DOI: 10.1590/1809-2950/e22015123en

ORIGINAL RESEARCH

Influence of the spring constant change on the electromyography activity of muscles of the powerhouse and shoulder during the long stretch exercise

Influência da mudança na constante elástica da mola na atividade eletromiográfica de músculos do powerhouse e do ombro durante o exercício de long stretch

Influencia del cambio de la constante elástica de las muelles en la actividad electromiográfica de los músculos del powerhouse y del hombro durante el ejercicio de long stretch

William Dhein[1], Edgar Santiago Wagner Neto[2], Danieli Sirlei de Moraes[3], Jefferson Fagundes Loss[4]

ABSTRACT | This study aimed to verify the effect of the spring constant change on the electromyographic activity of the powerhouse and shoulder muscles during the long stretch exercise. In total, 15 Pilates practitioners performed the Long Stretch exercise on the reformer with three different spring constants: (1) k=0.19kg/cm with 1 red spring; (2) k=0.27kg/cm with 1 red spring and 1 yellow; and (3) k=0.38kg/cm with 2 red springs. The Electromyographic activity of Rectus Abdominis (RA), External Oblique (EO), Internal Oblique/Transversus abdominis (OI/TS), Multifidus (MU), Iliocostalis (IC), Longissimus (LG), Lower Trapezius (LT), and Anterior Deltoid (AD) were evaluated. We observed that as the spring constant increases, the RA, OE, OI/TS muscles decrease their EMG activity, while the AD, LT, and LG increase their EMG activity. The MU and IC muscles were not influenced in their EMG activities. Therefore, we observed an influence of the change of the spring constant on the electromyographic activity of the RA, OE, OI/LG, AD, and LT muscles. However, we found no influence of the spring constant on the EMG activities of the MU and IC muscles during the long stretch.

Keywords | Pilates; Electromyography; Muscle Stretching Exercises.

RESUMO | O objetivo deste estudo é verificar o efeito da mudança da constante elástica na atividade eletromiográfica (EMG) dos músculos do *powerhouse* e do ombro durante o exercício de *long stretch*. Participaram da pesquisa 15 praticantes de Pilates que executaram o exercício de *long stretch* no *reformer* com três constantes elásticas: (1) k=0,19kg/cm, representado por uma mola vermelha; (2) k=0,27kg/cm, representado por uma mola vermelha e uma mola amarela; e (3) k=0,38kg/cm, representado por duas molas vermelhas. Foram avaliadas as atividades EMGs dos músculos reto abdominal (RA), oblíquo externo (OE), oblíquo interno/transverso (OI/TS), multífidos (MU), iliocostal (IC), longuíssimo (LG), deltoide anterior (DA) e trapézio inferior (TI). Pode-se observar que, conforme a constante elástica aumenta, os músculos RA, OE, OI/TS diminuem suas atividades EMG, enquanto os músculos DA, TI e LG as aumentam. Os músculos MU e IC não foram tiveram suas atividades EMG influenciadas. Portanto, conclui-se que houve influência da mudança da constante elástica sobre as atividades EMG dos músculos RA, OE, OI/TS, LG, DA e TI durante o *long stretch*, mas não nas atividades EMG dos músculos MU e IC.

Descritores | Pilates; Eletromiografia; Exercícios de Alongamento Muscular.

[1]Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre (RS), Brazil. E-mail: willdhein@gmail.com. ORCID-0000-0002-8476-7342
[2]Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre (RS), Brazil. E-mail: edgar.swagner@gmail.com. ORCID-0000-0003-0555-1891
[3]Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre (RS), Brazil. E-mail: danielimoraespilates@gmail.com. ORCID-0000-0003-3909-0018
[4]Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre (RS), Brazil. E-mail: jefferson.loss@ufrgs.br. ORCID-0000-0001-5948-6357

Corresponding address: William Dhein – Rua Felizardo, 750, Porto Alegre (RS), Brazil – ZIP Code: 90690-200 – E-mail: willdhein@gmail.com – Funding source: nothing to declare – Conflict of interests: nothing to declare – Presentation: Sep. 22nd, 2022 – Accepted for publication: Apr. 13th, 2023 – Approved by the Research Ethics Committee: Protocol No. 1,384,956.

RESUMEN | El objetivo de este estudio fue evaluar el efecto del cambio de la constante de la muelle en la actividad electromiográfica (EMG) de los músculos del *powerhouse* y del hombro durante el ejercicio de *long stretch*. En el estudio participaron quince practicantes de pilates que realizaron el ejercicio *long stretch* en el *reformer* con tres constantes elásticas: (1) k=0,19kg/cm, representado por 1 muelle roja; (2) k=0,27kg/cm, representado por 1 muelle roja y 1 muelle amarilla; y (3) k=0,38kg/cm, representado por 2 muelles rojas. Se evaluaron las actividades EMG de los músculos recto abdominal (RA), oblicuo externo (OE), oblicuo interno/transverso (OI/TS), multífidos (MU), iliocostal (IC), longuissimus (LG), deltoides anterior (DA) y trapecio inferior (TI). Se pudo observar que a medida que aumenta la constante elástica de la muelle, los músculos RA, OE, OI/TS disminuyen su actividad EMG, mientras que los músculos DA, TI y LG aumentan su actividad EMG. Los músculos MU e IC no fueron influenciados en sus actividades EMG. Se puede concluir que hubo influencia del cambio en la constante elástica de la muelle sobre la actividad EMG de los músculos RA, OE, OI/TS, LG, DA y TI durante el *long stretch,* pero no hubo influencia en las actividades EMG de los músculos MU e IC.
Palabras clave | Pilates; Electromiografía; Ejercicios de Estiramiento Muscular.

INTRODUCTION

The long stretch is a Pilates exercise performed in the reformer, in which the practitioner positions the feet on the shoulder rests of the cart and the hands clinging to the standing bar, keeping the body in a horizontal position, on a plank, while the shoulders perform flexion and extension movements[1]. Both the long stretch and the traditional plank aim to increase muscle strength, endurance, and stability of the muscles of the trunk, hip, and pelvis[2-5].

The recruitment of trunk muscles is essential for the spine since it leads to the maintenance of adequate postural control, the ability to resist external forces and, consequently, the decrease of the risk of musculoskeletal injuries, as well as the guarantee of improvement in physical performance[4,6-8].

Some studies of the literature evaluate the electromyographic (EMG) activities of powerhouse muscles in an isometric execution during the traditional plank[2,9], comparing surfaces, such as balls and bosu[4,5,10], and variations of the practitioner's positions[11]. They also evaluate movements of the lower[9] or upper[12] limbs, as well as in the long stretch. However, during plank, the external load is manipulated by the use of different accessories or the performance of movements of the upper/lower limb, while in the long stretch the load variations can also be provided by the springs.

The force of the spring is determined by the elastic constant (k), which represents its "stiffness". This force depends on the thickness of the spring, the diameter of its spirals, the material used in its manufacture, and the variation of the length and perpendicular distance of the spring[13-16]. During the long stretch, the springs are fixed below the trolley, which consists of a movable platform[17]. During the execution of a Pilates exercise, such as the long stretch, the practitioner moves this platform, whose load depends on the elastic constant, which is manipulated with the introduction of different thicknesses or quantities of springs.

The literature is scarce in the EMG evaluation of long stretch and only one study analyzed the pelvic stability and EMG activity of the external oblique, gluteus maximus, adductor longus, and multifidus with and without verbal instruction for powerhouse contraction[1], disregarding the investigation of the variations of the elastic constant in this exercise. Therefore, this study aimed to verify the effect of the change of the elastic constant on the EMG activity of the powerhouse and shoulder muscles during the long stretch exercise. Our hypothesis considers that the change in the elastic constant applied by the springs during the practice of this exercise generates different EMG activities. We assumed that the muscles will present greater EMG activities in situations in which the springs present higher elastic constant.

METHODOLOGY

Participants

The study included 15 women, aged 28.3 (±3.6) years, weight of 61.3 (±9.2) kilograms, and height of 1.65 (±0.10) meters. Physically active women practitioners of Pilates, whose minimum weekly training frequency was two days, were eligible. Participants with chronic or acute low back pain and/or a history of untreated musculoskeletal injury to the upper limbs or trunk were excluded. The sample size estimation was performed using the G*Power 3.1.9.2 software, adopting the following criteria: effect size of

0.35; error probability of 5%; and statistical power of 80% for the analysis of variance (ANOVA) family of statistical tests for repeated measures.

Procedures

The collections were carried out at the Exercise Research Laboratory (LAPEX), of the Physical Education School of the Federal University of Rio Grande do Sul, with prior scheduling with the participants. Initially, each of them signed the informed consent form and anthropometric aspects (age, weight, and height) were evaluated. Next, trichotomy was performed, followed by cleaning the area with alcohol and the placement of surface electrodes[18-22]. The EMG activities were evaluated for the following muscles: rectus abdominis (RA), external oblique abdominis (EO), internal oblique/transversus abdominis (OI/TS), iliocostal (IC), longissimus (LG), multifidus (MU), anterior deltoid (AD), and inferior trapezius (IT), unilaterally to the right. Data were obtained by the BTS Smart DX and BTS FREEEMG 1,000 capture systems, with a sampling rate of 2,000Hz.

After positioning the electrodes, two maximal voluntary isometric contractions (MVICs) were performed, lasting five seconds and interspersed with two-minute intervals. To perform the MVICs, the recommendations for the muscles evaluated in the literature were followed[19-22].

Then, the participants were instructed to perform the long stretch exercise (Figure 1) on the reformer (Physio Pilates®), initially kneeling on the equipment to then perform shoulder flexion up to 90°, with elbow extension, and position themselves on the shoulder support and the foot bar.

The volunteers were positioned with their feet in the shoulder support region, while their hands remained on the standing bar. The body was kept in the plank position, while they performed the shoulder flexion and extension movement. Three different elastic constants were randomly evaluated: k=0.19kg/cm (represented by a red spring), k=0.27kg/cm (represented by a red spring and a yellow spring), and k=0.38kg/cm (represented by two red springs). The springs were previously calibrated to obtain the desired elastic constants. In total, 10 repetitions were performed for each elastic constant variation, with a two minutes break between each series to avoid fatigue effects.

To control the movements of the long stretch, reflective markers were placed on the reformer's cart, which were later also used to cut and delimit the repetitions of the movements. The kinematic data were captured by the Smart DX system, by 10 infrared cameras synchronized with the EMG system. At the same time, an experienced Pilates instructor guided the patients to perform the movement slowly, seeking to leave the pelvis neutral and the movement fluid.

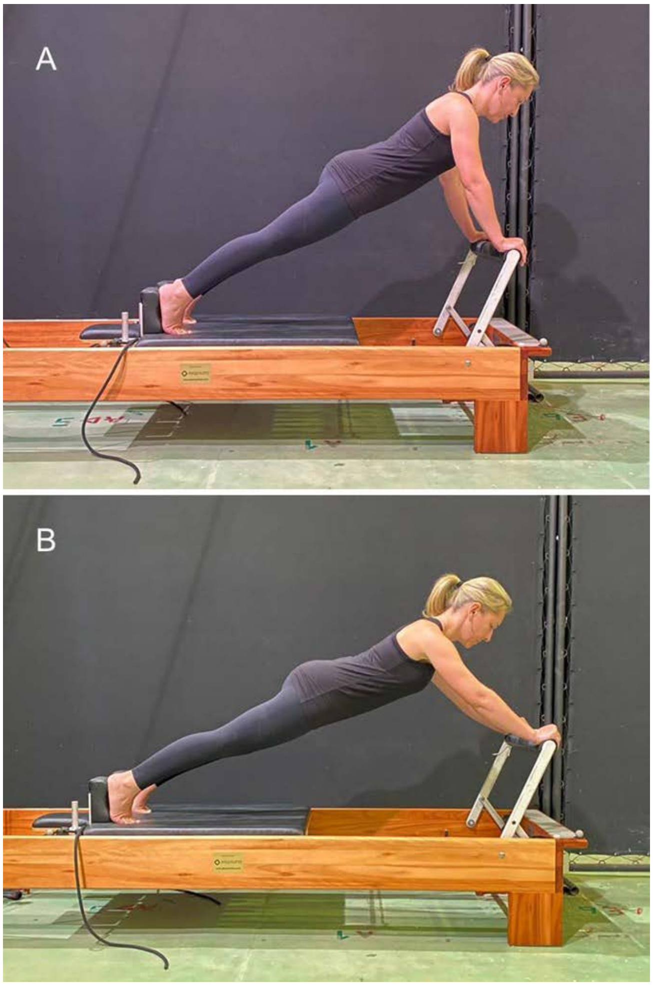

Figure 1. The long stretch exercise in the reformer: starting position (A); final position (B)

Data analysis

The electromyographic data were analyzed using the BTS SMART Analyser software. The EMG signals underwent offset removal with a 4th order Butterworth digital bandpass filter and cut-off frequencies between 20 and 400Hz. The five central repetitions of each exercise were considered valid for analysis, considering the cutout in kinematic data from the reformer's cart. The root mean square (RMS) value was calculated and normalized from the peak value obtained in the MVCIs.

Statistical analysis

Statistical analysis was performed using the SPSS software v.20.0. First, the sphericity was verified by the Mauchly's test; however, when violated, a Greenhouse-Geisser correction was applied. The electromyographic data were compared by repeated measures ANOVA, with a single three-level factor. Since there was a significant difference between the levels, the Bonferroni post hoc test was used. The significance level was $\alpha=0.05$.

RESULTS

There were changes in the EMG activities of the RA ($F=40.525$; $p<0.001$; $eta^2=0.81$), EO ($F=35.263$; $p<0.001$; $eta^2=0.74$), OI/TS ($F=10.866$; $p=0.003$; $eta^2=0.49$), LG ($F=13.943$; $p<0.001$; $eta^2=0.517$), AD ($F=33.996$; $p<0.001$; $eta^2=0.72$), and IT ($F=14.703$; $p<0.001$; $eta^2=0.55$) from the alteration of the elastic constant, while the MU ($F=0.579$; $p=0.567$; $eta^2=0.043$) and IC ($F=1.396$; $p=0.266$; $eta^2=0.097$) muscles were not influenced (Figure 2).

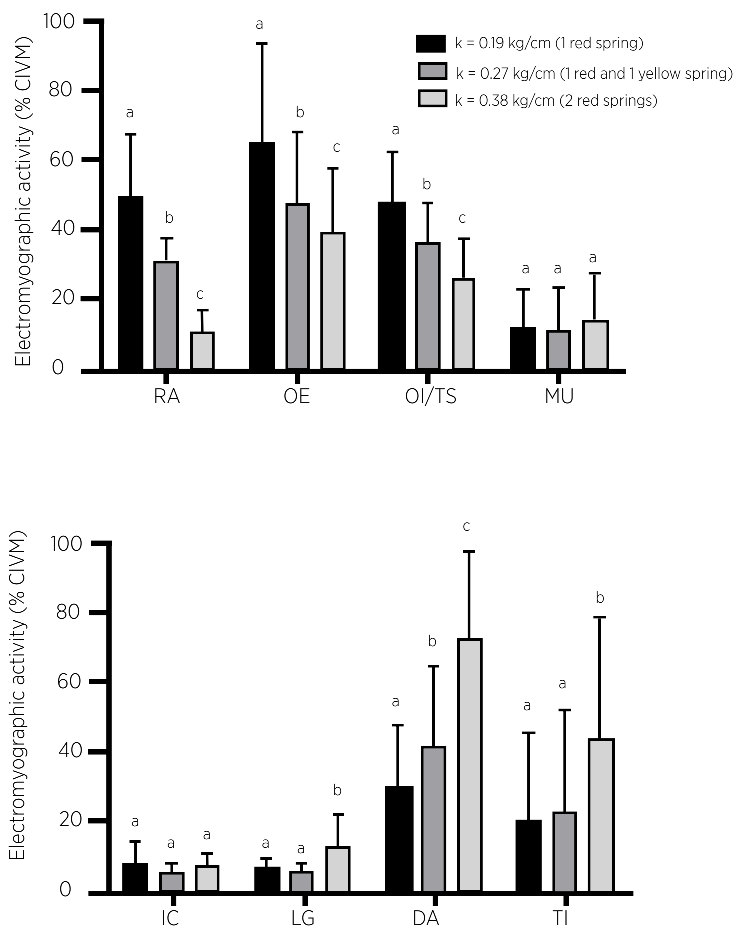

Figure 2. Electromyographic activity of the rectus abdominis (RA), external oblique (EO), internal/transverse oblique (TS/IO), multifidus (MU), iliocostal (IC), longissimus (LG), anterior deltoid (AD), and inferior trapezius (IT) muscles during long stretch
Different letters indicate a significant difference (p<0.05) in the same muscle.

DISCUSSION

The hypothesis that the change of the elastic constant of the springs during the long stretch would increase the EMG activity of the evaluated muscles was partially accepted. The RA, EO, and OI/TS muscles showed a decreasing activity in their EMG activities, contrary to our hypothesis. However, AD, IT, and LG muscles increased their EMG activities as the elastic constant also increased, agreeing with our hypothesis. The EMG activities of the MU and CI muscles were not influenced by the alteration of the elastic constant.

The high EMG activity of the EO and the low MU during the long stretch are also mentioned in the literature, in agreement with our findings[1]. During the traditional plank, high activities of the RA, EO, and OI/TS muscles are also mentioned[2,5,10-12]. The EMG activity of the TL during the plank with upper limb movement was similar to that of the serratus before another study[12], possibly due to the scapular movement, especially the upward rotation, which both muscles perform as the glenohumeral moves. Regarding glenohumeral, only the latissimus dorsum had been investigated in the literature[11,12], demonstrating low activities during the plank. We found no studies in the literature on EMG activity of the AD during the long stretch or the plank. However, the literature mentions that, during the execution of the exercise studied, the resistance torque imposed on the shoulder is related to extension, justifying the increase in the EMG activity of the AD[23].

Comparing the long stretch with the plank performed with flexion-extension movement of the upper limb on the Swiss ball, the literature mentions an increase in the EMG activity of the RA, EO, and OI/TS muscles, when compared to a situation without movement[12]. In our study, activities after the increase in the elastic constant decreased since, in the long stretch, the practitioner performs shoulder flexion and extension with the elbow extended and the hands grasped on the bar of the reformer, which is fixed. During the plank with upper limb movement occurs an instability promoted by the accessories placed on the upper limbs, also causing an increase in the muscles of the abdominal region to control instability.

We observed lower EMG activities in the MU, CI, and LG muscles, which can be explained by their action in the extension of the lumbar region, as well as suffering more intense activation during the dorsal plank[24], a result in agreement with other studies that evaluated these same muscles[11,12].

Based on the results of this study, we can present practical applications and suggest a progression for the long stretch exercise. If the aim is a greater focus on the muscles of RA, EO, and OI/TS, the exercises can be performed with less elastic constant (represented in this study by a red spring), providing greater EMG activity in these muscles. However, if the aim is to focus more on the AD, IT, and LG muscles, the exercises can be performed with greater elastic constant (here represented by two red springs). For MU and CI, there will be no progression, so exercise will be indifferent to muscle EMG activities.

Regarding the limitations of the study, the sample exclusively with participants who were used to the Pilates method can influence the results of the EMG activities, making it impossible to affirm that such results will be found at all levels of practitioners or in sedentary individuals. Furthermore, the control of the execution speed is limited to the guidance of an experienced instructor, which does not exclude the possibility of execution errors among the participants. Therefore, we suggest the delimitation of a speed and the use of a sound effect to guide the execution of the long stretch in future studies.

Notably, the elastic constants of the study refer to the colors of the marks of the springs used. These constants come from the springs of the manufacturer's equipment and were calibrated before data collection. Therefore, instructors should remember that the elastic constants of their springs will be different from those used in this study. For future studies, we suggest to obtain data from other muscles of the powerhouse (glutes, adductors, hamstrings) or shoulder muscles (pectoralis major, biceps brachii or triceps brachii) that may be involved in the long stretch movement.

CONCLUSION

The change of the elastic constant influenced the EMG activities of the RA, EO, OI/TS, LG, AD, and IT muscles during the execution of the long stretch. We observed that as the elastic constant increases the EMG activity of the RA, EO, and OI/TS muscles decreases, while that of the AD, IT, and LG muscles increases. However, we found no influence on the EMG activities of the MU and CI muscles during exercise.

ACKNOWLEDGMENTS

We thank Physio Pilates® for the equipment used in the study.

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