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Electromyographical Analysis and Comparison of Selected Abdominal Training Devices With a Traditional Crunch

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Abstract. Sternlicht, E., S.G. Rugg, M.D. Bernstein, and S.D. Armstrong. Electromyographical analysis and comparison of selected abdominal training devices with a traditional crunch. *J. Strength Cond. Res. 19(1):157–162. 2005.*—The present study compared the muscle activity elicited by selected abdominal training devices with muscle activity elicited by a traditional crunch. Forty-six adults participated in the study. The exercise devices tested included the Ab-ONE, Perfect Abs Roller, Ab Scissor, Ab Swing, 6SecondAbs, and the Torso Track. For those devices with variable resistances, all were tested at their high resistance setting. Surface electromyography (EMG) was recorded from the upper and lower portions of the rectus abdominis and the external oblique during each repetition. EMG values were analyzed using repeated measures analyses of variance (ANOVA) and pairwise comparisons. EMG measurements for each abdominal muscle analyzed were highly reliable and differed significantly across the exercises tested. Muscle activity for the upper and lower portions of the rectus abdominis for a normal crunch was lower than for the Ab-ONE, the same as for the Perfect Abs Roller, and higher than for the Ab Scissor, Ab Swing, 6SecondAbs, and Torso Track. External oblique muscle activity for a traditional crunch was higher than for the Perfect Abs Roller and did not differ from the other devices. These results support previous findings that portable abdominal devices are most effective if they not only mimic the mechanics of a traditional crunch, but also provide external resistance to increase involvement of the abdominal musculature.

Key Words. crunches, resistance exercise, muscle recruitment, portable training devices

Introduction

Over the past 3 decades dozens of portable abdominal exercise devices have been developed and marketed. The home exercise device market is a multi-billion dollar industry, with one of the most popular devices focusing on training the abdominal muscles. Of those devices currently or previously sold, only a few have been tested and proven to be more effective than a crunch, while many have been found to be equally or less effective than a traditional crunch at eliciting abdominal and external oblique muscle activity (1–3, 5, 18, 21, 22).

Strengthening the abdominal muscles is desired for trunk stability, injury prevention and rehabilitation, reduction of low back and lumbar pathologies, athletic performance, and general appearance. One of the greatest challenges consumers face is the selection of appropriate exercises and variations in equipment that best isolate and target the abdominal musculature. Typically, consumers and "experts" alike rely on anecdotal information or personal experiences to determine exercise technique. A more precise determination and quantification of exercise effectiveness can be made, however, with the use of electromyographical analysis. Numerous electromyographic (EMG) studies have been performed to assess the involvement of the anterior trunk muscles during various types of abdominal exercises in adults and children (1–15, 17–22).

Because the principal reason for performing a crunch or sit-up is to train the abdominals and not the hip flexors, the motion should be performed to minimize hip-flexor activity. In contrast to a sit-up, a crunch is typically performed by lifting only the head and shoulder blades off the floor. This not only minimizes lumbar motion but also reduces psoas activation, and therefore reduces the compressive and shear stress on the lumbar vertebra (9). Numerous exercises designed to target the lower portion of the rectus abdominis, however, generally recruit the stronger hip flexor muscles and result in less recruitment of the lower portion of the rectus abdominis. Differences in muscle activation between the upper and lower portions of the rectus abdominis have been shown when performing crunch-type motions (17, 18, 22). In addition, it has been well documented that the oblique muscles are significant contributors to trunk flexion along with the rectus abdominis (1–14, 17–22). This study will compare the muscle activity of the upper and lower portions of the rectus abdominis and the external oblique while performing crunch-type motions as dictated by the various portable devices tested.

According to Beim et al. (2), the Abflex abdominal training device was significantly more effective than a crunch at recruiting the upper rectus abdominis muscle. Although they showed the Abflex to be more effective than a crunch at recruiting the upper rectus abdominis, no differences existed between the Abflex and the crunch for the other abdominal muscles tested. Due to the limited number of subjects, 12, and the use of multiple paired *t*-tests used in their statistical analysis instead of an analysis of variance (ANOVA), no comparison between the other devices was made.

A second study by Demont et al. (3) compared the Abflex and Ab Roller to a standard crunch and found no significant differences between groups. The 6-week training study not only examined mean EMG activity, but also measured skin fold, isometric maximum voluntary contraction, and isokinetic average peak torque at $30^{\circ}\cdot s^{-1}$ of the abdominal muscles. While all the values were nonsignificant at the $p < 0.05$ level, the Abflex was the only group to show a positive pretest to posttest improvement, increasing by an average of 16.5%.

Since the initial studies on the Abflex in the late

1990s, the Ab-ONE was designed to incorporate the technology used in the Abflex with significant modifications and improvements. The current study was designed to look at the effectiveness of the Ab-ONE in comparison to other portable home abdominal exercise devices as well as to the traditional crunch.

Traditionally, the crunch exercise is the standard by which other abdominal exercises are compared for training the abdominal musculature. The Ab-ONE was designed to allow users to perform the crunch movement with variable resistance. For this reason it was hypothesized that the Ab-ONE was more effective at recruiting and training the abdominal musculature than a crunch.

The purpose of this study was to compare 6 portable abdominal training devices with a traditional abdominal crunch. The portable devices tested included the Ab-ONE, Ab Scissor, Ab Swing, 6SecondAbs, Perfect Abs Roller, and the Torso Track device. The current study examined and compared the recruitment patterns of the upper and lower regions of the rectus abdominis and the external oblique during each exercise. Measurement reliability was assessed to determine the overall quality of the data set and whether normalization of the data was warranted. A large sample size combined with a repeated measures experimental design provided powerful tests for differences among types of exercise, with appropriate protections against spurious inflation of type I error rate.

Methods

Experimental Approach to the Problem

In this study we wanted to determine if the 6 portable abdominal training devices used were as effective at recruiting the abdominal muscles as a traditional crunch. Mean EMG recordings from the upper and lower portions of the rectus abdominis and external oblique from 46 subjects provided data needed to evaluate the effectiveness of each device. All subjects performed a full crunch (head, neck, and shoulder blades raised from the floor) and were then instructed to duplicate that range of motion as closely as possible with each device, independent of whether they were seated or in the supine position. To ensure valid comparisons in our EMG data, velocity of movement was also controlled across devices and subjects. Over the years of testing numerous abdominal devices, we have found that our male and female subjects produced similar abdominal muscle activity patterns across devices. For that reason we did not separate the data by gender.

Subjects

Forty-six healthy adult volunteers (20 men and 26 women) participated in this study. The subjects' mean ± *SD* for age, height, and body mass were 21.4 ± 5.3 years, 67.5 ± 3.4 in., and 143.2 ± 26.8 lb, respectively. Subjects were instructed on how to use each device and perform each exercise properly prior to collecting data. After receiving an explanation of the experimental protocol, each subject practiced the proper technique for using each device and signed a university-approved informed consent form. All subjects were free of acute or chronic low back pain or injury prior to the study. Subject selection was limited to individuals with sufficiently low subcutaneous adipose tissue to permit accurate measurement of muscle activity.

Exercise Devices

Six portable exercise devices were tested. These devices included the Ab-ONE (E-Coach USA, LLC, Carlsbad, CA), Perfect Abs Roller (Guthy-Renker, Santa Monica, CA), Ab Scissor (Body by Jake Enterprises, Inc., Los Angeles, CA), Ab Swing (DCD, Inc., Malibu, CA), 6SecondAbs (Savvier, LP, Van Nuys, CA), and Torso Track 2 (Fitness Quest, Inc., Canton, OH). For those devices with variable resistances, all were tested at their highest resistance setting.

For the Ab-ONE movement, the subjects lay supine on the floor in a similar position to a crunch, with 45 degrees of hip flexion and 90 degrees of knee flexion in order to minimize hip flexor activity. The Ab-ONE consists of a banded resistance device held with an underhand grip, palms facing towards the subject's face with the pad of the device placed on the stomach at the level of the umbilicus. The movement consisted of the subject's pulling the elbows down towards the floor creating pressure on the abdomen while simultaneously performing a crunch motion.

The Perfect Abs Roller consists of tubular construction shaped to roll forward and backward as the person performs a crunch motion. During the motion the subject's head rests on a pad and the subject's arms are raised with the elbows resting on pads and hands holding the tube crossing overhead.

Used in a seated position, the Ab Scissor combines a crunch motion with a leg raise using the subject's body weight as resistance. Subjects grasp 2 handles that extend overhead and place their feet on a platform while sitting on the seat. Both the arms and feet move together and apart during the movement. The foot platform rises toward their downward moving arms during the concentric phase of the movement, and both reverse their actions during the eccentric phase.

The Ab Swing consists of an angled pad the subjects sit on while placing their feet on a foot bar and holding a handle that is at waist level. The seat rocks backwards as the feet and foot bar swing upward off the ground. During the movement subjects simultaneously flex at the hip, raising their legs, and flex their truck, moving their torso forward. Depending on the height of the hips relative to the pivot point, the resistance decreases the further the hips are above the pivot point.

The 6SecondAbs is a plunger-type device that provides resistance as the subject performs trunk flexion in a seated position. Subjects sit in an upright position with the device resting on their thighs and extending upwards. The subjects hold the 2 handles with a reverse grip and palms facing toward them. Clicking noises provide feedback that 1 complete concentric contraction and 1 complete eccentric contraction have been performed.

The Torso Track 2 is a variable resistance device that is based on the fundamental principle of the roller wheel. It requires the user to perform the movement in a kneeling position.

Experimental Design

After appropriate instruction on the proper technique for using each device and for executing a proper crunch, subjects performed 1 set of 8–10 repetitions for each abdominal exercise. Since most portable abdominal devices mimic the mechanics of performing a crunch and not a sit-up, this study used the traditional crunch as the cri-

TABLE 1. Mean electromyographic values (mean ± *SD*) for the 7 exercises tested ($N = 46$).

Device	Muscle (volts)		
	Upper rectus abdominis	Lower rectus abdominis	External oblique
Ab-ONE (supine position)	**1.72 ± 1.01**	**0.76 ± 0.38**	0.60 ± 0.39
Ab Scissor	0.87 ± 0.59*	0.35 ± 0.15*	0.67 ± 0.42
Ab Swing	0.47 ± 0.27*	0.25 ± 0.11*	0.62 ± 0.32
6SecondAbs	0.86 ± 0.68*	0.30 ± 0.14*	0.45 ± 0.25
Perfect Abs Roller	1.30 ± 0.72	0.54 ± 0.26	0.41 ± 0.27*
Torso Track	0.95 ± 0.63*	0.45 ± 0.24*	0.52 ± 0.26
Crunch	1.36 ± 0.79	0.58 ± 0.28	0.53 ± 0.31

* Indicates significantly lower muscle activity relative to a traditional crunch. **Bold** indicates significantly higher muscle activity relative to a traditional crunch. $p < 0.05$, using Dunnett's test to hold α at 0.05.

terion measure. Condition testing order was randomized across subjects, and all data for each subject were collected during a single session. All subjects performed a full crunch (head, neck, and shoulder blades raised from the floor) and were then instructed to duplicate that range of motion as closely as possible with each device, independent of whether they were seated or in the supine position. For most devices this was the range of motion they selected without our instruction.

To ensure temporal consistency, each subject was instructed to perform each set with a given device, and across devices, at a constant speed during the concentric and eccentric phase. A metronome was used to pace each phase of the movement at a rate of 2 seconds per phase (concentric and eccentric). Sufficient rest was allowed between trials to avoid fatigue. None of the subjects commented that they felt fatigued at any point during the data collection session. The EMG activity was assessed for 5 consecutive crunches in each set. The criterion measure was the mean EMG value for each set.

In the traditional crunch, hips and knees were flexed to approximately 45 and 90 degrees, respectively, with the hands at the sides of the subject's head. Each subject was instructed to flex his or her trunk so the head and shoulders, and therefore scapulas, would clear the mat. The same instructions were used for the Ab-ONE (supine position) and the Perfect Abs Roller, with the exception that the hands were on the handles of each device instead of at the sides of the head. For each of the other 4 devices, instructions were followed as described in each owner's manual. Starting from a vertical position, the same crunch motion was performed using the Ab Scissor, Ab Swing, and 6SecondAbs.

EMG Recording

Muscle activity was measured using a standard noninvasive EMG system (BIOPAC Systems, Inc., Goleta, CA). Electromyographical recordings were collected using silver-silver chloride bipolar surface electrodes (EL208S, BIOPAC) placed on the skin overlying the right upper portion of the rectus abdominis (URA), right lower portion of the rectus abdominis (LRA), and the right external oblique (EO). An unshielded ground electrode (EL208, BIOPAC) was placed on the skin overlying the acromion process. The electrodes were oriented parallel to the muscle fibers with an interelectrode distance of approximately 1.5 cm. Prior to electrode application, the skin over each electrode was shaved and cleansed with alcohol to reduce the impedance at the skin electrode interface. EMG signals were sampled at 1,000 Hz per channel and amplified (gain of 5,000) and band-pass filtered (10–400 Hz) using BIOPAC Systems amplifiers. Signals were then passed through a BIOPAC Systems Model MP150 connected to an IBM i1200 laptop computer for analysis.

Statistical Analyses

Statistical analyses of EMG values were performed using SPSS Version 11.5.1 (SPSS Inc., Chicago, IL). First, the intraclass correlation coefficient (ICC) for each muscle group was calculated as an index of measurement reliability. Second, overall differences among the 7 types of exercise, effect size, and observed power were examined with a repeated measures ANOVA on data for each muscle group; the Greenhouse-Geisser correction was used, as is recommended for repeated measures with more than 2 levels (24). Finally, a set of pairwise contrasts compared each of the 6 devices to the traditional crunch. The F value generated by SPSS for each contrast was evaluated for significance against Dunnett's critical value, which is designed to prevent inflation of type I error rate (α) specifically during comparison of multiple means to a single control condition (24). Differences between means were deemed statistically significant when $p \leq 0.05$.

RESULTS

Mean EMG values ± *SD* for the upper and lower portions of the rectus abdominis and the external oblique for each exercise tested are shown in Table 1. These means represent the data subjected to statistical analysis. A simple transformed measure of muscle activity was also calculated: Because the effectiveness of the devices relative to the crunch is of interest, Table 2 and Figure 1 show the EMG values for the 6 devices expressed relative to values during the crunch. These values were obtained by dividing the mean for a device by the mean for the crunch ($\times$ 100), such that muscle activity half that of the crunch would equal 50%, twice that of the crunch would equal 200%, and so on. This transformation makes the magnitude of differences more apparent to the eye.

Upper Portion of the Rectus Abdominis

Measurement of upper rectus abdominis activity was highly reliable (ICC = 0.86, $p < 0.001$), suggesting that normalization using maximal voluntary contraction or other standard was unnecessary and possibly even undesirable. Pairwise contrasts using Dunnett's test showed that the Ab Scissor, Ab Swing, 6SecondAbs, and Torso Track each elicited significantly less URA activity than a traditional crunch, $p < 0.05$ for all. URA activity for these devices was, respectively, 36, 65, 37, and 30% less than

TABLE 2. Percent difference of mean electromyographic (EMG) values relative to a traditional crunch ($N = 46$).*

Device	Muscle (volts)		
	Upper rectus abdominis (URA)	Lower rectus abdominis (LRA)	External oblique (EO)
Ab-ONE (supine position)	126	131	113
Ab Scissor	64	60	126
Ab Swing	35	43	117
6SecondAbs	63	52	85
Perfect Abs Roller	96	93	77
Torso Track	70	78	98
Crunch	100	100	100

* Because the crunch is the standard to which the other exercises were compared, the EMG values for the URA, LRA, and EO during the crunch were assigned a value of 100%.

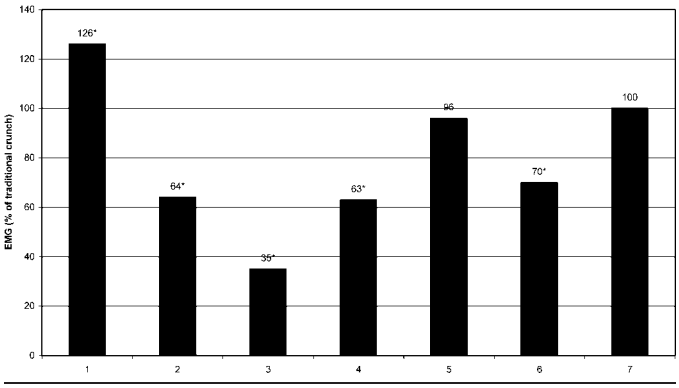

FIGURE 1. Percent difference of mean electromyographic (EMG) values for the upper rectus abdominis relative to the traditional crunch. The exercises tested were, numbered above in order, the Ab-ONE (supine position), Ab Scissor, Ab Swing, 6SecondAbs, Perfect Abs Roller, Torso Track, and the traditional crunch. The asterisk indicates significant differences in muscle activity relative to a traditional crunch, $p < 0.05$.

for the crunch (Table 2 and Figure 1). In contrast, the Ab-ONE performed in the supine position exhibited significantly greater URA activity than the crunch, $p < 0.05$; its advantage was 26% (Table 2 and Figure 1). The mean for the Perfect Abs Roller was not significantly different from a traditional crunch.

Lower Portion of the Rectus Abdominis

Measurement of lower rectus abdominis activity was highly reliable (ICC = 0.71, $p < 0.001$). Pairwise contrasts using Dunnett's test showed the same pattern of results as for URA: the Ab Scissor, Ab Swing, 6SecondAbs, and Torso Track each elicited significantly less LRA activity than a traditional crunch, $p < 0.05$ for all. LRA activity for these devices was, respectively, 40, 57, 48, and 22% less than for the crunch (Table 2 and Figure 2). The Ab-ONE performed in the supine position exhibited significantly greater LRA activity by 31% (Table 2 and Figure 2), and the mean for the Perfect Abs Roller was not significantly different from a traditional crunch.

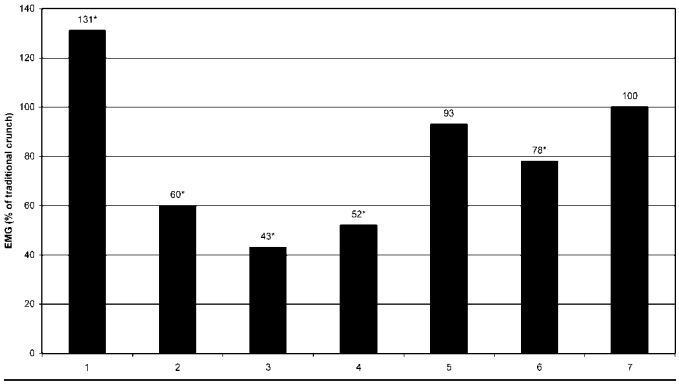

FIGURE 2. Percent difference of mean electromyographic (EMG) values for the lower rectus abdominis relative to the traditional crunch. The exercises tested were, numbered above in order, the Ab-ONE (supine position), Ab Scissor, Ab Swing, 6SecondAbs, Perfect Abs Roller, Torso Track, and the traditional crunch. The asterisk indicates significant differences in muscle activity relative to a traditional crunch, $p < 0.05$.

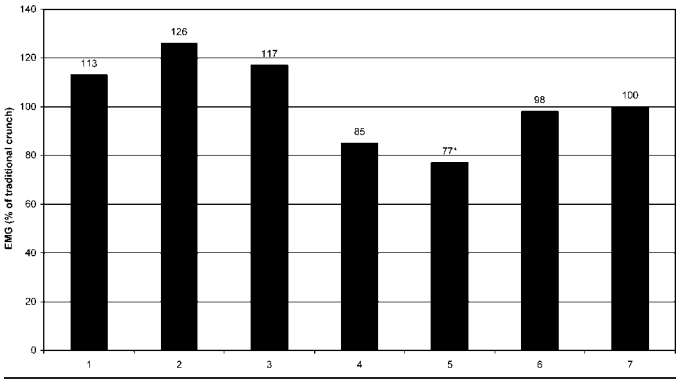

FIGURE 3. Percent difference of mean electromyographic (EMG) values for the external oblique relative to the traditional crunch. The exercises tested were, numbered above in order, the Ab-ONE (supine position), Ab Scissor, Ab Swing, 6SecondAbs, Perfect Abs Roller, Torso Track, and the traditional crunch. The asterisk indicates significant differences in muscle activity relative to a traditional crunch, $p < 0.05$.

External Oblique

Measurement of external oblique activity was highly reliable (ICC = 0.83, $p < 0.001$). Pairwise contrasts using Dunnett's test showed that the Perfect Abs Roller was the only exercise device that elicited significantly lower activity in the EO than a traditional crunch, $p < 0.05$ (23% less; Table 2 and Figure 3). No other means differed significantly from a traditional crunch.

DISCUSSION

As previous studies have shown, portable abdominal exercise devices used in the upright position elicit minimal abdominal muscle activity unless adequate resistance is provided (1, 6, 12, 18, 19). Resistance is required because gravity and momentum of the torso falling forward provide ample assistance to trunk flexion and limit muscle recruitment. For example, in this study the Ab Scissor, Ab Swing, and 6SecondAbs were used in the seated position and elicited significantly less muscle activity in the

upper and lower portion of the rectus abdominis than a traditional crunch, which is performed in the supine position.

This study also supports previous findings (3, 18, 22) that there is no significant difference in rectus abdominis muscle recruitment between the roller-type devices and a traditional crunch. Since roller-type devices are designed primarily to facilitate proper form without adding any external resistance, no increase in abdominal muscle activity should be expected when compared with a traditional crunch. The Perfect Abs roller was also the only device to elicit significantly less external oblique muscle activity than a crunch. One possible explanation for the lower external oblique activity is due to the added support the device provides to the torso, thus limiting rotation and necessary recruitment of the oblique to stabilize and support the torso from lateral rotation (9, 11, 14, 23).

The present study found that for the portable devices tested, the Ab-ONE was the only device to elicit significantly more EMG activity in the upper and lower portions of the rectus abdominis than a crunch. These results support those of Beim et al. (2), who found significantly greater muscle activity in the upper rectus abdominis for the Abflex relative to a traditional crunch.

The primary mechanism by which the Ab-ONE works is by placing additional resistance on the abdominal musculature due to the resistance provided by the elastic bands on the handle of the device and by the unit as a whole. Because of the mechanics of the Ab-ONE, the device is placed directly on the abdominal musculature at the level of the umbilicus and direct pressure is applied to the abdomen. Combined with the external and internal oblique and transverse abdominis muscles, all of the abdominal muscles play an important role in supporting and protecting abdominal viscera (internal organs). A secondary contributor to the increased rectus abdominis EMG activity therefore, appears to be a protective response of the abdominal musculature to the applied force of the unit on the abdomen.

Despite manufacturers' claims to the contrary, and like the findings of previously marketed devices that have been found to be less effective than a traditional crunch at recruiting the abdominal musculature (18, 19), the present study found the Ab Scissor, Ab Swing, 6SecondAbs, and the Torso Track to be significantly less effective than a traditional crunch at eliciting rectus abdominis muscle activity.

Research on abdominal exercise devices can also be applied to rehabilitation. Being able to vary position and intensity provides the possibility of progression for both exercise and rehabilitation as the subject improves his or her condition. For example, we have found varying degrees of abdominal muscle recruitment when performing a crunch movement on a stability ball (unpublished data). Significantly less abdominal muscle activity is recorded when the ball is placed directly under the scapula and significantly more muscle activity is elicited than a crunch when the ball is placed directly under the lumbar curve of the vertebrae.

In addition, finding effective abdominal exercise devices used in an upright position is helpful for patients who are limited to a seated as opposed to a supine position. In an earlier study (18), we reported on 1 such device, the Perfect Abs, which, when used in a seated position with a high resistance band, was as effective as a traditional crunch. When the Perfect Abs was used in the supine position with either the medium or high resistance band, however, it was more effective than a crunch at recruiting the abdominal musculature.

While all 6 devices elicited abdominal muscle activity, only the Ab-ONE for the URA and LRA was more effective than a traditional crunch at eliciting selected abdominal muscle activity. For the selected muscles, only the Ab-ONE provided adequate external resistance to elicit significantly greater rectus abdominis recruitment than a crunch.

Practical Applications

Contrary to many of the claims accompanying several of the devices tested, the AB Scissor, AB Swing, and 6SecondAbs were significantly less effective than a crunch at eliciting upper and lower rectus abdominis activity. Specifically, in the case of the 6SecondAbs, we found that, when used in the seated position, the device elicited 37 and 48% less activity for the URA and LRA, respectively, than a crunch—not more effective as implied in their advertising and infomercial. Similarly, the Ab Swing elicited 65 and 57% less activity for the URA and LRA, respectively, than a crunch. Based on these and other published results, it appears that more testing and verification of claims should be required prior to marketing and advertising of products. In addition, greater consumer education is necessary to make consumers more wary of unsubstantiated manufacturer claims. While some products are in fact effective, and in some cases significantly more effective than a traditional crunch, at recruiting and training the abdominal musculature, the majority are, at best, no more effective than a simple crunch.

It should be noted that the 6SecondAbs device would be more effective if used in the supine versus seated position. We selected to test the device in the seated position because the product manual and infomercial emphasize its use in the seated position. In the brochure that accompanies the device, however, a statement indicates that for a more effective workout the exercises can be performed in the supine position. The point being made here is that a device's effectiveness is dependent not only on its mechanical properties, but also on the technique of performing the crunch motion using the device and the way each research group decides to define effectiveness. If the quantity of muscle activity per repetition is used to determine device effectiveness, then every device, including the traditional crunch, would be deemed more effective if the crunch motion was performed more slowly. It is also true that, if EMG amplitude is to be used as a criterium measure, then the speed at which the exercise is performed would affect the EMG amplitude and, therefore, the exercise's effectiveness. Although using variable speeds and ranges of motion (ROM) may more accurately reflect the way the average person selects to use different devices or perform a movement, the data collected from such a study would more accurately reflect the effectiveness of the technique used rather than the effectiveness of the device being studied. It is not the nature of this study to determine how best to use each device to maximize its effectiveness, but rather, given similar speed and ROM across devices, to determine which device elicits the most muscle activity. The consumer, however, is typically unaware of methodological differences across studies and

therefore is often misled by the reported efficacy of a device.

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