the Williams series exercises, and if there is a dose-response effect for the exercise sustaining time.

It is relevant to investigate whether stretching durations routinely used in the clinical context for lumbar paravertebral muscles, modify the myoelectric activity characteristics of the multifidus since this muscle plays a relevant role in stabilizing the lumbopelvic region (18, 19), including changes in lumbago sufferers (20). Therefore, the objective of this study was to verify whether stretching to paravertebral muscles changes the electromyographic activity characteristics of the lumbar multifidus.

METHODS

Trial design

This cross-over clinical trial was approved by the Research Ethics Committee Involving Human Beings at the State University of Western Paraná (protocol number: 2748177 – date of approval: February 07, 2018). All volunteers gave their free and informed consent.

Participants

Young adults of both sexes were recruited through personal invitations and also publicity actions at the university center. Volunteers with no history of spinal or lower limb disorders (acute or chronic) in the past 12 months were included in the study, and who did not practice regular and systematic physical activity. Volunteers with abdominal, hip, and spine surgery history or neurological diseases, pregnant women, and make use of muscle relaxants were excluded.

For the sample calculation, the percentage magnitude relative to the maximum electromyographic activity of the paravertebral muscles was used during the push-ups of the Williams series (17), which generated an effect size in the order of 0.26. Using the G.Power 3.16 software, the sample size was obtained from the following input data: effect size: 0.25; alpha: 0.05; power: 0.85; number of groups: 4; number of measures: 3. The minimum sample size required was 44 volunteers.

Collection instruments

Myoelectric activity of the lumbar multifidus muscle, bilaterally, was quantified by a signal conditioning module (model BIO EMG 1000- 8-4l, brand LYNX® Tecnologia Eletrônica Ltda, São Paulo-SP, Brazil) with a sampling frequency of 2,000 Hz. For the signal acquisition, disposable, self-adhesive, bipolar electrodes with Ag/AgCl uptake sites and 10 mm diameter were used. The volunteer's skin was properly shaved and cleaned to fix the electrodes.

The electrodes were positioned on the lumbar multifidus muscles following the recommendation of the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM). The reference electrode was positioned in the lateral malleolus of the left lower limb, as shown in **figure 1**.

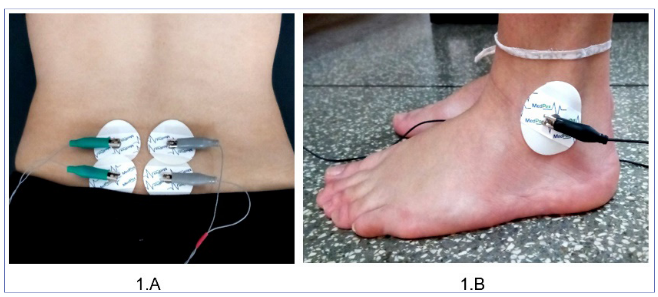


Figure 1. Position of the electrodes according to the recommendations of SENIAM.

(A) Positioning of the electrodes on the lumbar multifidus; **(B)** Positioning of the reference electrode.

Methodological procedures

Each volunteer participated in a battery of evaluations, familiarization, and stretching protocols, totaling five visits with a minimum interval of seven days and a maximum of 10 days between them. The stretching protocols were based on the lift time of 60 s or less, which are recommended for clinical use (4, 21), they being 10 (Strech_10), 30 (Strech_30) and 60 (Strech_60) s, and a control condition in which the volunteer only remained lying on the supine stretcher, with the legs extended, for 30 s.

Visit 1

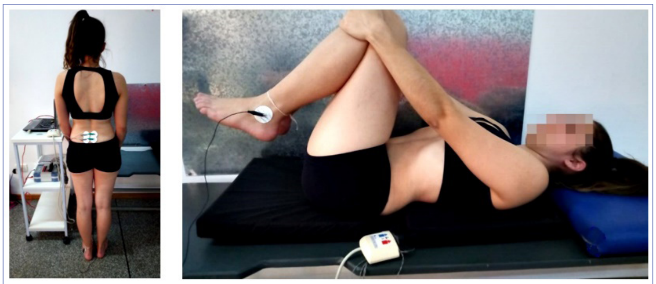
First, a brief clinical evaluation was carried out, containing personal data, history of injury, and use of medications. Then, the volunteer was familiarized with the intervention procedure. The stretch for the lumbar paravertebral musculature proposed was the exercise "Knees in the Chest", number three of the Williams Series (17), shown in **figure 2**. In this familiarization, the volunteer was asked to make repetitions of the stretching gesture, to the maximum extent possible, with the assistance of the evaluator if necessary, until the volunteer learned the correct execution of the stretching. After familiarization, the order of interventions was established by a lot carried out by the main researcher.

Visits 2 to 5

In each of these visits, the skin was initially prepared and the electrodes were subsequently placed to acquire the myoelectric signal. To ensure reproducibility in the placement of electrodes for recording myoelectric activity on different days, on visit 2, positioning maps were drawn on transparent slides that took into account signs on the skin such as blood vessels, stains, scars and anatomical references. In visits 3 to 5, the placement of the electrodes was based on these positioning maps.
All methodological procedures were the same in all visits, except for the length of time for which the stretch was sustained, following the order drawn for each volunteer. In the pre-intervention assessment, the electromyographic activity of the multifidus was measured in a neutral orthostatic position. Then, the target intervention of the visit was applied, during which the recording of electromyographic activity was also performed. After the intervention, myoelectric activity was reevaluated in the orthostatic position. The procedure can be seen in **figure 2**.

Data processing

The mathematical processing of the data occurred on MatLab (R2015b; Natick, MA, USA).



2.A 2.B

Figure 2. (A) Positions adopted in the pre and post-intervention assessments; **(B)** During the lumbar paravertebral musculature stretching intervention.

Time domain analysis

For the time domain treatment, a wavelet filter was initially applied to the raw signal and, subsequently, the Matlab "envelope" function that provided the RMS value. The RMS was normalized by the peak value of the signal (22).

Frequency domain analysis

For the time-frequency analysis, the central frequency was determined. A MatLab Wavelet code was used to decompose the signal into its frequency spectrum: Wavelet Packet Decomposition 1-D ("wpdec" function, level 6, and wavelet mother symlet14). By this processing, the frequencies that constitute the signal were stored in their corresponding scales, the latter being converted to frequency values by mathematical treatment. The amount of scales generated is dependent on the characteristics of the selected mother wavelet. As it is a time-scale analysis, the temporal information corresponded to the length of the vector originating from the signal corresponding to the duration of the stretching maintenance.
This decomposition generated a matrix with 64 columns, corresponding to the scales, and the number of lines corresponding to the length of the vector that contained the raw signal. In sequence, the MatLab function "wpspectrum" was applied, which returned a matrix of Wavelet Packet Power Spectrum, based on Wavelet Packet Transform, and identified the frequency values, expressed in Hz, contained in each scale, at each instant of collection, which corresponds to the period.
Then, for each column of the matrix, which corresponded to the scales and whose lines represented the frequencies that made up the signal stored in the scale over time, we calculated the median of these frequencies which resulted in a 1×64 line vector. Finally, we place the medians of frequencies in this vector line in an ascending order (from scale 1 to 64 scale) and divide it into three points: the median of frequencies in scale 1, which are the lowest frequencies in the spectrum, the median of frequencies on the 57

Table I. Median of frequencies observed on scales 1, 57, and 64 of the line vector resulting from the process of decomposition of the signal from the lumbar multifidus muscles.

	Scale 1	Scale 57	Scale 64
Median ± standard deviation (Hz)	2.3 ± 5.7	56.9 ± 86.5	263.3 ± 291.9

The values represent all evaluations carried out, in all interventions and moments of all volunteers.

scale, which represents 90% of the signal spectrum, and the median of frequencies on the 64 scale, which correspond to the highest frequencies in the spectrum. The values corresponding to each of these points can be seen in **table I**.
Considering that 90% of the signal frequency spectrum was between scales 1 to 57, for the statistical analysis of the present study, we assumed two frequency ranges: the low frequency range, obtained by the median of frequencies between scales 1 and 57, and the range of high frequencies, obtained by the median of frequencies between 58 and 64 scales.

Statistical methods

For statistical analysis, the software SPSS 20 was used. The significance level adopted was 5% ($\alpha = 0.05$).
As a first step in the data analysis, the mean values and the 95% confidence interval (IC-95) of all dependent variables were determined for each intervention at each time of collection (control / pre; control / during; control / post; Strech_10 / pre; Strech_10 / during; Strech_10 / post; Strech_30 / pre; Strech_30 / during; Strech_30 / post; Strech_60 / pre; Strech_60 / during; Strech_60 / post). It was assumed for the present study that data that are below the lower limit of the 95%CI subtracted from the value corresponding to 80% of that value (lower limit - 80% of the lower limit) or above the upper limit of the 95%CI added to the value corresponding to 80% of that value (upper limit + 80% of the upper limit) were considered as measurement error and excluded from the analysis. However, the missing data were imputed by the statistical model employed (23, 24).
For comparison, the statistical test used was the generalized estimation equation (GEE) model with data analysis based on the intention to treat using the maximum likelihood principle to extrapolate the missing data. The best fit of the data was tested by two distribution models: Linear and Gamma (23). The model that obtained the lowest quase-likelihood value under independence model criterion (QIC) was chosen as the model with the best fit. The Sidak test was used as a *post-hoc* test.
The factors used in time domain analyzes were intervention (control; Strech_10; Strech_30; Strech_60) and the time of collection (pre, during, and post). The dependent variable in the model was the RMS. The Gamma model presented the lowest QIC value and was used in the analysis: Linear (QIC = 417,145.148) and Gamma (QIC = 201.793).
The factors used in the analysis of the frequency domain were the same used in the time domain. The dependent variables in the model were the low and high frequency ranges. The Gamma model presented the lowest QIC value, both for low and high frequencies, and was used in the analyzes: range of low frequencies / Linear (QIC = 3,908.173) and Gamma (QIC = 173.158); high frequency range / Linear (QIC = 1,582,814.637) and Gamma (QIC = 261.2).
To present metrics complementary to inferential statistics, to better understand changes in outcomes or absence of changes, measures of reproducibility, responsiveness, and effect size were calculated.
To determine reproducibility and responsiveness, we used data from the control group at the pre and post collection times. The effect size was calculated by Hedges' g with the following interpretation (25): insignificant < 0.19; small 0.20-0.49; medium 0.50-0.79; large 0.80-1.29; very large > 1.30.
The relative reproducibility was tested by the intraclass correlation coefficient (ICC) and the absolute reproducibility by the standard error of measurement (SEM). We apply ICC2, k (bidirectional random model) (26), with the strength of reliability being described as: 0-0.50 poor; moderate 0.50-0.75; 0.75-0.90 good; greater than 0.90 excellent (27). The SEM was determined by the square root of the error variance. Responsiveness was assessed by the minimum detectable change (MDC) determined by the equation: $MDC = SEM \times 1.96 \times \sqrt{2}$ (26, 28).
Aiming comparisons between inferential and complementaries metrics, we calculated the difference average between comparison pairs (Diff) for all outcomes, being:
$$Diff = (|(\bar{x}_{GC} - \bar{x}_{G10})| + |(\bar{x}_{GC} - \bar{x}_{G30})| + |(\bar{x}_{GC} - \bar{x}_{G60})| + |(\bar{x}_{G10} - \bar{x}_{G30})| + |(\bar{x}_{G10} - \bar{x}_{G60})| + |(\bar{x}_{G30} - \bar{x}_{G60})|) / 6$$
where: $\bar{x}_{GC}$ = mean of the control group; $\bar{x}_{G10}$ = average of the Strech_10 group; $\bar{x}_{G30}$ = average of the Strech_30 group; $\bar{x}_{G60}$ = average of the Strech_60 group; | | = indicate that the value is absolute.

RESULTS

Forty-six volunteers participated in the study who were recruited from August 2018 to July 2019. The characterization of the sample and the flow of volunteers can be seen in **figure 3**.

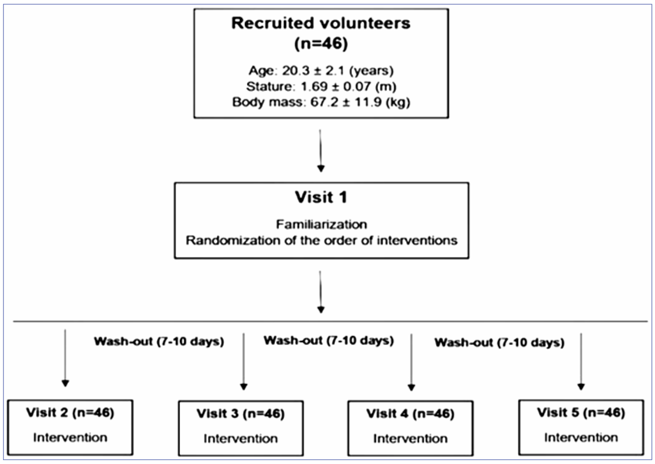


Figure 3. Flowchart of study participants in all interventions (control, elongation sustained for 10, 30, and 60 s) and sample characterization data (mean and standard deviation).

For time domain analyzes, no effects were observed for the interventions (Wald χ^2 (3) = 0.110; p = 0.991), for the moments of collection (Wald χ^2 (2) = 2.983; p = 0.225) and neither for the interaction interventions/moments (Wald χ^2 (6) = 10.276; p = 0.114) in the RMS.

For the analyzes of the frequency domain, no effects were observed for the moments (Wald χ^2 (2) = 0.366; p = 0.833) or for the interaction interventions/moments (Wald χ^2 (6) = 5.013; p = 0.542) in the range low frequencies, but there was a significant effect for the interventions (Wald χ^2 (3) = 15.383; p = 0.002) and the Strech_10 group had a higher average than the Strech_60 group.

Still in the analyzes of the frequency domain, there were no effects for the interventions (Wald χ^2 (3) = 5.701; p = 0.127), for the moments of collection (Wald χ^2 (2) = 2.867 p = 0.238) and neither for the interaction interventions / moments (Wald χ^2 (6) = 9.254; p = 0.160) in the high frequency range.

The average values of RMS, low frequencies, high frequencies and their respective 95% confidence intervals, both for interventions and for moments, can be seen in **figure 4**.

The ICC showed moderate reproducibility for the RMS measurements (ICC = 0.59 [0.25 to 0.77]; p = 0.002), good reproducibility for the low frequency range (ICC = 0.78 [0.61 to 0.88]; p < 0.001), and poor reproducibility for the high frequency range (ICC = 0.47 [0.05 to 0.70]; p = 0.016), all with an insignificant effect size (ES RMS = 0.004; ES low frequency = 0.04; ES high frequency = 0.17). For all outcomes, SEM and MDC showed important variability in measurements. However, it can be seen in **figure 5** that the average value of the differences between the averages of the interventions (Diff).

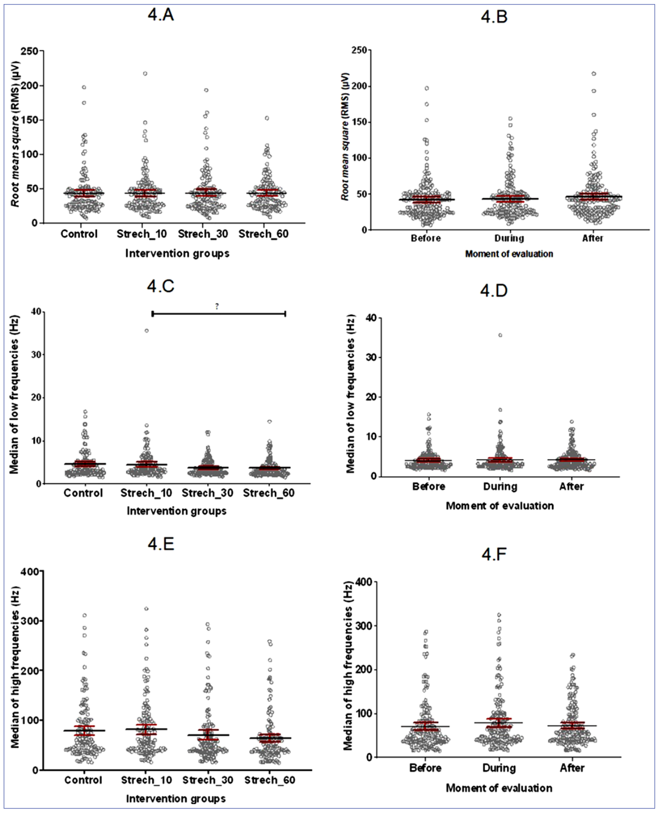


Figure 4. Unit distribution for each measure and for all volunteers around the mean and their respective 95% confidence intervals.

(A) Main effect of the intervention on the RMS; **(B)** Main effect of the moment of evaluation in the RMS; **(C)** Main effect of the intervention in the low frequency range; **(D)** Main effect of the moment of evaluation in the low frequency range; **(E)** Main effect of the intervention in the high frequency range; **(F)** Main effect of the moment of evaluation in the high frequency range.

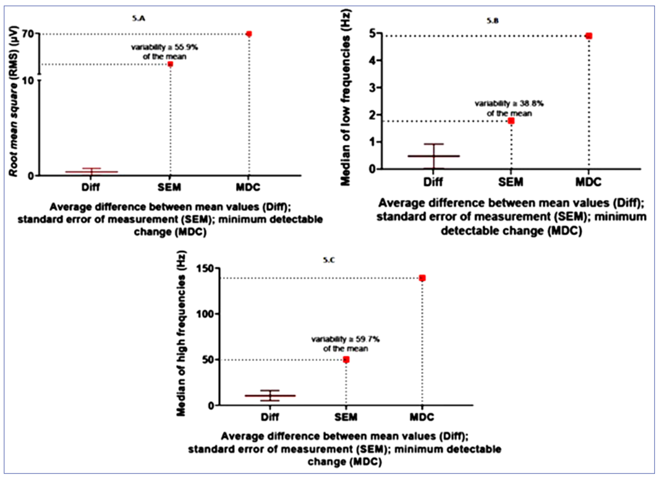


Figure 5. Average difference between mean values and complementary metrics of reproducibility (SEM) and responsiveness (MDC) for RMS **(A)**, median of low **(B)** and high frequencies **(C)** of the lumbar multifidus muscles.

DISCUSSION

In the present study, no statistical differences were found for most comparisons. For the median of low frequencies, comparing the interventions, a significant difference was found between Strech_10 and Strech_60. However, when considering the MDC value, it was noted that the difference between the groups was less than this measure. Thus, despite the statistical difference, it was not a real change, but a consequence of the variability in the measure.

Anatomically, the multifidus has superficial and deep fibers; a study that evaluated the fiber type distribution in the multifidus found that surface fibers have 57.4% type I fibers, while deep fibers at the level of L4-L5 have 62.6% and at the level of L5-S1 have 61.7% (29). Based on the rationale that whereas low frequencies in the EMG signal reflect the recruitment of slow and oxidative MUs, high frequencies indicate the recruitment of MU associated with fast fibers (30, 31), the spectral composition observed in the present study seems consistent with the literature. It was observed that the median of low frequencies, which corresponded to 90% of the spectral content, was around 4 Hz, suggesting that predominantly type I fibers were active.

However, about the relation between EMG spectral properties and the fiber-type composition of a muscle, we must be cautious. There is a wide range of confounding factors that permeate this relationship, which is based on the average conduction velocity of muscle fiber action potentials. Among these confounding factors, we can mention that both fiber types do not have distinct conduction velocities in humans, but the average conduction velocity of muscle fiber action potentials can differ among populations of motor units due to differences in fiber diameter and it is independent of changes in fiber-type proportions. We can also add that the number of muscle fibers innervated by a motor unit has a skewed distribution (32). Thus, the correspondence between the spectral content of our findings and the histological characteristics of the multifidus described in other studies regarding to the type of fiber can be considered only as a speculative coincidence.

Theories about the action of stretching on motor control suggest that stretching modifies muscle spindle activity (6, 33-37). Gamma intrafusal motor neurons act as facilitators for alpha extrafusal motor neurons; and this control is essential for maintaining muscle stiffness (38), which would be sharply reduced as an effect of stretching.

Since the results of the present study did not show a change in the activity of the multifidus by exercising the Williams series, it is speculated that the cause of the absence may be the amount of tension produced in the tissue by the stretching technique or consequence of the type of muscle studied. Some studies point to a relationship between intensity and the time for maintaining tension in the various outcomes produced by stretching. Investigations that inversely manipulated the stretching intensity and duration variables to gain knee amplitude, observed that the various compositions between intensity and duration tested generated different effects on the passive torque - angle curve (39).

In a study that compared the effect of stretching at a constant angle and that at constant torque in the range of motion, it was found that, although both improved stretching with constant torque was more effective in increasing the amplitude and the feeling of discomfort in the maximum amplitude, and to reduce the passive stiffness of the tendon muscle unit (40). Although these authors explain the results by changes in the mechanical components of the tissue, it is possible to speculate that stretches that impose greater torques are also more likely to affect the neural drive.

It is believed that the knee-to-chest technique did not produce enough tension to modify the EMG parameters, and this can be supported by the fact that the positioning of the trunk or pelvis during stretching affects muscle stiffness. Masaki and collaborators (41) evaluated the repercussion of the position of the trunk on the muscular stiffness of the lumbar multifidus in an elongated position by means of elastography by ultrasonic shear waves. They concluded that the multifidus are effectively stretched when the back is flexed between 40 and 45 degrees in a sitting position with the hips and knees fully flexed. The Blackburn and Portney study (17) also showed that pelvic tilt, whether anterior or posterior, affects differently electromyographic activity. However, in the present study, it was decided to perform the exercise as it is used in the clinical environment.

The muscle spindle is the only proprioceptor that receives motor innervation in addition to its sensorial innervation, and it can be subdivided into primary and secondary spindles. Although both are sensitive to changes in muscle length and velocity, the primary has greater dynamic sensitivity. Muscles with dynamic and postural functions have predominantly different types of muscle spindles (42) which may characterize different responses to stretching. The limitations of this study are that the sample consisted of young, healthy volunteers, so the results cannot be extrapolated. In addition, physical stress was subjectively individualized, and no method was used to control the force used.

CONCLUSIONS

As a conclusion, the stretching of the paravertebral muscles using the "Knees in the Chest" technique of the Williams series, sustained for 10, 30, and 60 s, does not produce acute changes in the activity of the multifidus, neither in the domain of time nor frequency. In other words, in the population in question, there are no problems with loss of muscular activity for exercises that require muscular endurance and power to be performed after stretching.

FUNDINGS

None.

DATA AVAILABILITY

The data are available under reasonable request to the correspondign author.

CONTRIBUTIONS

CAC, GRFB, ARC: conceptualization. CAC, PB, EP, MVF: data curation. CAC, PB, EP, MVF: formal analysis. ARC, FAM: funding acquisition. CAC, PB, EP, MVF: investigation. CAC, PB, EP, MVF, GRFB, FAM, ARC: methodology. ARC: project administration. FAM, ARC: resources. CAC: wriitng – original draft. PB, EP, MVF, GRFB, FAM, ARC: writing – review & editing.

CONFLICT OF INTERESTS

The author declare that they have no conflict of interests.

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