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ORIGINAL ARTICLE

Electromyography analysis of the abdominal crunch in stable and unstable surface

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ABSTRACT

BACKGROUND**:** This study observed the influence of the surface (stable and unstable) on the electrical activity of the muscles rectus abdominal (RA), extern abdominal oblique (EAO), and rectus femoral (RF), in the abdominal crunch exercise (AC).
METHODS**:** Twenty individuals, apparently healthy, Caucasians and physically actives (22.40±2.46 years old, 71.38±9.71 Kg body mass, 176.55±6.29 cm height and 5.47±2.64% estimated body fat), were performed 1 set, of 10 repetitions, of the abdominal crunch exercise on the floor (ACF) and on the Swiss Ball (ACSB), in random way, with a 10 minutes interval between the two conditions. It was collected the electrical signal of the RA, EAO and RF by surface electromyography and were analysed the peak signal.
RESULTS**:** It was observed a significant, ($F_{(2, 52)}$=11.213 p=0.002, η_p^2=0.228), differences on the peak signal, in the RF muscle, between the executions of the AC in the two surfaces. In the ACSB the peak signal of the RF was significantly higher than in the ACF (26.56 ±12.47 Hz x 44.15±19.91 Hz), respectively). In the AC execution, in both surfaces, the peak signal of the RA and EAO were significantly, (p<0.0001), higher than the RF muscle.
CONCLUSIONS**:** In conclusion, the abdominal crunch on the floor and on the Swiss ball promote a higher activation of the rectus abdominis and extern abdominal oblique muscles than the rectus femoral muscle. Subjects with low back injuries can performing the abdominal crunch on the floor, in detriment of the same exercise performed in the Swiss Ball.

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Physical exercises are prescribed in order to generate muscle overloads in order to improve the performance of the neuromuscular system. Considering the wide variety of available exercises for each muscle group, professionals in the health and physical activity faced with the challenge of choosing one that best fits the subject that is being trained.

There are several ways to strengthen the muscles of the abdominal region, most of them using the anterior flexion of the dorsal column.[1] However, there are still questions about the main angles of activation of different muscle groups of the abdominal region, and yet, if the activation of these muscles varies according to the stability of the surface used to perform the exercise.[2, 3]

Several researchers,[3-5] tried to analyse the influence of different equipment's and surfaces on the activation of different muscles of the abdominal region, by surface electromyography.

In relation to the surface variation, the abdominal exercises are being prescript in instability with the belief that improves the activation of the trunk muscles and promote the maintenance of the stability of the column.[6]

In the literature, studies in which the objective was to observe, by surface electromyography, the muscle activation of the abdominal region muscles, using the peak signal and the Root Mean Square, were observed contradictory results.[2, 4, 5, 7-9] Some studies report a greater recruitment in unstable surfaces [2, 4, 8, 9] and others did not observed significant differences between stable and unstable surfaces. In order to try an approach that better clarify this issue, we defined as aim of this study analyse through surface electromyography of RA, EAO, RF muscles activity, in thoracic spine flexion exercise on the floor and in Swiss ball, through the peak signal.

Materials and methods

Participants

Twenty healthy, physically active men volunteered to participate in this study. The characteristics of the participants can be observed in the Table I. Every select participant had been engaged in resistance training for at least two days per week over the previous 6 months and performed the ACF and the ACSB. The exclusion criteria were: i) an historical of chronic low back pain; ii) rectification lumbar; iii) accentuated hyper lordosis lumbar; iv) any surgeries performed on the abdomen, thigh or in the lumbar zone; v) a history of ligament, tendon and joint injuries of every region to be studied; and vi) an estimated percentage of body fat over the 13%, because an higher subcutaneous body fat can compromise the data collection of electrical signal.[10] Participants were informed about all the possible risks or discomforts involved in the experiment and provided written informed consent to participate in the study. All the procedures were designed according to Helsinki Declaration and were approved by the Ethics Committee of the institution.

Table I.—*Characteristics of the participants (N. 20).*

	Mean±Standard Deviation
Age (years)	22.40±2.46
Height (cm)	176.55±6.29
Body Mass (Kg)	71.38±9.71
SIS (mm)	7.05±2.54
ABS (mm)	7.89±2.74
TS (mm)	7.40±2.98
EBF (%)	5.47±2.64

SIS: suprailiac skinfold; ABS: abdominal skinfold; TS: thigh skinfold; EBF: estimated body fat

Procedures and measures

All participants were evaluated in an only session. Firstly, were measured the body mass, height, abdominal, suprailiac and thigh skinfolds and estimated body fat. Anthropometric measures were recorded with the participants in shorts using a scale with stadiometer (Welmy, model 110, BH, Brazil) with the protocol described by Neves.[11] A trained and experienced technician, using a skinfold calliper, assessed the Skinfold measurements (Sanny AD1010, Physical Nutri, Araraquara, SP, Brazil). The measurements were made in triplicate, and their averages were used in further calculation. Body fat was estimated from measurements of skinfold thickness by using the generalized skinfold equations from Jackson and Pollock.[12] After the anthropometric measurements the participants were submitted to preparation of the skin (hair removal and subsequent asepsis) at the place of fixation of the electrodes.[13] Sequentially were fixed three bipolar electrodes of type AE1010 – VRA0. The first electrode was fixed on the RA parallel muscle fibres, positioned 2 cm off the umbilical scar. The second was positioned at the midpoint the line extending from the anterior superior iliac spine to the top edge of the patella in the RF muscle. The third electrode was fixed at 15 cm off the umbilical scar, at the midpoint between the last rib and the upper iliac crest.[14] The reference electrode was fixed on the skin, on the wrist.

After that, the exercise execution order was randomly selected (ACF or ACSB). It was per-

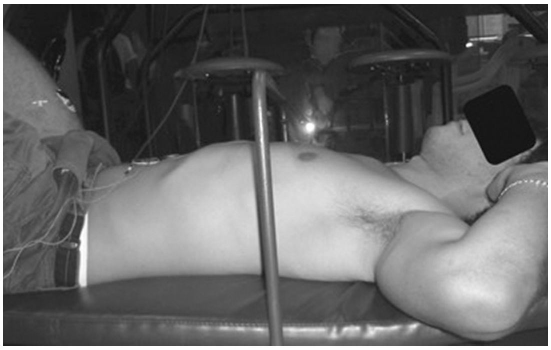

Figure 1.—Illustration of the electrode placement and positioning of participants to perform the exercises (ACF) on the floor.

Figure 2.—Illustration of the electrode placement positioning of participants to perform the exercises (ACSB) on the Swiss ball.

formed 1 set, of 10 repetitions, with 2 seconds in each phase of the movement (concentric and eccentric), of both exercises, with a rest interval of 10 minutes between them. The cadence of the exercise execution was controlled by a metronome (Seiko, DM11A, China). The amplitude of movement was limited to 30º of the flexion of the spine, as illustrated in Figure 1, controlled by a goniometer (Sanny, S. Bernardo do Campo, Brazil), taking as a point of reference the last intercostal arc. The Swiss Ball was positioned in the lumbar region of each participant in the execution of the ACSB as illustrated in Figure 2. The control of the hip and Knee angles was controlled by a goniometer (Sanny, S. Bernardo do Campo, Brazil) with angulation in both situations (ACF or ACSB) of 40º for the hip and 100º for the Knee.

The electromyography signal was acquired during the execution of the two exercises using 3 electrodes of Ag/Cl surface with 10 mm in diameter. For storage of signals was used a Lynx brand conditioner module EMG 1000 model-8-4I with digital Butterworth type filter with low-pass cut-off frequency of 500 Hz and a high-pass with cut-off frequency 10 Hz, according to the manual equipment recommendation, and final gain 1000 times. The acquisition of the signals in data files was made by 1.8 Bioinspector software (Lynx). The electromyography signal treatment was performed by software AqDAnalysis 7, where after the signal was filtered, it was possible to identify peak RA, EAO and RF muscle activity during the concentric and eccentric phases of each repetition in the ACF and ACSB. For inferential analyse it was used the average mean of the 10 repetitions in each conditions.

Statistical analysis

The analysis of the data was performed using software "Statistical Package for the Social Sciences, SPSS Science,Chicago, USA" version 21,0. All data were presented as mean and standard deviation. Shapiro-Wilk, Levene and Mauchly´s tests were used in order to check, respectively, the normality, homogeneity and sphericity of the sample's data variances. A multivariate ANOVA, with Bonferroni post hoc test, was used to verify the possibility of differences between the three muscles and the two surfaces in the electromyography peak signal. The significance level was established in 5%.

Results

Table II presents the Peak electrical signal of the RA, EAO, and FR, in the abdominal crunch exercise performed on the floor and on the Swiss Ball. It was observed a significant, ($F_{(1,\ 36)}$=10.567 p=0.002, $\eta_p{}^2$=0.228), differences on the peak signal, in the RF muscle, between the executions of the AC in the two surfaces. In the ACSB the peak signal of the RF was significantly higher than in the ACF (26.56 ±12.47 Hz x 44.15±19.91 Hz, respectively). In

TABLE II.—*Peak electrical signal of the muscles rectus abdominal, (RA), extern abdominal oblique, (EAO), and femoral rectus, (FR), in the abdominal crunch, (AC), exercise performed on the floor and on the Swiss Ball.*

Muscles	Floor	Swiss Ball
RA (Hz)	518.06±333.22	610.52±314.62
FR (Hz)	26.56±12.47†	44.15±19.91*†
EAO (Hz)	617.36±297.50	552.59±331.24

*P=0.002, significant differences between the execution of the AC on the floor and on the Swiss Ball †P<0.0001, significant differences between the RA and EAO muscles and the FR muscle.

the AC execution, in both surfaces, the peak signal of the RA and EAO were significantly, ($p<0.0001$), higher than the RF muscle.

Discussion

Several authors for the challenge provided by the solicitation of the neuromuscular system suggest the use of exercises in instability, thus a greater involvement of the muscles, including those of the core stabilizers.[2, 15]

However other authors when they sought to observe differences in the level of intervention of the core between exercises performed in stable and unstable surfaces did not found significant differences.[1, 16]

One of the limitations of these results is to isolate the muscle groups that make up the core, especially the deep muscles, because as in the present study surface EMG, all are recruited. This method of neuromuscular activity analysis only measures the level of muscle activation via an electromyography signal.[17] When there is an increase in the electromyographic activity, in a superficial muscle group, can be due the summation of this muscle activity and/or the participation of deep adjacent.[17]

The aim of this study was to observe the peak average values of muscle activation in the realization of the abdominal crunch, in stable and unstable surfaces, in the muscle groups RA, EAO and RF.

Regarding the activation of RA in stable and unstable surface were not found significant differences (518.06±333.22 versus 610.52±314.62, respectively), just as in the EAO (617.36±297.50 versus 552.59±331.24).

These results corroborate with the study of Anzai and Liberali [2] that reported no significant differences in the RA during the execution of the front trunk flexion. However, Petrofsky, Batt [8] found different results, showing that the exercises performed similarly on unstable surfaces (Swiss Ball) provide greater activation of the muscles RA and EAO. This difference can be attributed to the methodological differences of studies.

In this study, the flexion of spine was limited to 30° during the exercise, it was used with a ball of 55 cm of diameter and the ball was placed in the lumbar zone. Already in the study of Petrofsky, Batt [8] used the same form of exercise, but with several different angles of knee level (75-90°), hip (90-110°) and trunk flexion (35º), because the size of the Swiss balls that they used were different of ours. There are also studies that found greater activation of RA and EAO muscles when carried out on unstable surfaces, but cannot be compared with our findings, because the movement used was differently.

In the present study was also observed a lower muscle activation of the RF on the ACF (26.56 ±12.47 versus 44.15±19.91; $p=0.002$). These results corroborate with the studies of [9, 18, 4]. However, Lizardo *et al*.[19] found opposite results.

This variation in results may be related to a variety of methodologies employed in the studies. In the study of Lizardo *et al*.[19] the volume of exercise was lower, when compared to the present study, since we used 10 repetitions with 4 seconds for each cycle of movement, totalling 40 seconds of exercise. Also, Lizardo *et al*.[19] performed only 4 repetitions, with a cadence of 2 seconds for the concentric phase and 2 seconds for eccentric phase, with a total of 16 seconds for the exercise, another difference is in relation to the size of the ball, because it was used a ball with 55 cm in diameter, while Lizardo *et al*.[19] used a ball with 85 cm in diameter. Another fact may be related to placement of the reference electrode, we put into the wrist and [19] placed over the iliac crest on the right side.

All these methodological differences may have influence on the activation of RF. The other studies [4, 9, 18] used different exercises for the abdominal region. The RF muscle is important in abdominal exercise, as it has a direct relation with the hip, so any change in the posture of the pelvis affects the lumbar spine posture and consequently the electromyography signal of RA, EAO and RF muscles.[20]

Some studies with electromyography shows that at the beginning of the movement of flexion of the spine there is a greater RA muscle activation.[21, 22] Subsequently, when the lumbar region loses contact with the ground (30º to 45° of flexion of the trunk) occurs a decrease in electrical activity of this muscle and muscle activation hip curl.[23] This fact occurs, because from the moment that the lumbar spine starts to lose contact with the ground, the pelvis is in ante-version with resultant hyperextension of the lumbar spine.[21] This hyperextension compresses the intervertebral disc and articular facets causing that the performer activate the hip flexors more than the muscles of the abdominal wall, in addition, hyperextension of the lumbar spine limits the amount of flexion of the thoracic spine, which helps to decrease the action of spinal flexors.[20]

To minimize this interference of the hip flexors in abdominal exercises is recommended a flexion of the hip joint, with this occurs a decrease of the passive influence of muscles hip flexors, affecting thus the force-length relationship, which decreases the production capacity of strength of these muscles on the pelvis and lumbar spine,[20] as we defined in our study.

Another factor that may have influence on the activation of the muscles curl of the hip is the degree of flexion of the knees. However, this point is not consensual in the literature. The same authors say that the degree of knee flexion did not made any difference [23] others say that this joint flexion can decrease the action of the hip flexors.[24]

Finally, based on the results of this study we can affirm that instability does not provide significant differences in activation of the muscles RA and OAE, in the abdominal crunch exercise. However, performing this exercise in instability, (Swiss Ball), promotes a higher activation of the RF muscle evaluated by Peak electrical signal.

Conclusions

Performing the abdominal crunch in unstable surface, should be discouraged in people who exhibit some kind of pathology in the lumbar region, because of the greater activation of the RF muscle that carries out an increase of the tractive forces on the lumbar spine. This way, we recommending to these individuals performed this exercise on the floor.

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