Muscle Activity in Upper and Lower Rectus Abdominus During Abdominal Exercises

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ABSTRACT. Sarti MA, Monfort M, Fuster MA, Villaplana LA. Muscle activity in upper and lower rectus abdominus during abdominal exercises. Arch Phys Med Rehabil 1996;77:1293-7.

Objective: To compare the intensity of the upper versus lower rectus abdominis (RA) muscle activity provoked by each of two different abdominal exercises and to contrast the intensity of contraction elicited by two different abdominal exercises on each RA muscle portion.

Design: Nonrandomized control trial.

Setting: Kinesiology laboratory in a university medicine faculty.

Participants: Convenience sample of 33 healthy volunteers. Subjects who had practiced endurance or strength training activities (1.5 hours 3 days a week for 3 years) and those who had not accomplished that criterion comprised a high and a low physical activity group, respectively. Each of these two groups was divided by the ability to perform the exercises into two subgroups: correct and incorrect performers (cp, ic).

Main Outcome Measure: Average surface iEMG was compared between upper and lower RA and on each muscle portion performing curl-up (CU) and posterior pelvic tilt (PT) exercises. The coefficient of variation, a two-way analysis of variance, and the *t* test were calculated.

Results: The upper RA showed significantly greater activity during performance of CU exercise by the cp subgroups of both high ($t = 2.14302$, 95%) and low ($t = 2.35875$, 95%) activity groups. Only the cp subgroup of the high activity group showed that PT was significantly more strenuous than CU exercise on lower RA ($t = -2.06467$, 95%).

Conclusions: Among correct performers, CU produces greater activity on upper RA. For persons who have a high level of activity, PT is more strenuous than CU on lower RA. Among incorrect performers, either exercise indistinctly activates the muscle portions.

THERE ARE MANY exercise methods for strengthening the abdominal muscles. Theoretically, sit-up and trunk curl-up exercises are practiced for strengthening the upper rectus abdominis (RA) muscle, and double straight leg raising or posterior pelvic tilt exercises strengthen the lower RA muscle. The justification for this regimen has not frequently been stated,[1] but it could be explained by the metameric nerve supply of the RA muscle by the anterior primary rami of the lower six or seven thoracic nerves (T6/7 to T12).[2-5]

Upper and lower RA muscle activity during abdominal exercises have been studied by electromyography (EMG).[6-12] For example Lipetz and Gutin,[10] Sheffield and Major,[11] and Monfort and associates[12] studied muscle intensity on upper versus lower RA during sit-ups, curl-ups, posterior pelvic tilt, and double leg raising exercises. These studies showed significantly greater muscle activity and duration of muscle action potentials on upper RA than on lower RA. In contrast, Flint and Gudgell,[8] Carman and colleagues,[13] and Richardson et al[14] reported that posterior pelvic tilt exercise elicited greater intensity of contraction on lower RA than on upper RA. On the other hand, Guimaraes et al[1] compared the muscle intensity of contraction on each RA muscle portion produced by double leg lifts, sit-ups, and curl-ups, and found that those exercises created similar action potentials within each RA muscle portion.

In all of the above studies,[1,7,8,10-12,14,15] individuals with different levels of physical activity or different skills in performing the exercises were not studied in the same research. To study subjects with different levels of physical activity and different skills in accomplishing the exercises, we compared the upper RA versus lower RA muscle action potentials provoked by each of two different abdominal exercises and contrasted the intensity of contraction elicited by two different abdominal exercises on each RA muscle portion.

METHODS

Subjects

Thirty-three healthy subjects were studied (13 women and 20 men). The average age, weight, and height of the women were 22.5yr, 54.7kg, and 158.37cm, respectively; for the men, 21.4yr, 74.4kg, and 175.21cm, respectively. All subjects were volunteers who had no history of chronic low back pain, abdominal surgery, heart disease, musculoskeletal dysfunction, or any other contraindications to exercise.

All volunteers completed a survey questionnaire about leisure exercise habits. The number of hours and the incidence of structured physical activity per week per subject were recorded. Structured physical activity was defined as the practice of endurance and strength training activities in a regular exercise program for at least 3 years' duration. Subjects who practiced at least $1\frac{1}{2}$ hours 3 days a week comprised the high activity group and subjects who practiced less were the low activity group. This grouping was established to optimize the results, because we predicted that people with different levels of physical activity would have different levels of skill when exercising. Informed consent to participate in the investigation was obtained from the subjects.

Instruments and Recordings

An echograph,[a] mode B dynamic wave 5MHz was used for mapping the segmentation of the RA muscle on the abdominal skin, from the xiphoid process to the symphysis pubis as first, second, third, and fourth segments, and to signal the midpoint

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Submitted for publication February 15, 1996. Accepted in revised form May 1, 1996.

Supported by Generalitat Valenciana, Conselleria de Cultura Educación y Ciencia, Project GV-1059/93.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the authors or upon any organization with which the authors are associated.

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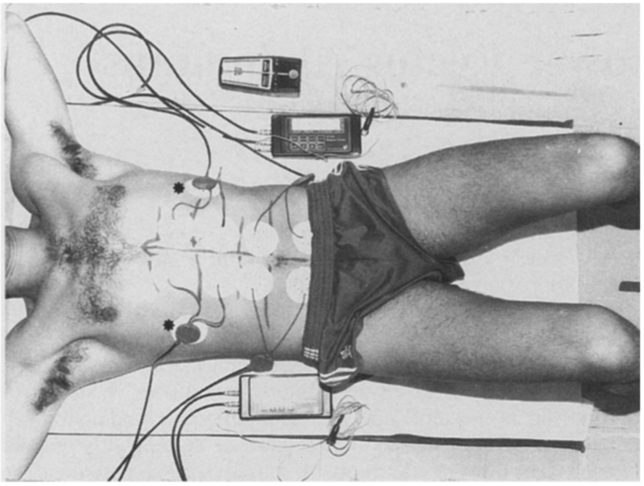

Fig 1. The two pairs of electrodes are placed on first-second and third-fourth segments of the right and left RA muscle (*, ground electrodes). One ME-3000 is placed on each side of the subject.

of each one. The echography therefore enabled the accurate identification of the number of segments, so that we could choose individuals with only four segments in the RA muscle. This made our sample more uniform.

Two portable microcomputers and two channel muscle testers (ME 3000[b]) were used to record integrated electromyography (iEMG) from right and left RA muscles. Skin preparation of the electrode sites was performed as described by Anderson and Champion.[16] Electrodes were placed parallel to the muscle fibers. The distance between the center of the two electrodes was greater than 2cm. Two pairs of surface disk electrodes (silver chloride) were placed in bipolar configuration symmetrically on each side of the abdomen and 3cm apart from the midline in the following positions: the upper portion was monitored on the geometric midpoint of the first and second segments by channel 1, and the lower portion on midpoint of the third and fourth segments by channel 2.[17,18] An earth electrode was placed on the 5th to 6th rib of both sides (fig 1).

The ME-3000 records, amplifies, and digitally stores on memory cards the electrical signal as raw and integrated electromyography. The sensitivity of the EMG preamplifier was 1 microvolt with a metering band for EMG of 20 to 500Hz. The microcomputer converted the raw EMG signals into digital signals, which were then transformed into absolute values (full wave rectification). The absolute EMG values were integrated every 0.1 second. The data stored in the ME-3000 was transferred via an optical interface to a computer and analyzed with the software version 1.4.

The performances of the exercises were recorded on a video tape with a camera (couple charge device and super video home system, Panasonic MS1[c]). Camera objective was kept in line with the coxofemoral joint on each individual and the camera was placed at a standard distance for all of the subjects (fig 2).

Procedure

Participants were taught how to perform the exercises by a physician and were instructed to maintain their pace. The warm-up was adequately performed before iEMG recordings were recorded. After resting 2 minutes, subjects were asked to take the starting position and to perform the two exercises. A set of 10 repetitions of both exercises was performed with 2 minutes of rest between them. The pace of performance was sounded out by a metronome to a speed of 60 beats per minute, one repetition every 3 seconds (one-up, two-hold, three-down).

To maximize the results and to prevent overlapping of the information from different levels of accomplishment of the exercises, the performance of the two exercises was verified as either correct or incorrect by two experienced observers. These scores were established at two different stages of the study: first, during EMG data collection, and second, when the performances of the exercises recorded on the videotape were reviewed and assessed again by each of the two observers. The scores given by each of the two observers for the performance of the exercise by each subject were compared, and any conflicts were resolved by consensus. "Incorrect performance" was considered as follows: in the curl-up exercise, when the head was lifted looking up instead of looking at navel or when some jerking movement was made by arms throughout exercise; in the posterior pelvic tilt exercise, when RA muscle was contracted and no pelvic lifting was achieved without thigh movement. "Correct performance" was considered when the exercises were accomplished as they were described.

As a result, each participant was labeled as a correct or incorrect performer of the exercises. Then, each of the two main groups of high and low activity was divided into two subgroups of correct and incorrect performers (fig 3).

Exercise Descriptions

Shoulder lift curl up: hook lying position. Knees are flexed at 90°. This is a curl-up exercise in which the subject elevates the trunk to the point where the scapula is lifted from the mat. Fingers behind the ears and elbows are maintained in line with the head throughout the movement, omitting any jerking movements (fig 2).

Posterior pelvic tilt: crook lying position. Feet are off the ground. Hips and knees are flexed at 90°, and thighs are kept without movement throughout the exercise. This exercise consists of a pelvic tilt contracting abdominal muscles to roll the pelvis backwards while pulling the pubic symphysis up towards the chest. The lumbar region touches the mat, and the sacrum bone, lliac crest, and buttocks are raised from the mat (fig 4).

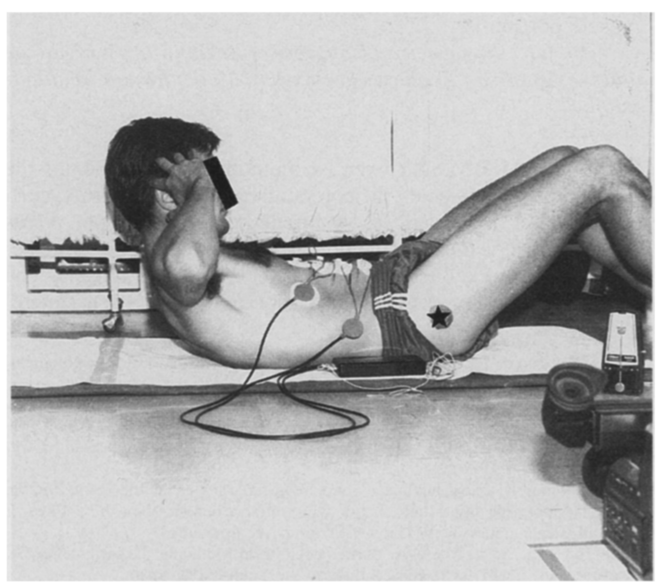

Fig 2. Shoulder lift curl-up exercise (*, signal marker at trochanter major location). The video camera is placed in line with the trochanter major.

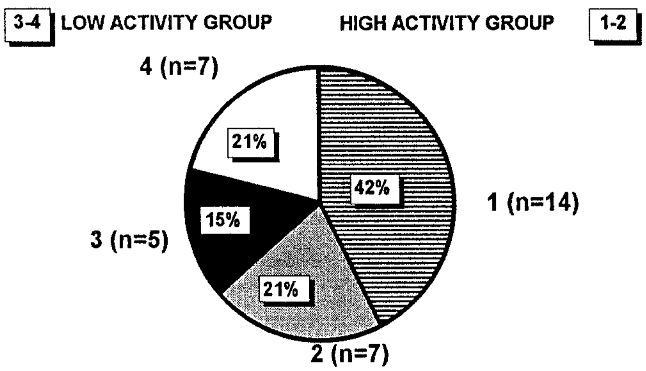

Fig 3. Subject distribution. High-activity group: correct and incorrect performer subgroups (1 and 2, respectively). Low activity group: correct and incorrect performer subgroups (3 and 4, respectively).

Data and Statistical Analysis

An interval of 24 seconds was selected from iEMG curves, which involved analyzing the 8 most central EMG deflections from a possible choice of 10. This meant eliminating the 1st and the 10th deflections in each exercise. Each deflection involved the concentric and eccentric phases of the muscle contraction. The mean muscle action potential (MAP) of this interval per exercise, per subject, and per portion of the RA was used for making the calculations. Afterwards, the mean of the MAPs for all subjects was computed in microvolts for each exercise and RA portion. Paired t test and Pearson correlation coefficients were performed to determine the reliability of the mean MAPs for each exercise and each muscular portion across eight repetitions.

Coefficients of variation were computed to compare the homogeneity among mean MAPs of different subgroups. A two-way analysis of variance (ANOVA), exercise × MAP, muscular portion × MAP, was performed to determine significant differences of activity between each muscle portion during each of the two different exercises and between two different exercises on each muscle portion. The paired t test was then applied to establish the differences between MAP means. Statistical analyses were performed with Statgraphics v.7.0.[d] The level .05 of significance was used for rejection of all null hypothesis.

RESULTS

The reliability of the test was shown by no significant differences with the t test and strong correlation coefficients ($.8808 < r < .9983$) across the eight repetitions of each of the exercises. Coefficients of variation showed the mean variability of the neural outputs during the exercises among the different subgroups (table 1).

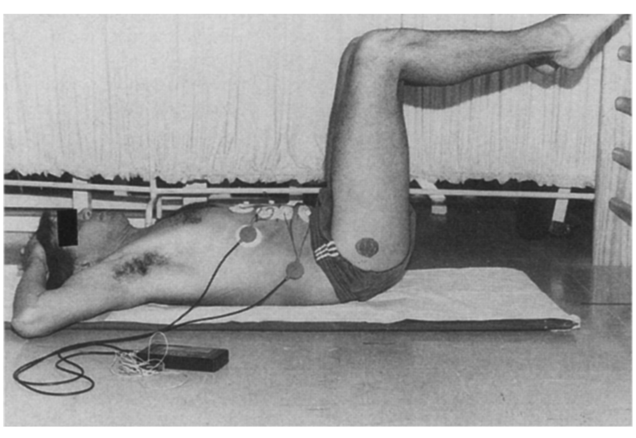

Fig 4. Posterior pelvic tilt exercise from crook lying position, flexed, hips and knees at 90°, buttocks off floor and lumbar region touching the floor.

Table 1: Coefficient of Variation of Mean MAPs During the Two Exercises Among Different Subgroups

	Correct Performers	Incorrect Performers
High activity	40.09%	93.45%
Low activity	40.02%	44.43%

The ANOVA only revealed significant differences of activity between each muscle portion during each of the two different exercises ($F = 6.802, p < .05$). The paired t test showed significant differences: recordings during the curl-up exercise showed significantly greater activity on upper RA than on lower RA. This finding was shown only by the subjects in the correct performer subgroups of both the high activity ($t = 2.14302, p < .05$) and the low activity ($t = 2.35875, p < .05$) groups (fig 5). On the other hand, only the subjects in the correct performer subgroup of the high activity group showed the posterior pelvic tilt to be significantly more strenuous than the curl-up exercise on lower RA ($t = -2.06467, p < .05$) (fig 6).

No significant differences were shown by the subjects of the incorrect performer subgroups.

DISCUSSION

Before comparing the results of this investigation with results from similar studies, an explanation of some methodological aspects will be provided. For example, to study the muscular function in kinesiological EMG, great interelectrode distances are preferred.[19] Also, the speed of the performance of the exercise seems to be an influential factor when comparing EMG to muscle tension produced by velocity of shortening.[15,21] For this reason, in the present study EMG recordings were taken on the RA on each side on each of the four muscle segments, and the speed of the performance of the exercises was controlled during data collection. However, other investigations[1,7,8,14,15,20,21] related the activity recorded in the RA muscle from standardized distances from the umbilicus and did not take the speed of the performance into consideration.[8,14,15,20] These two aspects could have been sources of bias in the results of those investigations.

The sample in this study involved persons with high and low levels of physical activity, with the assumption that persons with high levels would perform exercises more skillfully than persons with low levels, and that skilled motor performance may influence the results. These speculations were confirmed by the assessment of the accomplishments of the exercises,

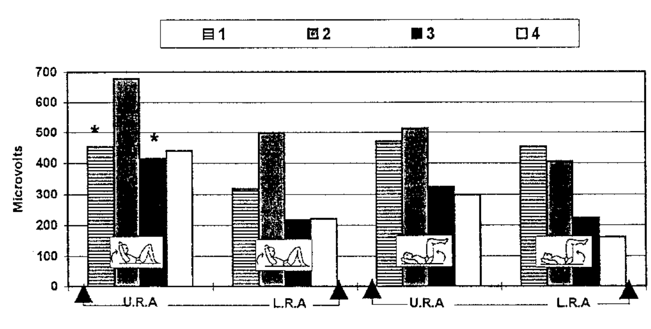

Fig 5. Comparison between the mean MAPs elicited in upper vs lower RA muscle (URA, LRA) by each of the two abdominal exercises. High activity group: correct and incorrect performer subgroups (1 and 2, respectively). Low activity group: correct and incorrect performer subgroups (3 and 4, respectively). (*, statistical significance)

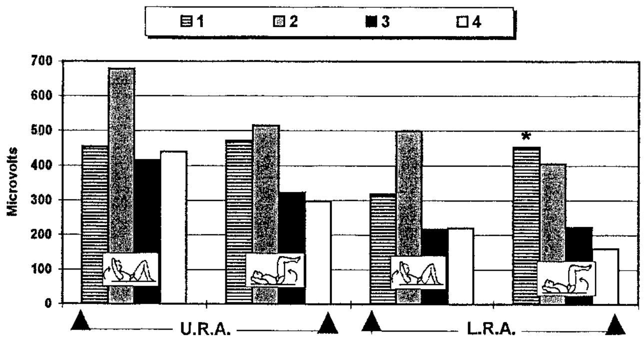

Fig 6. Comparison between mean MAPs elicited by two exercises on upper and lower RA (URA, LRA). High activity group: correct and incorrect performer subgroups (1 and 2, respectively). Low activity group: correct and incorrect performer subgroups (3 and 4, respectively). (*, statistical significance)

because the percentage of correct performers within the high activity group was greater than within the low activity group. Furthermore, this grouping was supported by significant reductions in the neural output variability as shown by smaller coefficient of variation in the subgroups of correct performers. This suggests major homogeneity among individuals included in these subgroups.[22] This grouping also showed that the results were different between the subgroups of correct and incorrect performers. Thus, this last methodological aspect in our study made the information about the topics studied in previous research[1,7,8,10,14,15,20,21] more precise.

The results of our study show that the use of the curl-up exercise significantly affected the MAP obtained for upper RA region versus lower RA. This result supports the findings of Lipez,[10] Gutin,[15] Monfort,[12] and Carman.[13] In comparison Flint[8] and Richardson[14] found that posterior pelvic tilt exercise was more strenuous on lower RA than on upper RA. This finding was not confirmed by the results of our investigation; the differences may be methodological. Flint's data[8] were not analyzed statistically. In Richardson's work[14] the placement of electrodes on lower RA muscle was restricted exclusively to the fourth RA muscle segment, and the speeds of the exercise performances were not related, which made accurate comparisons difficult; in our study, the third and the fourth muscle segments were included as lower RA, and individuals used controlled speed to perform the exercises.

The theoretical speculation that posterior pelvic tilt exercise was more strenuous than curl-ups on lower RA was only confirmed in the correct performer subgroup of the high activity group. This could not be demonstrated by Guimaraes,[1] who found that straight leg raising was not a more strenuous exercise than curl-ups and sit-ups on the lower RA. Perhaps, the differences could be due to the different types of exercise performed. Straight leg raising has not been accepted as a healthy or a strenuous exercise for strengthening abdominal muscles.[7,23-26] Nevertheless, the posterior pelvic tilt performed in our study prevented the use of hip extensor muscles to help accomplish the posterior pelvic tilt movement. The Iliaco-psoas functioned as a stabilizer muscle maintaining flexed hips at 90° throughout the movement. As a consequence, RA action was isolated as the unique muscular agonist of posterior pelvic tilt to facilitate the study of its activation.[12]

All of the above results confirmed that the ability to perform the exercises was an influential factor in proving the hypotheses, and this was reflected in the different results obtained among the subgroups of correct and incorrect performances. This suggests that the population studied in kinesiological EMG investigations should be selected in relation to the ability to perform the exercises, rather than by the level of physical activity.

On the basis of the work reported here, together with the results of earlier studies, we conclude the followings points: persons who correctly accomplish these exercises and want upper RA muscle activity should perform curl-up exercises; persons who want lower RA muscle activity can perform either curl-up or posterior pelvic tilt exercises. In addition, persons wanting a more strenuous exercise on lower RA who have a high level of physical activity should select the posterior pelvic tilt exercise from crook lying position with hips flexed at 90°.

Persons who incorrectly accomplish the exercises and are concerned about either upper or lower RA muscle activity can attempt either of the exercises.

Acknowledgment: The authors thank the following people for assistance: all the students who participated in this research, and Ms. A. Padbury, Ms. J. Boesen, and Mr. G. Holbrook for reviewing the manuscript.

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