# COMPARATION OF ABDOMINAL WALL ACTIVATION DURING SIT- UP AND CURL- UP EXERCISES IN WOMEN

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In order to carry out this study, fourteen healthy females performed series of sit-up and curl-up exercises, with and without fixation for the legs. Electrogoniometers were placed on the hip and dorsal spine. Surface EMG was recorded from the superior and inferior portions of the rectus abdominis, external oblique, internal oblique, and rectus femoris of both sides. Muscle patterns were compared to normalized values of integrated EMG. The results showed that the sit-up exercise required higher activity of the abdominal muscles than the curl-up, when the exercises were performed with or without fixation of the legs. In the same way, the sit-up exercise required high activity of the rectus femoris, mainly with fixation for the legs.

**KEY WORDS**: abdominal wall, rectus femoris, sit-up, curl-up, electromyography.

**INTRODUCTION:** In training and related sciences, a special attention has been paid to the muscles of the abdominal wall and to the best ways to develop their strength. The sit-up and curl-up are two of the exercises most often used for that purpose. Experimental research used electromyographic (EMG) methods to characterize the activation of trunk flexors during curl-up and sit-up performed in different conditions. Using surface and needle electrodes, Andersson, Nilsson, Ma and Thorstensson (1997) and Juker, McGill, Kropf and Steffen (1998) recorded EMG from the abdominal muscles together with hip flexors, in a variety of abdominal exercises; probably because of the cost of using needle EMG to access deep muscles small samples have been studied. The placement of only one pair of electrodes on the rectus abdominis, did not allow to separate the different portions of this muscle. The general purpose of the present study was to compare the activation pattern of abdominal muscles in two different exercises, the sit-up and the curl-up, performed with and without fixation of the legs in young females.

**METHODS:** Fourteen healthy females (age = 22.14 ± 2.51 yr, height = 1.65 ± 0.05 m, mass = 54.2 ± 4.11 kg) participated in the study. After a practice period prior to the study, all subjects performed a series of five cycles for each condition: sit-up (combination of trunk and hip flexion) with fixation of the legs, sit-up with no fixation of the legs, curl-up (trunk flexion with no movement at the hip and lumbar spine) with fixation of the legs, curl-up with no fixation for of legs the position was the following the feet were on the floor, legs bent with knee at 115°, the upper arms were placed lateral to the body with the hands in contact with the floor during the whole cycle. The exercises were performed at a pre-set rhythm of a metronome. The duration of the entire cycle (upward and downward phases) was 3 s in the curl-ups and 4 s in the sit-ups. The different conditions were randomized for each subject. Three cycles of each condition were selected for analysis. Before measurements each subject performed three maximal isometric contractions of the abdominal muscles and three of the rectus femoris in order to provide a reference for EMG normalization. Maximal abdominal contraction was performed through trunk isometric flexion against a resistance on the shoulders. The legs were flexed (knees at 90°) and the feet fixed. The Maximum activation for the rectus femoris was obtained with the subjects lying supine, straight legs (knees at 180°), shoulders fixed, while they performed hip flexion against resistance and tried to keep knee extension. Electrogoniometers (ELG) were placed on the hip and dorsal spine. Surface EMGs (Medicoelectrics, Denmark) were recorded using bipolar electrodes with an inter-electrode distance of 20 mm. The electrodes were placed on the superior (10 cm above the umbilicus and 3 cm lateral to the sagital line) and inferior (5 cm below the umbilicus and 3 cm lateral to the sagital line) portions of the rectus abdominis, external oblique (15 cm lateral to the umbilicus), internal oblique (just above the inguinal ligament and below the electrodes of the external oblique), and rectus femoris (8 cm below the inguinal ligament); these Electrodes were placed on muscles of both sides. The myoelectric signals were amplified with a gain of 2500 band pass filter of 10 - 700 Hz and common mode rejection ratio greater than 120 dB. The EMGs were digitised together with the EGN signals, by means of a 16-bits A/D converter with a sample rate of 1024 Hz. The pure EMG signals were digitally filtered (20 to 500 Hz) and fullwave rectified. The integrated EMG (iEMG) was calculated separately during the upward and downward phases, and divided for the respective phases duration to obtain the amplitude value (iEMG/T). For amplitude normalization, the average iEMG/T value for each individual muscle in each condition was put into a percentage of the highest amplitude value found for that muscle in the maximal isometric contraction. Mean values and standard deviation of iEMG/T were determined for muscle, phase and condition. Differences between conditions for each muscle were tested as differences using Wilcoxon matched pairs tests at a level of significance of 95%.

**RESULTS AND DISCUSSION:** The muscular pattern was different between curl-up and sit-up exercises. The main qualitative differences have to do with the EMG patterns during the downward phase. During the curl-up (Fig. 1) the abdominal muscles showed an initial burst on the begginining of the upward phase, probably related with thorax stabilization, which is needed for the head flexion.

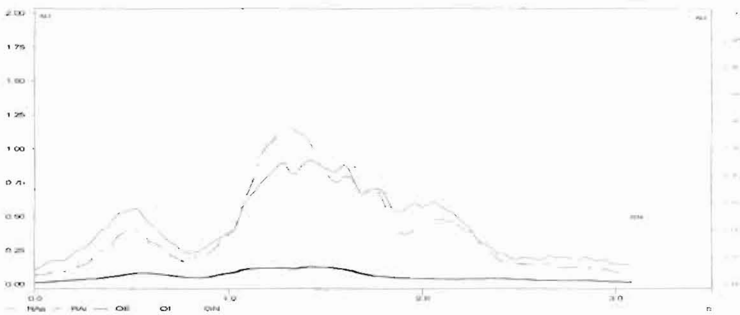

**Figure 1.** An example of the abdominal muscle pattern during the curl-up performed with fixation of the legs: EMG signals of the superior (RAs) and inferior (RAi) portions of rectus abdominis, external oblique (OE), internal oblique (OI) from left side and the position curve of the dorsal spine (GN) representing the upward and downward movement of the trunk.

The main activation during the trunk flexion, reached the EMG peak 50 ms before the end of the upward phase. During the downward phase, only low levels of myoelectric activity were observed. The abdominal muscle pattern in the sit-up (Fig. 2) showed a first burst during the upward phase, followed for a myoelectric silence when the trunk reached the vertical (upright position).

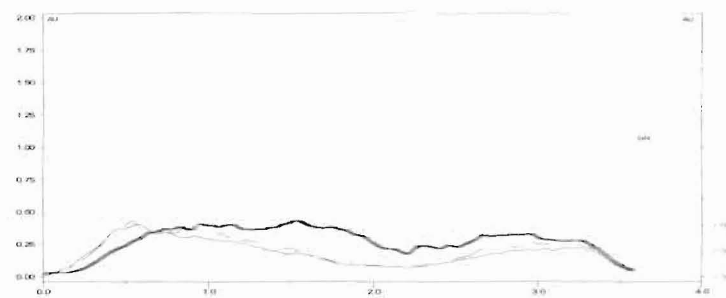

**Figure 2.** An example of the abdominal muscle pattern during the sit-up performed with fixation for the legs: EMG signals of the superior (RAs) and inferior (RAi) portions of rectus abdominis, external

oblique (OE), internal oblique (OI) from left side and the position curve of the dorsal spine (GN) representing the upward and downward movement of the trunk.

A burst during the downward phase was also observed and differences in the EMG patterns of the rectus femoris were also found. During the curl-up exercise the rectus femoris showed a low level activity over the whole cycle. However, during the sit-up exercise we observed a clear transfer between the abdominal muscles and the rectus femoris, related to the beginning of the hip flexion (Fig. 3).

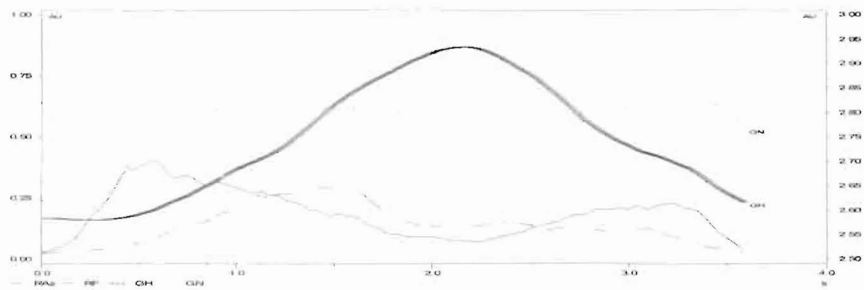


**Figure 3.** An example of the pattern of the abdominal muscles and rectus femoris during the sit-up performed with fixation for the legs: EMG signals of superior portion of the rectus abdominis (dark curve) and rectus femoris (grey curve) from left side and position curve of the hip. These results indicate that the sit-up exercise is the best way to get high levels of abdominal muscle activation. However, during the sit-up, the risk for the lumbar spine compression is higher because of a stronger participation of the hip flexor muscles during the trunk flexion, as we observed for the rectus femoris and previously showed for the psoas (Juker, McGill, Kropf and Steffen, 1998), the iliacus and the sartorius (Andersson, Nilsson, Ma and Thorstensson, 1997) muscles. This effect was mainly observed when the legs were fixed.

The comparison of the mean values of integrated to normalized EMG values (Table 1), showed that, with the exception of the upper portion of the rectus abdominis, all the abdominal muscles were recruited with a significantly higher intensity during the sit-up exercises than during the curl-up. This was right in the case the upward and downward phases. Using the average of percentage values of all abdominal muscles from the fourteen subjects as a value representative of *abdominal synergy,* as it was done by Andersson, Nilsson, Ma and Thorstensson (1997), we can confirm these findings when the comparison was done between sit-up and curl-up performed with fixation for the legs (89% - 66% for the upward phase, 59% - 34% for the downward phase) or without fixation (87% - 60% for the upward phase, 66% - 29% for the downward phase). The external oblique showed the most acute difference, corroborating the results of Andersson, Nilsson, Ma and Thorstensson (1997). For the rectus femoris, a clear and significant increase of activation during the sit-up exercise was observed, but the difference was more accentuated when the exercises were performed with fixation of the legs. The influence of the fixation for the legs did not affect the muscle patterns in curl-up and sit-up exercises, but differences were found in the intensity of activation. The *abdominal synergy* showed small differences when the sit-up with fixation for the legs was compared to the sit-up without fixation (89% - 87% for the upward phase, 59% - 66% for the downward phase). The external oblique was the only abdominal muscle that improved the activation when the sit-up was performed without legs fixed. However, the most marked difference was observed for the rectus femoris in the sit-up with fixation for the legs, the condition of its maximum solicitation, as was also observed by Andersson, Nilsson, Ma and Thorstensson (1997). Regarding the curl-up, an important increase was observed with fixed legs compared with the exercise performed without fixation (66% - 60% for the upward phase, 34% - 29% for the downward phase). The most consistent change of abdominal wall muscles was the significant increase of activation for both portions from rectus abdominis in the curl-up performed with fixation for the legs. As expected, the fixation of the legs did not affect the EMG of the rectus femoris during the curl-up.

**Table 1.** Mean values and standard deviation of the iEMG/T percentual values during the upward (UP) and downward (DP) phases of curl-up and sit-up performed with fixation for the legs (F) and without fixation (NF). Muscles studied were: superior portion of the rectus abdominis from the right (RAsR) and left side (RAsL), inferior portion of the rectus abdominis from the right (RAiR) and left side (RAiL), external oblique from the right (OER) and left side (OEL), internal oblique from the right (OIR) and left side (OIL) and rectus femoris from the right (RFR) and left side (RFL). * Indicates a level of significance of 95%.

| | | F | | | | | | | NF | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Curl-up | | Sit-up | | | | | Curl-up | | Sit-up | | |
| | | Mean (%) | SD | Mean (%) | SD | | | | Mean (%) | SD | Mean (%) | SD | |
| RAsR | UP | 82,04 | ±1,97 | 78,66 | ±2,10 | | RAsR | UP | 77,02 | ±2,22 | 65,71 | ±2,50 | |
| | DP | 35,25 | ±1,99 | 49,39 | ±2,11 | * | | DP | 32,51 | ±1,54 | 51.88 | ±1,74 | * |
| RAsL | UP | 78,18 | ±2,21 | 87,05 | ±2,36 | * | RAsL | UP | 72,61 | ±1,81 | 71,28 | ±2,03 | * |
| | DP | 35,28 | ±2,16 | 55,14 | ±2,30 | * | | DP | 31,79 | ±1,75 | 58,83 | ±1,96 | * |
| RAiR | UP | 81,54 | ±2,65 | 89,57 | ±2,81 | * | RAiR | UP | 72,58 | ±2,05 | 85,03 | ±2,31 | * |
| | DP | 39,23 | ±2,50 | 58,16 | ±2,66 | * | | DP | 33,23 | ±2,06 | 67,11 | ±2,31 | * |
| RAiL | UP | 74,15 | ±2,77 | 92,4 | ±2,94 | * | RAiL | UP | 71,5 | ±1,89 | 83,98 | ±2,12 | * |
| | DP | 37,59 | ±2,46 | 60,51 | ±2,61 | * | | DP | 31,48 | ±1,97 | 70,25 | ±2,21 | * |
| OER | UP | 46,29 | ±2,92 | 98,26 | ±3,10 | * | OER | UP | 41,31 | ±2,25 | 130,79 | ±2,53 | * |
| | DP | 29,36 | ±2,52 | 67,18 | ±2,68 | * | | DP | 23,68 | ±1,97 | 84,54 | ±2,21 | * |
| OEL | UP | 46,42 | ±1,45 | 104,67 | ±1,54 | * | OEL | UP | 38,61 | 2,91 | 110,98 | 3,27 | * |
| | DP | 30,42 | ±2,62 | 70,67 | ±2,78 | * | | DP | 25,03 | ±1,83 | 81,63 | ±2,06 | * |
| OIR | UP | 61,32 | ±2,78 | 79,25 | ±2,95 | * | OIR | UP | 54,06 | 1,94 | 75,47 | 2,18 | * |
| | DP | 33,59 | ±3,23 | 52,08 | ±3,44 | * | | DP | 28,24 | ±1,68 | 58,54 | ±1,89 | * |
| OIL | UP | 60,76 | ±2,56 | 81,77 | ±2,72 | * | OIL | UP | 53,61 | ±1,69 | 73,03 | ±1,89 | * |
| | DP | 33,1 | ±2,24 | 55,07 | ±2,38 | * | | DP | 26,19 | ±1,40 | 53,05 | ±1,57 | * |
| RFR | UP | 9,16 | ±1,51 | 69,68 | ±4,35 | * | RFR | UP | 9,31 | ±1,52 | 45,42 | ±4,63 | * |
| | DP | 7,14 | ±0,95 | 53,94 | ±5,55 | * | | DP | 7,54 | ±0,95 | 37,18 | ±5,90 | * |
| RFL | UP | 11,39 | ±0,52 | 70,68 | ±3,14 | * | RFL | UP | 10,96 | ±0,50 | 45,42 | ±3,34 | * |
| | DP | 12,26 | ±1,50 | 56,69 | ±5,48 | * | | DP | 12,32 | ±0,82 | 32,82 | ±5,83 | * |

**CONCLUSIONS:** From the data obtained in this study, we can come to the conclusion that, for healthy and young women without signals of low back pain, the sit-up exercises required a different muscle pattern and higher activity levels of the abdominal muscles when compared to the curl-up. This was observed in two conditions: with and without fixation of the legs. The external oblique was the abdominal muscle that showed the most acute difference. The only exception was verified for the superior portion of the rectus abdominis that was more activated, but not significantly, in the curl-up exercise. The influence of the fixation for the legs showed different effects in the sit-up and curl-up. In the curl-up the main result was a higher activation of the two portions of the rectus abdominis while in the sit-up the effect was an increase of the rectus femoris activity. For the external oblique, the highest activity was developed on the sit-up without fixation for the legs.

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