ABSTRACT

Introduction: Scoliosis is a three-dimensional deformity of the spine, characterized by a lateral shift that affects body posture. The Pilates Method (PM) promotes alterations in the biomechanics and neuromuscular activation pattern. Objective: The aim of this study was to analyze electromyography (EMG) and symmetrography (SMTG) technologies applied in the evaluation of neuromuscular and postural effects on right convex thoracolumbar scoliosis (RCTS) after applying a PM therapeutic protocol. Methods: This is an exploratory study of 5 male and female adolescents, with an average age of 14.4 years. The subjects underwent postural asymmetry assessments through SMTG and neuromuscular assessment through surface EMG of the trapezius (TRAP), erector spinae (ERE), oblique (OBLI) and rectus abdominis (RA) muscles. The electromyographic signals were processed in the temporal (EMGtemp) and spectral (EMGspectrum) domains. The therapeutic protocol consisted of 24 sessions of Pilates floor exercises held twice a week with a duration of 45 minutes. Results: There was an improvement in scoliosis and asymmetric shoulders in one subject (20%) and in three other subjects with hip asymmetry. There was an improvement in one subject (33.33%), as demonstrated by SMTG. EMGtemp measurements demonstrated a significant difference between before and after (p≈0) and among the muscles (p≈0). EMGspectrum measurements demonstrated that there was only a difference between before and after (p≈0). It was verified that the most noteworthy muscles in terms of EMGtemp were TRAP and ERE, emphasizing the existence of an increase in the mean EMGtemp for ERE. Muscle behavior for measurements in EMGspectrum demonstrated a higher mean increase for RA and OBLI muscles. Conclusion: It is concluded that the EMG and SMTG technologies are important tests for monitoring the progress of scoliosis and in treatment decisions. *Level of Evidence III; Diagnostic Studies – Investigating diagnostic tests.*

Keywords: Pilates Training; Scoliosis; Electromyography; Posture.
toracolumbar dextroconvexa (ETLDC) después de aplicación de un protocolo terapéutico del MP. Métodos: Se trata de un estudio exploratorio con cinco adolescentes de ambos sexos con edad promedio de 14,4 años. Los encuestados fueron sometidos a evaluaciones de postura corporal a través de la SMTG y evaluación neuromuscular por medio de la EMG de superficie de los músculos trapecio (TRAP), erectores espinales (ERE), oblicuos (OBLJ) y recto abdominal (RA). Las señales electromiográficas fueron procesadas en los dominios temporal (EMG_media) y espectral (EMG_eig). El protocolo terapéutico fue constituido por 24 sesiones de MP de suelo, aplicada dos veces por semana, con duración de 45 minutos. Resultados: Hubo mejora en la postura y de los hombros simétricos en un individuo (20%) y en tres otros con asimetría de cadera; hubo mejora en un individuo, (33,33%), de acuerdo con la SMTG. Las medidas de la EMG_media demostraron diferencia significativa entre antes y después (p=0) y entre los músculos (p=0). Las medidas de la EMG_eig demostraron que hubo diferencia sólo entre antes y después (p=0). Se verificó que los músculos de mayor destaque para EMG_media fueron TRAP y ERE, resaltando que hubo un aumento en el promedio de EMG_media para ERE. El comportamiento de la musculatura para las medidas en EMG_eig demostró un aumento promedio superior para los músculos RA y OBLJ. Conclusión: Se concluye que las tecnologías de la EMG y la SMTG son importantes exámenes en el acompañamiento del cuadro evolutivo de la escoliosis y en las decisiones de tratamiento. Nivel de evidencia III, Estudios Diagnósticos – Investigación de Exámenes Diagnósticos.

**Descriptores:** Método Pilates; Escoliosis; Electromiografía; Postura.

**INTRODUCTION**

Scoliosis is one of the most common spinal disorders, and its diagnosis and late treatment can lead to complications in body posture. The prevalence of scoliosis in Brazil ranges from 2% to 4% in adolescents aged between 10 and 16 years.

Most cases of scoliosis occur during the accelerated growth phase because of the uneven growth of the vertebrae or by the unbalanced development of the dorsal muscles. The overload on capsules, ligaments, and intervertebral disks, which are responsible for the stability of the spine, promote muscle damage to structures and cause pain.

Treatment protocols in accordance with the classification of scoliosis provide biomechanical changes to soft tissues, which lead to a reduction in the progression of the scoliotic curvature and promote the sagittal balance of the spine.

The Pilates method (PM) is based on the following six principles: breathing, control, concentration, centering, flow of movement, and precision. The muscle exercises in the PM are characterized by low contractional impact, with emphasis on strengthening the abdominal and paravertebral musculatures. However, even with the beneficial effects provided by this technique, studies on this modality as a therapeutic alternative are scarce.

Therefore, the objective of this study was to analyze posture using symmetrygraphy (SMTG) and surface electromyography (EMG) technologies used in the evaluation of neuromuscular effects and postural application of a therapeutic protocol consisting of PM floor exercises in adolescents with a medical diagnosis of right convex thoracolumbar scoliosis (RCTS), including a case of RCTS presenting with a Cobb angle of >40°, and an indication of corrective surgery.

**MATERIALS AND METHODS**

Five male and five female adolescents with a mean age of 14.4 years and medical diagnosis of RCTS were selected for the study. The study was approved by the Research Ethics Committee Involving Humans of the Federal Technological University of Paraná – UTFPR under No. CAAE: 36614014.0.0000.5547. The study was conducted over a period of 12 weeks, from February to April 2015. All the participants signed the Free and Informed Assent Term (FICT), and the legal representatives signed the Free and Informed Consent Term (TCLE).

The EMG System do Brasil® Model 1600-U12 electromyography equipment with 16 channels and 3 M Ag/AgCl surface electrodes were used for the evaluation of the electromyographic signals. Postural asymmetries were analyzed with a Caridiomed WCS symme-
For postural evaluation, the adolescents were positioned behind the symmetrograph, on the base platform (for elevation to the level of the lines drawn on the device), in an orthostatic position with the arms positioned along the body, heels slightly apart, and feet abducted approximately 15°, with the head in the Frankfurt plane. In this analysis, the bases of the Kendall protocol were held. As a reference, the anatomical structures observed in the evaluation of the postural ideal were in the anterior view, beginning from the centerline of the symmetrograph between the middle distance of the heels; ascending and passing through the lower limbs, dividing them into equal parts; the mid and central lines of the pelvis; Alba line; sternum; and skull. The structures in the lateral view were those between the anterior to the lateral malleolus, joint center of the hip, the shoulder, and the external auditory meatus. Finally, the structures in the posterior view were those between the average distance of the heels; rising and passing through the lower limbs, dividing them into equal parts; the middle and central line of the pelvis; the spinous processes of the spine, from the lumbar region to the thoracic region; and then culminating in the cervical region and skull.

The adolescents assessed underwent 24 sessions of a treatment protocol consisting of 14 PM floor exercises as follows, with classes twice a week with a duration of 45 min: hundred, roll-up, front support push-up, leg pull-down, neck pull, teaser, scissors, rollover, swimming, single-leg stretch, double-leg stretch, crisscross, shoulder bridge, and spine twist. Statistical analyses were performed with the statistical software R 3.2.0. EMG Amp and EMGFmed measurements were compared with an analysis of variance (ANOVA). ANOVA is used to evaluate the influence of factors on the characteristic of interest. In the present study, the factors associated with EMG Amp and EMGFmed values were as follows: Period, before or after the PM; Muscle, musculature (trapezius, erector spinae, oblique, and rectus abdominis), and Side, side of the body (right or left). In the ANOVA, statistical methods are applied that partition the total variability of the data between the factors analyzed and the residuals, and then an F test is applied to verify if the variation explained by the factors is significant compared with the variation of the residuals. The model that was tested can be written using equation (3),

\[ y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \epsilon_{ijkl} \]  

(3)

where \( l = 1, \ldots, n \), \( i = 1,2 \), \( j = 1, \ldots, 4 \), \( k = 1,2 \), and \( l \) is the observation of level \( i \) of Period, level \( j \) of Muscle, and level \( k \) of Side; \( \mu \) = general mean of data; \( \alpha_i \) = effect of level \( i \) of Period; \( \beta_j \) = effect of level \( j \) of Muscle; \( \gamma_k \) = effect of level \( k \) of Side; and \( \epsilon_{ijkl} \) = random component of the error.

To enable such an analysis, we assumed that the experimental errors were independent random variables and identically distributed with a normal distribution with zero mean and constant variance. This verification of these assumptions was performed graphically, seeking an absence of patterns in the residuals versus fitted graph. Possible outliers with more than three residuals in the Normal Q-Q graph were removed from the analysis. The adherence of the points to the line of the theoretical normal distribution was also observed in the Normal Q-Q graphs. In cases where the adequacy of the residuals was not achieved, a log transformation was applied to the measures observed; in all cases where transformation was needed, this measure was sufficient to validate the assumptions. It is important to emphasize that with the use of the transformation, we cannot refer to the measures of EMG Amp or EMGFmed in their original scale but instead apply the Napierian logarithm to these measures. Given the small sample size, the level of statistical significance adopted was 10%.

The hypotheses tested with ANOVA were

\[ H_0: \alpha_1 = \alpha_2 \]
\[ H_1: \alpha_1 \neq \alpha_2 \]  

(4)

\[ H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 \]
\[ H_1: \beta_j \neq \beta_i, \text{ for at least one pair with } i \neq j \]  

(5)

\[ H_0: \gamma_1 = \gamma_2 \]
\[ H_1: \gamma_1 \neq \gamma_2 \]  

(6)

The McNemar’s test was used for the symmetrogenic analysis. This nonparametric test was applied in comparative situations before and after, evaluating the same individual in these two periods to verify the statistical significance of the class changes that occurred. Asymmetrical Thales triangle, scapular protraction, trapezius shortening, asymmetric shoulders, abdominal protrusion, and hip asymmetry were verified, as well as the presence or absence of scoliosis. The p-value was obtained through a binomial test, as the sample size of the class changes was small, and in which \( p_0 = 0.5, x = 0 \) for all cases, and \( n \) is the number of individuals that presented evolution (difference between Yes before and Yes after).

**RESULTS**

In the RCTS, the measure of EMG Amp was transformed, and a significant difference was found between before and after (\( p = 0 \)) and between the muscles (\( p = 0 \)), according to Table 1. The measures of EMG Amp showed a difference only between before and after (\( p = 0 \)), according to Table 2. The analyses of residuals (Figure 1) show the adequacy of the models and the validity of the analyses, even with a slight deviation from normality of the residuals of the \( f \) measures. Figure 2 shows the mean EMG Amp (left) and EMGFmed (right) per period and musculature. The most prominent muscles for EMG Amp were the TRAP and ERE. An increase in mean EMG Amp was found for ERE in cases of RCTS. In turn, the behavior of the muscles for measures of EMG Amp revealed a higher mean increase for the RA and OBLI muscles.

**DISCUSSION**

In the classification of RCTS, the decrease in EMG Amp in the TRAP, OBLI, and RA muscles, and the increases in EMGFmed on both sides of the spine promoted neuromuscular adjustments and thus showed improvement in the postural evaluation measured with SMGT in one of the adolescents assessed.

These findings are in agreement with a study that reported that the first few weeks are considered responsible for the neural adaptations to the exercises and that only after the eighth to the tenth week do the physiological adaptations of strength and resistance occur. Thus, some statements are important because they provide evidence that the short period of application of the therapeutic protocol proposed in the...
In this context, one must mention a case study held in the city of Bauru, São Paulo, of an 11-year-old girl with a 16º RCTS scoliosis confirmed radiographically who underwent a 9-month treatment protocol consisting of kinesiotherapeutic exercises together with the techniques of iso-stretching, Pilates, Williams series, and exercises using the Swiss ball. The Cobb angle was reduced by 4º, and clear postural improvement was observed. These results support in part the results presented herein in which the importance of treatment protocols applied during longer therapeutic intervention periods relative to the postural benefits can be observed.

Likewise, a 19-year-old patient was evaluated, and a decrease in muscle retractions was observed after using the iso-stretching method and Swiss ball, and the patient presented an improvement in postural pattern and pain sensation, but without reducing the scoliotic curvature. These results corroborate also in part those presented in this study, which verified that the treatment protocol with 24 PM sessions was also not effective in reducing all muscular asymmetries evaluated in the frontal and sagittal plane using SMTG, presenting only improvement in one adolescent in terms of scoliotic curve reduction.

Another case study of a 14-year-old male adolescent with RCTS corroborated the usefulness of physiotherapeutic treatments in scoliosis disease. The treatment consisted of isometric, symmetrical, and asymmetric kinesiotherapeutic exercises on the concave and convex sides, and stretching favoring axial growth performed in the sitting and lying positions. After 22 months of treatment with two to three sessions a week and 1-hour interventions, the results showed a reduction of scoliotic curvature on radiographic examinations.

This remarkable reduction of the scoliotic curvature confirms the need for treatments performed through exercises during an extended period of therapeutic intervention as a factor of postural benefits. Isometric exercises present study was insufficient to promote satisfactory muscle strength changes to generate small modifications in the asymmetries presented in all five adolescents with the classification of RCTS, where only one of the adolescents assessed displayed improvement in scoliosis and asymmetric shoulders. However, they provided relevant neuromuscular activation. The electromyographic examination revealed a significant effect on the neuromuscular activation pattern due to the restoration of the strength of the muscle through neuromuscular facilitation and increasing the velocity of propagation of action potentials of motor units that promote an increase in muscular action and improves intermuscular and intramuscular coordination of agonists and antagonists. The assessment of postural control represents a challenging task but has important implications to professionals from diverse areas such as neurology, physiotherapy, and orthopedics. Moreover, as scoliosis is a potentially progressive disease, surface EMG examination is important in controlling the evolution of this deformity and in treatment decisions.

The PM provides a strengthening of the basic muscle components, producing proprioceptive stimuli that result in improvement of the static equilibrium of the spine. Accordingly, these assertions are fundamental in the validation of the conservative treatment with the PM in spinal diseases. However, in the pathology of RCTS scoliosis, the variable Cobb angle of >40º is suggested to be a limiting factor in the benefits relating to therapeutic action, promoting only stabilization in the progression of the disease.

The postural responses may also be related to the constant interruption in movement resulting from pain, in which the volunteer with surgical indication had to cease the execution of movements on several occasions, not completing the number of repetitions necessary in each exercise elected to structure the conservative PM treatment protocol.

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The time of application of the PM therapeutic intervention protocol was not effective in reducing all bodily asymmetries assessed, as only one of the five adolescents studied showed improvement in scoliosis and asymmetrical shoulders (representing 20%). In addition, in three individuals with hip asymmetry, only one volunteer (33.33%) showed an improvement, as demonstrated on SMTG.

In the RCTS, measures of EMG Amp demonstrated a significant difference between before and after the protocol ($p \approx 0$) and among the muscles ($p \approx 0$). The measures of EMG fmed demonstrated a significant difference only between before and after the protocol ($p \approx 0$).

The most prominent muscles for EMG Amp were the TRAP and ERE, and the mean EMG Amp for ERE was increased in the RCTS cases. Regarding the measurements of EMG fmed, the mean increase was higher for the RA and OBL muscles.

Thus, EMG can be an important examination in the study and monitoring of neuromuscular activity concerning the evolution of scoliosis, and SMTG is an efficient technology with low cost and accessible application in postural evaluation.

All authors declare no potential conflict of interest related to this article.