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# ELECTROMYOGRAPHIC AND POSTURAL ANALYSIS IN SCOLIOSIS DISEASE

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## RESUMO

O estudo avaliou o Método Pilates (MP) no alinhamento postural de 22 adolescentes escolióticos por meio de eletromiografia e simetrografia. Métodos: Os participantes foram submetidos à avaliação postural e eletromiográfica dos músculos trapézio, eretores da espinha, oblíquos e retos abdominais, processados no domínio do tempo (EMGAmp) e espectral (EMGFmed). Após a avaliação, foram realizadas 24 sessões de um protocolo de MP e novamente submetidas às avaliações iniciais. Resultados: Os resultados mostraram diferenças estatisticamente significativas no alinhamento postural (40,9%) (p<0,001). No exame eletromiográfico, verificou-se, em relação à EMGAmp, diferenças comparativas entre os lados direito e esquerdo. EMGAmp diminuiu em ambos os lados da coluna com maior diminuição para o lado direito na escoliose postural direita (EPD) (p = 0,004), na escoliose torácica direita (ETD) (p <0,001), na escoliose torácica esquerda (ETE) (p <0,001) ), na escoliose toracolombar direita (ETLD) (p = 0,030) e na escoliose toracolombar dextroconvexa à esquerda (ETLEDC). Em relação ao EMGFmed, verificou-se aumento em ambos os lados da coluna em todas as classificações de escoliose investigadas, com destaque para o lado direito em EPD (p<0,001), ETD (p<0,001) e ETE (p = 0,005). Nos lados direito e esquerdo do ETLD (p = 0,002), no ETLE, lado esquerdo (p = 0,066) e lado direito do ETLEDC. Conclusão: Os achados apontam para a importância da MP como meio de tratamento conservador da escoliose, gerando aumento das ativações neuromusculares e posturais. Existem diferenças significativas nas classificações da escoliose que apresentam apenas uma curvatura.
**PALAVRAS-CHAVE:** Pilates. Escoliose. Eletromiografia. Simetrografia.

## ABSTRACT

Introduction:The study evaluated Pilates Method (PM) in postural alignment of 22 scoliotic teenagers by electromyography and simetrography. Methods:The participants underwent postural assessment and electromyographic evaluation of trapezius, spinae erectors, oblique and rectus abdominis' muscles, processed in time domain (EMGAmp) and spectral (EMGFmed). After the evaluation, 24 sessions of an MP protocol were performed and they were again subjected to initial assessments. Results: Results showed statistically significant differences in postural alignment (40.9%) (p <0.001). In electromyographic examination, it was found, related to EMGAmp, comparative differences between right and left sides. EMGAmp decreased on both spine's sides with greater decrease toward the right side in right postural scoliosis (EPD) (p = 0.004), in right thoracic scoliosis (ETD) (p <0.001), in left thoracic scoliosis (ETE) (p <0.001), in right thoracolumbar scoliosis (ETLD) (p = 0.030) and dextroconvex thoracolumbar scoliosis to the left (ETLEDC). Regarding EMGFmed, it was verified an increase in both sides of the spine in all investigated scoliosis ratings, with emphasis on the right side in EPD (p <0.001), ETD (p <0.001) and ETE (p = 0.005). In the right and left ETLD sides (p = 0.002), in ETLE, left side (p = 0.066) and ETLEDC right side. Conclusion: Findings point to MP importance as a means of conservative scoliosis' treatment, creating increased neuromuscular and postural activations. There are significant differences in scoliosis' ratings that present only one curvature.

**KEYWORDS:** Pilates. Scoliosis. Electromyography. Simetrography.

## 1.Introduction

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Scoliosis is a three-dimensional deformity of the spine (Sakai et al., 2014), with physiological curvatures' deviations in sagittal and frontal planes (Rosanova et al., 2013), characterized by a lateral diversion (Souza et al., 2013). This alteration produces power and torso's muscles length imbalances, favoring muscles' shortening of the concave side and muscles' stretching of the convex side (Segura et al., 2013; Schmid, 2010).

This postural deviation affects both male and female (about 3% of adolescents), before sexual maturity (Rivett et al., 2009), being more frequent in females (Horne et al., 2014; Sperandio et al., 2014), in a ratio of 4:1 (Dayer et al., 2.013). It affects anatomy, lung function and cause severe aesthetic and psychosocial effects (Segura et al., 2013), as well as affects body symmetry and patients' quality of life (Rosanova et al., 2013).

Pilates Method (PM) is considered a complementary therapy in rehabilitation (Wells, 2012; Petrini, 2015; De Moura et al., 2015.). PM practice provides benefits on overall flexibility, postural alignment and coordination, as well as muscle strength's increase, which demonstrate a direct relationship with postural re-education process (Comunello, 2011; Sinzato, 2013; De Moura et al., 2015).

The aim of this study was to evaluate neuromuscular and postural responses from PM application in adolescents with scoliosis, through electromyography and simetrography.

## 2.Methods

Procedures for this study met ethical recommendations of 466/12 Resolution and were approved by Ethics in Research Committee involving human beings of Paraná Federal Technological University - UTFPR under CAEE number: 36614014.0.0000.5547, on October, 9th 2014. All surveyed volunteers filled the Free and Clarified Assent Term and parents/guardians filled the Free and Clarified Consent Term (TCLE).

The research's application took place in three-month period, from February to April 2015. This study sample was intentional: were included individuals with medical scoliosis' diagnosis, aged between 12 and 18 years old, of both genders, physically active, with no experience in PM resistance training and that had not underwent spine's orthopedic corrective surgery nor presented rheumatic disease diagnosis.

Body's symmetry assessment was performed by direct observation in frontal, sagittal and transverse planes in front, side and rear individuals' views. The equipment used was a Cardiomed® WCS symmetrograph, made in flexible crystal banner type, measuring 180x70cm² with squares divided into 5cm to 5cm; and a base platform with footprints' drawings, measuring 40x40cm. We used the symmetrograph aligned vertically to the plumb line for static postural analysis.

Individuals were instructed individually and placed behind the symmetrograph on the base platform (assessed participants' elevation at drawing lines' level of the device), in orthostatic position, with arms along the body, slightly apart heels and feet abducted about 15 degrees, with head in Frankfurt plan. To carry out the assessments, boys accomplished the collection using only school uniform's shorts and girls with top and lycra shorts.

For postural analysis, were considered Kendall, Maccreary&Provance protocol basis (1995). The observed anatomical structures corresponded to the following: in the previous view, starting from symmetrograph's central line between average heels' distance rated, going up and passing through lower limbs, dividing them equally, middle and pelvis' central lines, Alba line, sternum and skull. In the side view, prior to lateral malleolus, hip's articular center, shoulder and external auditory meatus. In addition to, finally, in the rear view, between individual heels' average distance, going up and passing through lower limbs, dividing them equally, middle and pelvis' central lines, over spine's spinous processes, from lower back through thoracic region, and culminating in cranial cervical region. Regarding scoliosis' condition, confirmatory radiographic examinations of spinal deviation with a medical diagnosis of scoliosis were presented.

Of the twenty-two evaluated, five (22.72%) volunteers presented right postural scoliosis ($EP_D$), with a Cobb angle of 10° to 20°, showing a mild degree severity. Fifteen volunteers had a diagnosis of structural scoliosis with a Cobb angle between 30° and 40°, showing a moderate degree of severity (six (27.27%) right thoracic scoliosis ($ET_D$); five (22.72%) left thoracic scoliosis ($ET_E$) and four volunteers presented (18.18%) right thoracolumbar scoliosis ($ETL_D$). Only one volunteer (4.54%) with dextroconvex thoracolumbar scoliosis to the left ($ETL_E$DC), had a diagnosis of severe structural scoliosis, indicative of corrective surgery, with a Cobb angle >45°, according Table 1.

Table 1 - Characteristic of spinal deviation

| Diagnosis of scoliosis | Number of volunteers | Characteristic of spinal deviation |
|---|---|---|
| Postural to the Right | 5 | Side curve C |
| Thoracic to the Right | 6 | Side curve C |
| Thoracic to the Left | 5 | Side curve C |
| Thoracolumbar to the Right | 4 | Side curve S |
| Thoracolumbar to the Left | 1 | Side curve S |
| RHC Thoracolumbar to the Left | 1 | Side curve S |

It was used a System EMG Brasil® brand equipment, 1600-U12 model of 16 channels, and surface electrodes Ag/AgCl from 3M® brand, in bipolar configuration, positioned in fibers' orientation direction of the analyzed muscles. The reference electrode was located on C7 spinous process. The sampling frequency was 1 kHz. Electrical activation signals were investigated from trapezius, spinal erectors and oblique rectus abdominis' muscles. Surface electrodes pairs' placement was performed according to SENIAM (Surface Electromyography for Non-Invasive Assessment of Muscles) protocol. For evaluated areas' trichotomy, were used procedures' gloves, individual and disposable razor and skin cleansing with sterile cotton and alcohol for better grip and electrodes' attachment, maintained inter-electrodes distance of 2.5 cm.

Signals were processed in MatLab® R2008 program (MathWorks, Inc) with 30-450Hz third-order Butterworth low-pass filter, and band-reject filters on power grid's harmonics (60, 120, 180, 240, 300, 360 and 420Hz). Temporal EMGAmp (energy's median) and spectral EMGFmed (frequency's median) reviews were held. Fast Fourier Transform processed frequency's median, according to equation (1). Where "FM" is frequency's median, P (f) is power's spectrum and fs is sample's frequency.

$$\int_0^{MF} P(f)df = \frac{1}{2}\int_0^{fs/2} P(f)df \int_0^{MF} P(f)df = \frac{1}{2}\int_0^{fs/2} P(f)df \quad (1)$$

EMG signal processing in time domain was carried out using absolute amplitude's median equation (or rectified), as disclosed in equation (2). Where "EM" is energy's median (absolute amplitude's median), MMGaxis is EMG sign (originating from the accelerometer's log axis) and n is data analysis' time window (3 to 5 seconds' variables).

$$ME_{eixo} = \frac{1}{2}\left(|EMG_{eixo}|_{\frac{n}{2}} + |EMG_{eixo}|_{\frac{n}{2}+1}\right)ME_{eixo} = \frac{1}{2}\left(|EMG_{eixo}|_{\frac{n}{2}} + |EMG_{eixo}|_{\frac{n}{2}+1}\right) \qquad (2)$$

The research's participants were evaluated seated on a medical table, torso upright, hands relaxed on thighs, balancing a book on the head during submaximal contraction. Three 15s measurements were performed, with 30s range between them, in checking spine stabilizing function.

Tests were redone after 24 application sessions (twelve weeks) of a treatment protocol consisting of 14 PM soil exercises (MatPilates), with classes twice a week with 45 min duration. To study achievement, the following exercises were selected to compose the treatment protocol: Hundred, Roll Up, Front Support Push Up, Leg Pull Down, Neck Pull, Teaser, Scissors, Roll Over, Swimming, Single Leg Stretch, Double Leg Stretch, Criss/Cross, Shoulder Bridge, and Spine Twist.

Data were processed in Microsoft Office Excel 2010 and Statistical Package for Social Science v.21 software. In all analyzes it was considered $p < 0.05$ significance level.

Shapiro-Wilk test was applied to verify distributions' normality. Variables are described from average, standard deviation and median (interquartile amplitude). The comparison between values obtained before and after the intervention was performed, using paired t test, Wilcoxon signposts' test (Barbetta, 1999; Field, 2009; Bussab and Morettin, 2013; De Andrade Martins, 2014) and Cohen effect's size. These methods were based on standardized means' differences, being d = below 0.20, considered a small or modest effect; between d = 0.20 and d = 0.80, an average or moderate effect; and d values higher than or equal to 0.80, a large or important effect (Cohen, 1992; Lindenau et al., 2012).

### 3.Results

Out of the 22 teenager volunteers of both genders, 16 individuals (72.7%) were female and six males. The volunteers presented an average age of 14.68 ± 1.67 years; between 12 and 18 years old.

### *Evaluation through simetrography*

Regarding the assessment made through simetrography, values shown in Table 2 disclose a significant improvement in scoliosis (p <0.001), in which nine surveyed (40.9%) obtained postural alignment and significant difference in shoulders' alignment by Fisher's test, where p <0.001.

Table 2 - Postural variables' analysis after Pilates protocol through symmetrography

| | Before | | After | | |
|---|---|---|---|---|---|
| | Yes | No | Yes | No | p |
| Scoliosis | 22 (100.0%) | 0 (0.0%) | 13 (59.1%) | 9 (40.9%) | 0.001* |
| Asymmetric Tales Triangle | 8 (36.4%) | 14 (63.6%) | 7 (31.8%) | 15 (68.2%) | 1.000 |
| Scapular Protraction | 5 (22.7%) | 17 (77.3%) | 3 (13.6%) | 19 (86.4%) | 0.698 |
| Trapezius Shortening | 19 (86.4%) | 3 (13.6%) | 14 (63.6%) | 8 (36.4%) | 0.162 |
| Asymmetrical Shoulders | 22 (100.0%) | 0 (0.0%) | 13 (59.1%) | 9 (40.9%) | 0.001* |
| Hip Asymmetry | 6 (27.3%) | 16 (72.7%) | 3 (13.6%) | 19 (86.4%) | 0.457 |
| Abdominal Protrusion | 3 (13.6%) | 19 (86.4%) | 3 (13.6%) | 19 (86.4%) | 1.000 |

* There was a statistically significant difference.

Referring to scoliosis' disease classification, results featured that in the five cases of right postural scoliosis ($EP_D$) there was improvement in three (60%) of the investigated individuals. In the six cases of right thoracic scoliosis ($ET_D$), there was improvement in three (50%) of the investigated. In five cases of left thoracic scoliosis ($ET_E$), there was improvement in two (40%) of the assessed. In four cases of right thoracolumbar scoliosis ($ETL_D$), there was improvement in one (25%) of the surveyed participants. In the only case of left thoracolumbar scoliosis, there was no postural improvement and, equally in the only case of dextroconvex thoracolumbar scoliosis to the left ($ETL_E$DC), either was not registered postural improvement, according to data presented in Table 3.

Table 3 – Scoliosis' Variable Analysis according to the disease's classification after Pilates protocol by symmetrography

| | | Before | | After | |
|---|---|---|---|---|---|
| | | Yes | No | Yes | No |
| Postural to the Right | Scoliosis | 5 (100.0%) | 0 (0.0%) | 2 (40.0%) | 3 (60.0%) |
| Thoracic to the Right | Scoliosis | 6 (100.0%) | 0 (0.0%) | 3 (50.0%) | 3 (50.0%) |
| Thoracic to the Left | Scoliosis | 5 (100.0%) | 0 (0.0%) | 3 (60.0%) | 2 (40.0%) |
| Thoracolumbar to the Right | Scoliosis | 4 (100.0%) | 0 (0.0%) | 3 (75.0%) | 1 (25.0%) |
| Thoracolumbar to the Left | Scoliosis | 1 (100.0%) | 0 (0.0%) | 1 (100.0%) | 0 (0.0%) |
| RHC Thoracolumbar to the Left | Scoliosis | 1 (100.0%) | 0 (0.0%) | 1 (100.0%) | 0 (0.0%) |

### ***Evaluation by electromyography***

*Right Postural Scoliosis ($EP_D$)*

Regarding electromyography evaluation, it was found after therapeutic intervention, an $EMG_{Amp}$ reduction in in all tested muscles on both sides, with a more pronounced decrease to the right side ($p = 0.004$).

Regarding $EMG_{Fmed,}$ there was noticed an increase in all muscle groups, on both sides, especially to the right bending ($p < 0.001$). Stand out spinal right erectors ($ERE_D$) ($p = 0.485$), right oblique muscles ($OBLI_D$) ($p < 0.001$) and left ($OBLI_E$) ($p = 0034$), and left rectus abdominis ($RA_E$) ($p < 0.001$).

D value shows that there was a mean effect on $EMG_{Amp}$ on the left side and a small effect on $EMG_{Amp}$on the right side, as well as a small effect on $EMG_{Fmed}$ in both spine sides, according to data exhibited in Table 4.

Table 4 – $EMG_{Amp}$ and $EMG_{Fmed}$ from EDP on right and left sides by the Wilcoxon test.

| | | Before | After | |
|---|---|---|---|---|
| Right Side | $EMG_{Amp}$ | 1.24 (4.53) | 0.02 (0.02) | .010* |
| | $EMG_{Fmed}$ | 137.0 (33.0) | 216.5 (28.0) | .151* |
| Left Side | $EMG_{Amp}$ | 2.59 (6.68) | 1.00 (5.58) | .217* |
| | $EMG_{Fmed}$ | 129.0 (36.8) | 183.0 (92.5) | .091* |

* There was a statistically significant difference.

### *Right Thoracic Scoliosis ($ET_D$)*

Regarding $EMG_{Amp}$, findings indicate decrease of electrical activity in concave and convex sides of scoliotic curvature, with a more pronounced decrease to the right side, concave ($p < 0.001$).

Present decrease on $EMG_{Amp}$, ERE, OBLI, $RA_D$ and $RA_E$. Reported a statistically significant difference, $ERE_E$ ($p = 0.025$), $OBLI_D$ ($p = 0.017$), $OBLI_E$ ($p = 0.012$) and $RA_E$ ($p = 0.006$).

Concerning $EMG_{Fmed}$, there was increase in all investigated muscles, with emphasis on the concave side ($p < 0.001$). $ERE_E$ muscles ($p = 0.020$), $OBLI_D$ ($p = 0.002$), $OBLI_E$ ($p < 0.001$) and $RA_E$ ($p = 0.004$) were the most triggered after treatment protocol.

D value, according to Cohen's classification, demonstrates that there was a small effect after applying the protocol developed in this study.

Table 5 - $EMG_{Amp}$ and $EMG_{Fmed}$ from EDP on right and left sides by the Wilcoxon test.

| | | Before | After | |
|---|---|---|---|---|
| Right Side | $EMG_{Amp}$ | 1.23 (4.97) | 0.02 (3.04) | .100* |
| | $EMG_{Fmed}$ | 134.5 (46.8) | 218.0 (59.0) | .127* |
| Left Side | $EMG_{Amp}$ | 2.97 (7.35) | 0.80 (7.35) | .053* |
| | $EMG_{Fmed}$ | 133.0 (40.0) | 198.5 (87.5) | .085* |

** There was a statistically significant difference.*

### *Left Thoracic Scoliosis ($ET_E$)*

Data express $EMG_{Amp}$ decrease on both spine sides, with more significantly decrease to the right side, convex ($p < 0.001$). It was verified $EMG_{Amp}$ decrease in $TRAP_D$ ($p = 0.307$), $ERE_E$ ($p = 0.063$), $OBLI_D$ ($p = 0.306$) and $OBLI_E$ ($p = 0.151$) and $RA_D$ (0.370) and $RA_E$ ($p = 0.156$).

There was an $EMG_{Amp}$ increase in $TRAP_E$ ($p = 0.298$), $ERE_D$ ($p = 0.059$).

Regarding $EMG_{Fmed}$, results showed increase in all investigated muscle groups, presenting significant differences in $TRAP_E$ ($p = 0.016$), $ERE_E$ ($p = 0.015$) and $OBLI_E$ ($p = 0.046$). There was an increase on both sides, especially to the right side ($p = 0.005$).

D value, in accordance to Cohen's classification, reports that there was a small effect relating to $EMG_{Amp}$ and $EMG_{Fmed}$ on both sides of the spinal column after protocol's application developed in this study, according to data presented in Table 6.

Table 6 - $EMG_{Amp}$ and $EMG_{Fmed}$ from ETE on right and left sides by the Wilcoxon test

| | | Before | After | |
|---|---|---|---|---|
| Right Side | $EMG_{Amp}$ | 1.91 (4.23) | 0.02 (1.54) | .027* |
| | $EMG_{Fmed}$ | 122.5 (58.8) | 200.0 (83.8) | .127* |
| Left Side | $EMG_{Amp}$ | 1.74 (4.17) | 1.39 (5.28) | .012 |
| | $EMG_{Fmed}$ | 119.5 (35.5) | 139.5 (111.5) | .109 |

* There was a statistically significant difference.

### *Right Thoracolumbar Scoliosis ($ETL_D$)*

Results disclosed decreased on $EMG_{Amp}$ both sides, but with more pronounced decrease to the left, convex ($p = 0.030$).

There was $EMG_{Amp}$ reduction in $TRAP_D$ ($p = 0.414$) and $ERE_D$ ($p = 0.869$) and $ERE_E$ ($p = 0.079$), $OBLI_D$ ($p = 0.137$) and $OBLI_E$ ($p = 0.150$) and $RA_D$ ($p = 0.075$) and $RA_E$ ($p = 0.159$). Only $TRAP_E$ ($p = 0.893$) submitted a slight increase on $EMG_{Amp}$ after therapeutic intervention.

Regarding $EMG_{Fmed}$, results proved an increase in both sides with emphasis on the left side, in which greater neuromuscular activation occurred (p = 0.002). There was an increase in all analyzed muscle groups, being that $OBLI_D$ (p = 0.027), $OBLI_E$ (p = 0.028), $RA_D$ (p = 0.030) and $RA_E$ (p = 0.006) disclosed significant differences. It also emphasizes that in $RA_E$ muscle, a greater neuromuscular activation was registered after treatment.

D value reports that there was a moderate effect on $EMG_{Amp}$ in both sides and a small effect on $EMG_{Fmed}$in both sides, according to data presented in Table 7.

Table 7 - $EMG_{Amp}$ and $EMG_{Fmed}$ from thoracolumbar scoliosis to the right on right and left sides by the Wilcoxon test

| | | Before | After | |
|---|---|---|---|---|
| Right side | $EMG_{Amp}$ | 2.09 (2.12) | 1.62 (6.22) | .543 |
| | $EMG_{Fmed}$ | 112.0 (21.5) | 143.0 (102.0) | .134* |
| Left side | $EMG_{Amp}$ | 1.82 (3.33) | 1.23 (4.85) | .156* |
| | $EMG_{Fmed}$ | 117.5 (34.8) | 160.0 (85.0) | .150* |

** There was a statistically significant difference.*

## *Left Thoracolumbar Scoliosis ($ETL_E$)*

Featured results infer $EMG_{Amp}$decreased on the right side, convex (p = 0.068) and increase to the left side, concave (P = 0465). There was $EMG_{Amp}$ decrease in $TRAP_D$ (7,40μV) $ERE_E$ (0,03μV) $OBLI_D$ (0,01μV) and $OBLI_E$ (0,01μV) and $RA_D$ (0,02μV) and $RA_E$ (0,01μV).

There was an increase in signal's amplitude in $TRAP_E$ (15.59 μV), with a difference of only 3.09 microvolts after treatment protocol's application, and in $ERE_D$ (7.39 microvolts), showing a difference of 3.42 μV after therapeutic intervention.

Regarding $EMG_{Fmed}$, all muscles presented increase in signal, being that $OBLI_D$ was the one that got greater neuromuscular activation (232Hz) with a difference of (153Hz), followed by $RA_E$ (230Hz), $RA_D$ (227Hz), $OBLI_E$ (225Hz) and $ERE_E$ (208Hz), featuring increased neuromuscular activity in lumbar and abdominal regions.

Results displayed an increase in both sides with small evidence to the left side (concave), presenting 69.5 Hz (p = 0.066) difference in median, although they are not significant statically. D value discloses that there was a moderate effect in $EMG_{Amp}$ in both sides and a small effect on $EMG_{Fmed}$ on both sides, according to data presented in Table 8.

Table 8 - $EMG_{Amp}$ and $EMG_{Fmed}$ from ETLE on the right side by the Wilcoxon test*Dextroconvex Thoracolumbar Scoliosis to the left ($ETL_E DC$)*

| | | Before | After | |
|---|---|---|---|---|
| Right side | $EMG_{Amp}$ | 1.90 (9.92) | 0.02 (5.55) | .270 |
| | $EMG_{Fmed}$ | 105.5 (33.3) | 219.0 (94.0) | .074 |
| Left side | $EMG_{Amp}$ | 2.68 (9.29) | 3.71 (13.53) | .289 |
| | $EMG_{Fmed}$ | 99.0 (5.8) | 168.5 (119.8) | .081 |

Obtained results elicit significant $EMG_{Amp}$ reduction on the right bending, convex (p = 0.068) with de1.81 microvolts decreasing difference and also on the left side, concave (p = 1.000), with 0.13 microvolts' difference.

There was $EMG_{Amp}$ decrease in $TRAP_D$ (0,03μV), $ERE_E$ (0,02μV), $OBLI_D$( 0,03μV) and $OBLI_E$ (0,02μV) and $RA_D$ ( 0,01μV) and $RA_E$ (0,00μV) muscles. It was verified an $EMG_{Amp}$ increase in $TRAP_E$ muscles (1,96μV) with a difference of only (0,94μV) and $ERE_D$ (13,75μV) with 10,19μV difference.

Concerning $EMG_{Fmed}$, all muscles exhibited signal's increase, while in $RA_E$ muscle a greater neuromuscular activation was registered, pointing 231Hz, with 131Hz increase after treatment, followed by $TRAP_D$ in an equal way to 231 Hz, $OBLI_D$ (222Hz), $RA_D$ (217Hz), $ERE_E$ (215 Hz), $OBLI_E$ (211Hz), $ERE_D$ (145Hz). It is possible to observe that $TRAP_E$ muscle portrayed a lower neuromuscular activation (124 Hz), manifesting only 8 Hz average's difference after therapeutic action's administration.

Results showed an increase in both spine bending with emphasis on the right side (convex), in which higher neuromuscular activation was registered, presenting 104,5Hz difference and p = 0.068. On the left side (concave), average's difference was manifested with 55Hz and p = 0.068 increase.

D value demonstrates that there was a great effect on $EMG_{Amp}$ right side, but a moderate result in $EMG_{Amp}$ left bending. Related to $EMG_{Fmed}$, a small effect occurred on both sides, according to data presented in Table 9.

Table 9 - $EMG_{Amp}$ and $EMG_{Fmed}$ from ETLEDEC scoliosis on the right side by the Wilcoxon test

| | | Before | After | |
|---|---|---|---|---|
| Right side | $EMG_{Amp}$ | 1.83 (3.11) | 0.02 (0.02) | .810 |
| | $EMG_{Fmed}$ | 122.0 (31.8) | 226.5 (14.3) | .106 |
| Left side | $EMG_{Amp}$ | 1.12 (1.98) | 0.99 (10.79) | .271 |
| | $EMG_{Fmed}$ | 123.0 (20.8) | 178.0 (86.3) | .165 |

## 4.Discussion

The performed research demonstrates neuromuscular activation asymmetry, with myoelectric activity increase at scoliotic curvature convexity's side and lower activation of the concave side. These findings are strengthened by statements found in literature (Zuk, 1962; Farahpour*et al.*, 2015), showing that convex side has greater electromyographic activity and that this bioelectric signal increase's characterization is interpreted as muscle's weakness (Zuk, 1962; Farahpour*et al.*, 2015). Asymmetric scoliosis' electromyographic activity occurs through neuromuscular system adaptation due to biomechanical changes caused by spine's scoliotic curves (Kuo*et al.*, 2011 Chawala*et al*., 2014; Farahpour*et al*., 2015.).

In another study, also conducted by Farahpour*et al*. (2014), authors found that muscle asymmetry (MA) in scoliosis' disease depends on muscle's disorder direction and it is not limited to the curvature's bend.

According to Chwala*et al.* (2012), bioelectric signals' prevalence is higher in scoliotic curve's convexity, though the concave side has decreased its functional capacity of spine's support due to lower motor units' recruitment as a result of their inactivity. This process causes these musculatures' flexibility reduction.

This $EMG_{Amp}$decreasing is brought about by therapeutic treatment that provides less muscle activity, according to Gomes *et al.* (2012), who electromyographically evaluated trapezius muscle bilaterally in 10 individuals with psychological stress after treatment by acupuncture. In this study of Gomes *et al*., it was observed that $EMG_{Amp}$ values were lower after treatment, thus corroborating this study's findings, which also showed decrease after therapeutic intervention.

In this direction, $EMG_{Amp}$ elevation in contralateral muscles is due to increased motor units' recruitment caused by muscle strengthening and by stretching of shortened muscles by scoliotic curve. This motor units' synchronization occurs due to increase in potential triggering action's number arising from multiple synergistic muscle groups' motor units in one same unit time (Folland& Williams., 2007, Ide *et al,* 2014; Bishop & Oliveira, 2015; Noda *et al*, 2014;. Siqueira, 2015) and also due to muscle's strength restoration through neuromuscular facilitation, which promotes consequent increase in muscular action (Bohorquez*et al*, 2013).

However, in all studied scoliosis' cases, there was an increase in $EMG_{Fmed}$ after treatment protocol's completion. Particularly, a considerable activation increase in oblique and rectus abdominis' muscles, responsible for segmental stabilization and spine's mobility due to conduction velocity' increase of larger diameter motor units' action potentials (Parsaei and Stashuk, 2013; Ide *et al*, 2014.; Noda *et al*, 2014.; Siqueira, 2015). These results generated by PM therapeutic intervention, which provided greater neuromuscular stimulation in scoliotic curvature's concave and convex bending.

Thus, it was verified that EMG can be an important complementary examination in this disease's evaluation as a factor's control in scoliotic curvature's progression. Motor units' significant trigger rate is one of the most important results of electromyography. The reason is because this information allows technique's clinical use in neuromotor recruitment's close analysis (Siqueira Junior, 2015), and in understanding postural control system (Coelho *et al*., 2009).This provides conditions to analyze quickly treatments protocols' validity in different types of muscle contractions, as well as elements to assess how results converge to therapeutic expectation (Schwartz et al., 2011).

In comparing evaluated postural variables through simetrography, results showed statistically significant differences for shoulders' aligning ($p < 0.001$), in which nine surveyed individuals obtained improvement in postural alignment after PM treatment protocol's application.

In accordance to the present study's findings, Ferreira *et al*. (2013) conducted an experimental study, in which, before intervention, participants (n = 40) presented right shoulder lower than left. After PM intervention for six months (48 sessions), twice a week, with 60 minutes' sessions, participants achieved significant results, displaying shoulders virtually aligned. In this study, only nine surveyed participants obtained shoulders' alignment. It can be inferred that some factors would explain the difference observed between this survey's results and Ferreira and collaborators' research, such as larger sample and superior intervention treatment time in Ferreira *et al*. research.

PM exercises act mainly in abdominal muscles and paravertebral muscles, as observed in this study's results, in which some volunteers reached postural alignment (40.9% of the sample). However, it is believed that the proposed protocol could have been applied for a longer time in order to obtain beneficial results in postural alignment for all volunteers, since each individual responds differently and in a unique way to treatment.

On shoulders' symmetry, there is the case study by De Moura *et al*. (2014) on the effects of PM in an adolescent of 11 years old, with right lumbar idiopathic scoliosis. The protocol proposed by the researchers was 10 sessions, three times a week for a month. Floor exercises and accessories were used and were analyzed aspects of postural alignment, in addition to Wells' bench to assess flexibility and trunk's muscle strength. Postural assessment was also used a symmetrograph in association with digital postural assessment SAPO® software. It is also interesting to highlight in this research, that the evaluated teenager presented a significant improvement in shoulders' symmetry, head and Tales' angle, as observed in this survey's results, in which nine evaluated volunteers (40.9%) obtained shoulders' alignment.

To corroborate postural alignment results, Segura *et al*. (2014) conducted a survey on 16 female patients, aged from 10 to 16 years old, diagnosed with thoracolumbar scoliosis, divided into two groups, one submitted to global postural re-education method (GPR) and the other to PM technique. Were performed sitting and frog in the air postures in the RPG group, and MP exercises used in treatment's protocol were spine stretch forward, swimming, leg pull front and its variation leg pull back, on up-down leg and rolling back, classes lasting 40 minutes, twice a week, totaling 20 sessions. Results demonstrate a significant scoliotic curvature's improvement, postural alignment in both treatment's techniques applied. Thus, RPG and MP can be considered therapeutic techniques indicated in scoliosis' conservative treatment.

In accordance to this study's results, there is another case study on PM's intervention effect in thoracolumbar scoliosis, the one of Ribeiro *et al*. (2012). The investigation was performed with a 12 years old volunteer, with a six months treatment's protocol in Pilates' studio. There was a significant improvement in muscle flexibility, in relative paravertebral lumbar muscles' hypertrophy and considerable postural alignment.

In this sense, De Oliveira *et al*. (2015) study corroborates the results relatively for scoliosis disease's physiotherapeutic treatments. In evaluating a case study of a male 14-year-old with right dextroconvex thoracolumbar scoliosis, treatment consisted of isometric kinesiotherapic, symmetrical and asymmetrical exercises on concave and convex sides, and stretches favoring axial growth, performed in sitting and lying positions. After 22 months of treatment, sessions two to three times a week, and an hour interventions, results showed a reduction in scoliosis' curvature through radiographic exams.

Thus, De Oliveira *et al*. (2015) research's completion turns out to be a comparative parameter to this study, in which it was also realized that maybe six months or a year of treatment could result in postural alignment improvement and in reducing adolescents' scoliosis curvatures integrating the research.

In the case of study by Sinzato*et al*. (2013) on postural alignment and articular flexibility in 33 healthy young females, aged from 18 to 30 years old, it was demonstrated that a Pilates' program applied to the soil, twice a week, beneficiated articular flexibility. However, the 20 method's sessions, applied in the study, were not sufficient to generate postural adaptations. Again, the study confirms findings of what has been proposed here, in which 24 PM sessions either were not effective in postural alignment of all adolescents with scoliosis, but there was higher electrical activation of scoliosis' curvature affected muscles.

Rivett *et al*. (2014) conducted a study in 50 girls with scoliosis' condition, aged from 12 and 16 years old. In the survey, half of the group had treatment vest for 20 hours daily and performed exercises more than three times a week, and the other group used vest for less than 20 hours daily and performed exercises less than three times a week. It was possible to conclude that performing exercises was important to prevent scoliosis curvature's progression, but it also depended on the maturity level of each participant in performing the exercises correctly, as noted in the study proposed here. Certain movements, in line with relevant PM proper breathing, were difficult to perform for a small number of investigated adolescents with scoliosis, a fact that probably interfered with the study's results and demonstration on postural alignment.

## 5.Conclusion

Results pointed out alteration in neuromuscular activation pattern in scoliosis disease. Referring to $EMG_{Amp}$, comparing the spine's right and left sides, it was found in $EP_D$ a decrease in all tested muscles on both sides. In $ET_D$ succeeded $TRAP_E$ muscle increase. In $ET_E$, there was an increase in $TRAP_E$ and $ERE_D$ muscles. In $ETL_D$, it was observed an increase in $TRAP_E$ muscle. In $ETL_E$ occurred increase in $TRAP_E$ and $ERE_D$ muscles and in $ETL_E$DC, there was an increase in $TRAP_E$ and $ERE_D$ muscles. In all studied scoliosis' cases, there was an increase of $EMG_{Fmed}$ after treatment protocol's completion, especially in external oblique and rectus abdominis' muscles.In this direction, results indicate the importance of PM as a means of conservative treatment for scoliosis disease.

However, it is believed that with 24 sessions of therapeutic intervention with PM, the intensity of muscle recruitment was not sufficient to provide postural alignment and reduction of the characteristic "S" scoliotic curve in 59.1% of adolescents investigated in the diagnoses of thoracolumbar scoliosis. right, left thoracolumbar scoliosis, and left dextroconvex thoracolumbar scoliosis, as observed by symmetrographic evaluation.

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