J SPORTS MED PHYS FITNESS 1999;39:253-8

Comparison of two abdominal training devices with an abdominal crunch using strength and EMG measurements

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Background. **The purpose of this study was to compare the training effects of the Ab-Flex (F), Ab-Roller (R) and standard crunch (C) on EMG production, isometric maximum voluntary contraction (MVC), and isokinetic average peak torque at 30°/sec (ISO) of the abdominal muscles. It was hypothesized that the training devices would have similar value in a strength training program.**

Methods. **Experimental design: this was a prospective study involving 18 training sessions of progressively increasing repetitions. Setting: Neuromuscular Research Laboratory, University of Pittsburgh. Subjects: thirty-two subjects volunteered for this study, but only 26 completed the training. Each subject participated in recreational activity, but had not performed any abdominal training prior to starting this study. Each subject was randomly assigned to either the control group or one of the treatment groups. Interventions: there were three interventions: two training devices (Ab-Flex and Ab-Roller) and the standard crunch, considered a control group. Measures: the pretest consisted of skin fold measurements (%), EMG activity (V) during the three interventions, and peak torque (Nm) plus EMG during the MVC and ISO tasks. The 18 training sessions over three weeks consisted of three sets of exercise with increasing repetitions from 10 to 20, by 2, every three sessions. The difference in pretest/posttest scores were compared using a One-way ANOVA on the mean differences (Mdiff) for each of: MVC, ISO (peak torque), and EMG for upper rectus (UR), lower rectus (LR), internal oblique (IO), and external oblique (EO). A T-Test was used to detect significance for the body fat measures.**

Results. **Mean differences (Mdiff) were normally distributed about zero for both MVC and ISO (MVC= -0.55, ISO=4.57). The analysis by group showed no difference (p=0.596) on the reported means (Nm) -3.16 (C), 5.84 (F) and -4.83 (R). The change associated to the treatment during MVC was only 4% (η=0.04). For the ISO the Mdiff (Nm) were 1.39 (C), 13.66 (F) and -2.06 (R) which were not significant (p=0.127). The Ab-Flex was the only group to have a 95% confidence interval above zero, increasing by an average of 16.5%. There were no significant differences for the EMG activity for Mdiff or between group scores.**

Conclusions. **No significant differences were found with this study. These results would suggest that using these devices does not add significantly to overall abdominal strength development, or reduction of body fat. A suggestion could be made that certain devices influence muscles differently.**

KEY WORDS: Abdominal muscles - Muscle skeletal physiology - Exercise physiology - Training devices - Crunch.

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Strong abdominal musculature are considered important in both prevention and rehabilitation of lumbar pathologies. Many authors have suggested that back pain is associated with weak abdominal muscles, and strengthening of these muscles is beneficial in reducing pain.[1-4] Youdas [5] associated abdominal muscle length with standing lumbar lordosis and pel-

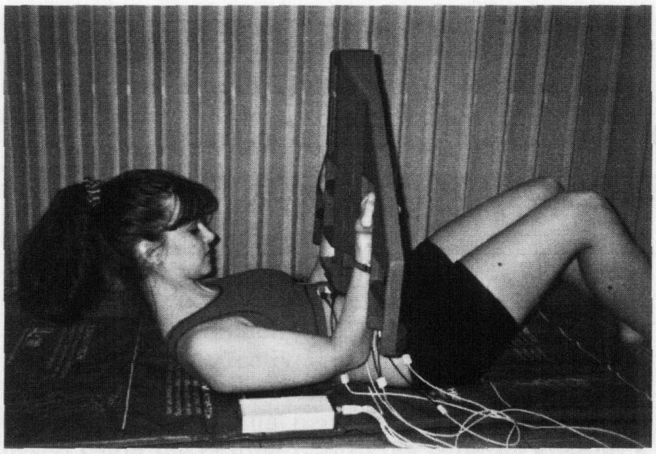

Fig. 1.—Ab-Flex in contracted position. Note different arm position than other conditions.

vic tilt angle, although no correlation was found between pelvic tilt and lumbar lordosis. The link between pain and posture with abdominal strength may come from the increased interest in pelvic and lumbar or "core" stabilization.[4-8] Norris [6] stresses the importance of pelvic control and suggests that abdominal exercises performed incorrectly will result in a muscle imbalance. The theory of stabilization is supported by Hodges and Richardson,[7] who reported an increase in abdominal and back muscle contraction in anticipation of limb movement. Luoto *et al.* noted a need for the speed of stabilization, suggesting that psychomotor reaction time was faster in those subjects without back pain, and that the reaction time can be influenced with training.[9]

Many commercial methods for improving abdominal strength are available, and manufacturers suggest that by using these devices there will be improvements in muscle strength while simultaneously protecting the back and neck. The efficacy of these abdominal devices increasing strength is not researched sufficiently. Beim *et al.*[10] compared the EMG activity produced using several devices with the activity during a standard abdominal crunch and found increased upper rectus activity with the Ab-Flex, but no long term training studies have been done. Consequently, consumers purchase these devices without experimental data and rely on anecdotal information. The main styles of device are the "roller" type where the goal is to protect the head while isolating the abdominal muscles [11] and the Ab-Flex which uses a pressure pad to impart direct resistance on the abdominal muscles. Each manufacture suggests that using the device is the optimal way to increase abdominal strength.

The purpose of this study was to compare the training effects of the Ab-Flex, Ab-Roller and standard crunch on EMG production, isometric maximum voluntary contraction (MVC), and isokinetic average peak torque at 30°/sec (ISO).

Materials and methods

This was a training study involving 18 sessions of progressively increasing repetitions. Each subject was randomly assigned to either the control group (standard crunch) or one of the two treatment (device) groups. Following the training period the difference in pretest/posttest scores were compared using a One-way ANOVA for each of: MVC, ISO peak torque, and EMG for upper rectus (UR), lower rectus (LR), internal oblique (IO), and external oblique (EO) at a preset alpha level of 0.05 ($p<0.05$).

Subjects were recruited from recreationally active population at the University of Pittsburgh. The subject pool consisted of 21 females and 5 males, and had a mean body fat percentage of 22.5% (±5.2). The mean age was 21.6 (±3.9) and the mean height and weight were 168.7 (±7.9) cm, and 61.18 (±13.9) kg, respectively.

Exercise procedures

Ab-Flex.—The subject lay supine with knees and hips flexed to a comfortable position, which generally was approximately 90 of knee flexion and 45 of hip flexion, in an attempt to reduced hip flexor involvement.[6] The Ab-Flex was held by the inside handles with the palms directed towards the subjects face. The resistance pad was placed on the stomach just above the umbilicus. The movement pattern for the subject was to pull the elbows down towards the ground creating pressure on the abdomen, while simultaneously lifting the head and shoulders as outlined by the manufacturer's protocol.[12] The subject was instructed to lift the scapulae of the ground by at least one inch (Fig. 1). This position was held for 5 seconds and then the subject returned to the starting position.

Ab-Roller.—The subject was supine with the knees and hips at approximately 90 and 45, respectively. The

Ab-Roller was positioned so that the subject's head rested comfortably on the head pad. The arms were crossed at the wrist and placed at the center of the cross bar above the head (Fig. 2).[11] The subject was instructed to lift his/her shoulders, so that the scapulae cleared the ground by at least one inch. This position was held for 5 seconds and then the subject returned to the starting position.

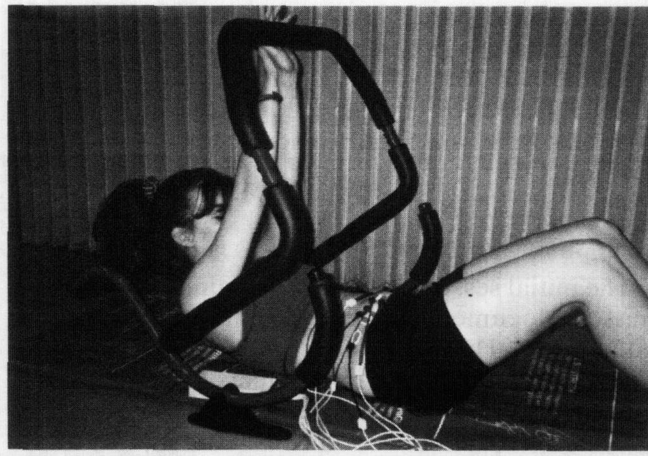
Fig. 2.—Ab-Roller in contracted position, with arms above head.

Crunch.—Again the subject was supine with knees and hips flexed to a comfortable position, (approximately 90 of knee flexion and 45 of hip flexion). The hands were behind the head or neck depending on the subject's preference, but the fingers were not locked together. The subject then lifted his/her head and shoulders so the scapulae were raised at least one inch (Fig. 3). This position was held for 5 seconds and then the subject returned to the starting position.

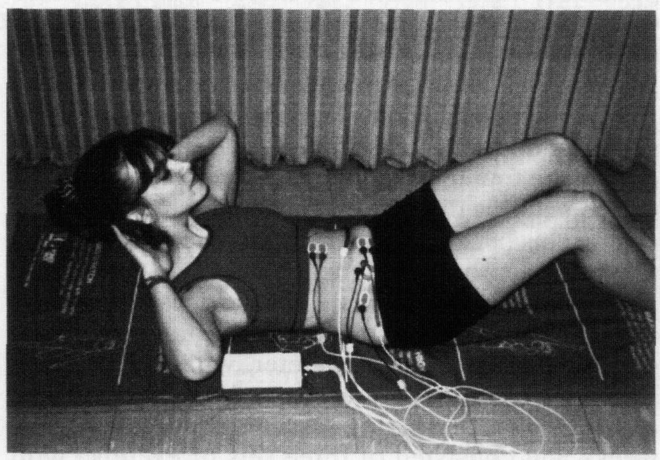
Fig. 3.—Standard crunch.

MVC and isokinetic protocol

The Biodex System II Isokinetic Dynamometer (Biodex Inc., Shirley, NY) was used for the MVC and ISO measurements. The subject sat on the Back Attachment which was fixed to the Biodex. The posterior iliac crest was lined up with the rotation point of the attachment and the feet were placed on the adjustable foot shelf so that the subject was not reaching for the foot shelf and the thighs were flush with the seat. The seat was angled to allow 80° of flexion at the hips to limit the iliopsoas form contributing to the trunk flexion. The subject leaned back against the upright body portion of the attachment, and the thoracic pad and head rest were adjusted according to the subjects height. The four securing straps were tightened around the thighs and the chest (2 each).

The Biodex, having been previously calibrated and in fixed position for subject positioning, was set at a fixed spot approximately 30° from vertical towards the posterior side. We used a straight vertical position of the subject's back as the neutral position. This generally put the back attachment arm at approximately 30° towards the extension side, because of the positioning of the thoracic pad. The subject was told not to allow an uncomfortable position as the extension stop was fixed. To improve consistency the extension stop was limited to 20° of range (-20°) for all subjects, even if they were comfortable beyond this range. The flexion stop was set at a maximum of 25° even if the subject could comfortably go beyond this range, so the maximum total range was 45°. The range stops would be less than the maximum if the subject was uncomfortable or limited in either end of the range.

During the MVC the Biodex was set at ten degrees of extension (-10°) from the neutral position of the subject. The subjects were instructed in procedure and allowed to familiarize themselves with the range of motion and resistance of the Biodex. After a short rest, and checking for transmitter power and calibration, the subjects were asked to cross their arms and contract their abdominal muscles so as to pull the shoulders towards the knees. This contraction was held for 5 seconds.

The same subject position was used for the ISO evaluation. The Biodex was set at 30°/second and the subject's starting position was at the end of extension (maximum of 20°). After the familiarization and start command the subject contracted forward to the end of allowable range and then extended back to the starting position. One set of four contractions was completed.

Testing and training procedure

The initial session consisted of signing of informed consent documents approved by the University of Pittsburgh's Health Sciences Institutional Review Board. The subjects were volunteers from the university community who were recreationally active, but were not involved in abdominal training prior to the time of data collection. Three site skin fold measurements were taken to assess percentage of body fat, and no subject was eliminated for excessive adipose tissue which could jeopardize accurate EMG signals. Each subject was randomly assigned to one of three training groups: Ab-Flex (F), Ab-Roller (R), or crunch (C).

After skin preparation, electrodes were applied to the subject's abdomen as outlined by Beim *et al.*,[10] for each of the four muscles plus a ground reference point on the anterior iliac crest. The subject was asked to contract his/her abdominal muscles to check the detection of an appropriate signal.

Each subject then used the two devices, the crunch, and performed MVC and 4 repetitions of 30°/sec (ISO) on the isokinetic dynamometer, while monitoring EMG. We recorded peak torque only during the MVC and ISO. The 18 training sessions occurred over six weeks and consisted of three sets of exercise with increasing repetitions from 10 to 20, by 2, every three sessions. Each subject followed the same training schedule. The training sessions began the first day, following the pretest. After completing the last training session the subjects scheduled the posttest which was performed on a different day. The posttest utilized the same format as the pretest, but did not include any training sessions.

Data acquisition

The Biodex was integrated with a PC equipped with MyoResearch 97 EMG software (Noraxon, Scottsdale AZ) via the Telemyo system (Noraxon, Scottsdale AZ) so torque and position movements could be analyzed in coordination with the EMG signal. The Telemyo system sampled the muscle activity at 1000 Hz with a common mode rejection ratio of 130 db, and bandpassed filtered (Burtterworth) the signal at 10 Hz (low) and 500 Hz (high). The signal was amplified (gain 500) and transferred using 8 channel FM transmitter to a receiver, where it was further amplified (gain 500, total gain 1000). The signal was then digitized by an analogue-to-digital converter (CIO DAS 330), and further processed using the MyoResearch97 software. The time interval of 5 seconds was selected for the MVC by setting markers on the signal that was normalized to the mean amplitude.

Results

The pretest/posttest mean differences (Mdiff) for strength were measured in Newton-meters (Nm) and normally distributed about zero for both MVC and ISO (MVC= -0.75, ISO= 6.19 Nm). Analysis by group showed no difference in MVC (p=0.596). The Mdiff for the MVC were at -4.28 (C), 7.91 (F) and -6.55 (R) Nm. with a StDev (pooled) of 31.6 Nm. The findings of the ISO Mdiff were 1.88 (C), 18.52 (F) and -2.79 (R). with a StDev (pooled) of 21.96 Nm, which again was not significant (p=0.127). In the ISO test the Ab-Flex device users were the only group to have a 95% confidence interval above zero suggesting an increase from pretest to posttest. The change associated to the treatment during MVC test was only 4% (η=0.04) whereas the change associated with the treatment for ISO was 16.5% (η=0.16). The MVC and ISO results (mean, s.d.) are presented in Table I.

EMG Mdiff measured in microvolts (V) for each muscle examined was not significant among groups (UR p=0.764, LR p=0.513, IO p=0.358, EO p=0.340). Large standard deviations were associated with these means. The UR Mdiff showed a positive score with the Ab-Flex. Positive changes for the LR were associated with both devices, but not the crunch. EO positive changes were found only in those subjects using the roller style device and the IO had positive Mdiff scores for all groups. There was no significant difference on pretest posttest body fat percentage. The EMG results are presented in Table II.

Discussion

No significant differences between the training devices were found with this study, so the effectiveness

TABLE I.—*Pre- and post-test mean and SD values by group for skin fold measurements (%), isokinetic and isometric strength (peak torque, Nm).*

Exercise	Skin-fold				Isokinetic strength				Isometric strength			
	Pre		Post		Pre		Post		Pre		Post	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ab-Flex	21.3	6.2	20.9	5.8	75.43	35.39	71.90	31.09	67.58	40.08	71.90	31.09
Ab-Roller	22.8	4.1	23.8	4.0	75.45	32.59	73.93	36.65	62.23	28.92	58.67	35.01
Crunch	23.5	5.3	24.1	5.7	66.01	23.34	67.04	14.47	55.74	32.91	53.40	17.97

TABLE II.—*EMG (μV) mean and SD values by group for upper rectus, lower rectus, internal and external obliques.*

Exercise	Upper rectus				Lower rectus				Internal oblique				External oblique			
	Pre		Post		Pre		Post		Pre		Post		Pre		Post	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Crunch	848.5	651.1	727.6	576.9	377.2	410.6	325.8	284.5	229.9	180.6	249.3	163.9	152.4	89.3	125.4	75.5
AB-Flex	507.8	258.4	546.7	259.5	458.5	377.8	503.4	371.7	205.9	188.8	234.2	128.3	173.1	135.2	112.2	53.9
AB-Roller	817.8	317.8	808.4	511.8	513.7	354.4	617.3	585.6	168.7	49.8	298.4	189.5	208.7	189.1	233.3	254.9

of either device is not supported. Excessive pooled standard deviations for the MVC and ISO could account for the lack of significant difference. Examining the confidence intervals allows us to suggest a clinical relevance that may exist, but are not supported by p-values.

The Ab-Flex group was the only group to show a positive mean for the MVC difference score, and it is possible that there was an increase in strength for this group. This suspicion is consistent with the ISO Mdiff. One possible explanation of the improvements in the MVC and ISO strength while using the Ab-Flex could be the tactile sensation that is given by this device. Tactile sensation is reported [13] to aid muscle contraction. This sensory information could account for the increase in MVC and ISO means due to contact with the abdomen. The position of the Ab-Flex supports this theory because it is placed on the upper abdominal muscles, above the umbilicus. The direct pressure is similar to the use of a medicine ball, creating an "artificial joint",[12] while protecting the back. Our EMG results support this increase in strength as measured by muscle activity by recording a positive Mdiff score for the UR in this group, where as the other groups showed negative mean differences. This result is in support of Beim who found an increase in UR EMG activity using the Ab-Flex, when compared with other devices.[10]

Interestingly, the IO and EO recorded higher levels of EMG activity with the roller device. Although there were no twists or turns associated with the training we expected the pressure of the Ab-Flex pad would increase the IO and EO contraction in a stabilizing fashion. This increased contraction would increase intra-abdominal pressure which would be beneficial in stabilization as suggested by Norris [6] and Cresswell,[14] yet this was not found in the Ab-Flex group. One possible explanation for this increase with the Ab-Roller is due to the arm position. The curling portion of the exercise was similar across devices, but the arm position for the Ab-Roller was crossed over the head (Fig. 2). This position may have altered the efficiency of the abdominal muscles, and limb movement is shown to have an effect on reactive forces of the transverse abdominis and the oblique muscles.[7]

Although we cannot recommend these devices based on the merit of improving strength, we would suggest that these devices possibly could aid some individuals in their motivation to do abdominal exercises. Although we did not include any questionnaire or other evaluation of the subject's motivation, we did anecdotally notice subjects approval or disappointment with the group to which they were assigned. The disappointment appeared to mostly be associated with the control group subjects, and the device groups were pleased that they were not assigned to the control group.

Limitations of this study that could account for the lack of significant results could be that the 18 session training period was not sufficient in length, that there were not enough subjects to detect the small ETA, or the high variability associated with the EMG and isokinetic dynamometer results during our testing. Although we attempted to choose methods of exercise that used similar movement patterns, we did not use any motion analysis to confirm the similar nature of each device pattern. Anderson [15] found an increase in activation of the abdominal muscles as the flexion angle increased during trunk flexion. Sarti *et al.*[16] found different EMG activity levels between the UR and LR when performing a pelvic tilt compared to a curl up in trained individuals. In untrained individuals there was no distinction between muscle when performing pelvic tilt or curl up. It is possible that if some of our subjects adjusted the method they used to contract their abdominal muscles, from a trunk curl up towards a pelvic tilt, the altered angle of pull could in turn alter the EMG activity.

Conclusions

We found no statistical differences when comparing EMG or strength between training groups using the Ab-Flex, the Ab-Roller plus, or an abdominal crunch. There is some clinical suggestion that the Ab-Roller will aid in generating more internal and external oblique EMG activity, while the Ab-Flex may generate higher upper rectus EMG activity. Although the Ab-Flex group had higher means for strength gains, they were not statistically different. Within the limitations of our results we would suggest that these devices do not add significantly when concerned with overall abdominal strength development, improving the neuromuscular input to the abdominal muscles, or a reduction of body fat.

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