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A Kinematic Comparison of Four Abdominal Training Devices and a Traditional Abdominal Crunch

WILLIAM A. SANDS[1] **AND JENI R. McNEAL**[2]

[1]*Department of Kinesiology, California Lutheran University, Thousand Oaks, California 91360;* [2]*Department of Physical Education, Health, and Recreation, Eastern Washington University, Cheney, Washington 99004.*

ABSTRACT

Abdominal exercises are often performed on roller or rocker mechanisms, which have been aggressively promoted through the television and print media. However, justifications are lacking as to why these devices are superior to traditional abdominal exercises such as crunches. This study sought to describe and compare the range of motion (ROM) of several joints during crunches performed on 4 different abdominal conditioning devices (2 roller and 2 pivot types) and a traditional crunch exercise. Ten men (29 ± 5.87 years, 177.5 ± 6.46 cm, 80.96 ± 11.72 kg) and 10 women (33.4 ± 10.16 years, 162.23 ± 3.83 cm, 56.99 ± 7.36 kg) subjects agreed to participate in the study. Subjects were videotaped in the sagittal plane (60 Hz) using standard kinematic methods. Reflective markers were placed on the right temple, auditory meatus, shoulder, hip, knee, ankle, heel, toe, and 2 sternum markers placed on a foam piece strapped to the subject's chest. The videotaped movements were automatically digitized (PEAK5 2-D) and the data smoothed using a Butterworth filter. Relative angular ROMs of the head (temple, auditory meatus, shoulder); neck (auditory meatus, shoulder, hip); trunk (near sternum, shoulder, hip); hip (shoulder, hip, knee); sternum/head (sternum near and sternum far with temple and auditory meatus); sternum/trunk (sternum near and sternum far with shoulder and hip); and a sum of 4 angles (head, neck, trunk, hip) were calculated. Sex by equipment repeated measures analyses of variance (ANOVAs) were calculated on the angles of the 5 exercises. When no main effect for sex was found, the data were collapsed across sex and a one-way ANOVA with repeated measures was calculated on the resulting data. Post hoc analyses of pairwise differences were calculated using Tukey's honestly significant difference statistic. Results showed that crunches performed with the abdominal devices resulted in less ROM in all angles measured when compared with a traditional crunch. The traditional crunch exercise was most closely simulated by the pivot-type devices. The results indicated that prescription of abdominal conditioning exercises via these devices results in training through smaller ROMs compared with a traditional crunch. The specific angle changes may require careful judgment as to appropriate application for exercisers with specific back and neck motion limitations.

Key Words: abdominal, kinematics, exercise comparison, exercise devices

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Introduction

Abdominal muscle conditioning has been receiving considerable attention in the popular media largely because of the development and marketing of abdominal conditioning devices. The advertisers of these devices claim that the devices make abdominal conditioning more comfortable than the more traditional abdominal crunch exercise and may reduce neck strain (7). The traditional crunch exercise involves clasping the hands behind the head and flexing the cervical and thoracic spine to approximately 30° of trunk flexion. The crunch exercise has been criticized for producing neck strain when the participant pulls on the head with the hands and arms during the upward portion of the trunk flexion motion (7). Discussion regarding the efficacy of these conditioning devices and other abdominal conditioning methods is commonplace on various Internet and World Wide Web pages. Health clubs and fitness facilities as well as private individuals are readily purchasing these abdominal training devices. Due to the aggressive marketing of these devices, it is appropriate to investigate their characteristics and increase our understanding of their actions. Range of motion (ROM) assessments of these devices when compared with a traditional crunch-type exercise may serve as an important leading step in the analysis of the efficacy of these devices. This type of investigation has been encouraged to determine the kinematics of the trunk during trunk flexion motion (8).

The purpose of this study was to describe and compare the ROM of 4 abdominal conditioning roller-

Figure 1. The devices shown are (left to right) the AB Trainer, ABS HealthRider, ABS T45, and AB Shaper. Note the different design and construction approaches.

and pivot-type devices and a traditional abdominal crunch exercise. Angular displacements of several angles and the total summed angular displacement of these angles were measured by traditional kinematic procedures.

Methods

Subjects

Subjects were recruited from the university student and faculty population. Informed consent was provided prior to all testing as required by the University Institutional Review Board on the Study of Human Subjects. All subjects were over 18 years of age and reported no history of back pain or injury.

Equipment

Four abdominal exercise devices were included in this study (Figure 1). The 2 roller-type devices tested each had a curved steel pipe that rocked along the floor during execution of the abdominal exercise (AB Trainer, Precise Exercise Equipment Inc., Colorado Springs, CO, and Weider AB Shaper, ICON Health and Fitness Inc., Logan, UT). The two pivot-type devices each had a fixed rotational axis (ABS T45, HealthRider, Logan, UT, and ABS HealthRider, HealthRider). One of the roller-type devices (AB Trainer) also included a headrest segment that rotated in the sagittal plane, allowing the head and neck to move independently of the position of the rest of the roller device. All of the remaining devices had fixed head rests.

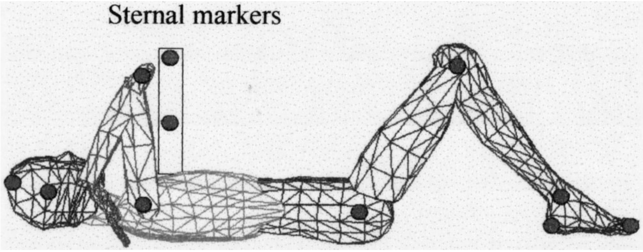

Figure 2. Location of joint markers for digitizing.

Data Collection

Each subject was clothed completely in black (shirt, tights, gloves, socks, and ski mask). White reflective markers were placed on the right side of each subject on the toe, heel, ankle, knee, hip, elbow, shoulder, auditory meatus, and temple (Figure 2). Each subject also wore a strap around the upper chest at the level of the sternum. The strap (5 cm) held a vertical piece of stiff, lightweight Ethafoam ($8 \times 28 \times 3$ cm). The Ethafoam was wrapped in black crepe paper and marked with 2 white reflective markers in a vertical relationship providing a lower (near) and upper (far) sternum marker. The strap was attached snugly and designed to move with the upper trunk by remaining perpendicular to the upper trunk segment during the trunk flexion and extension motion. Errors in the automatic digitizing procedure were minimized by providing a high contrast between the reflective markers (white) and the subjects, devices, and background (black). The order of exercise devices was chosen at random.

Subjects had varying experience with the exercises being investigated. Therefore subjects were allowed to practice performing the exercises prior to videotaping until they felt comfortable with the movements, and the investigators were satisfied that the movements resembled those recommended by the manufacturers of the devices. Subjects self-selected their hip and knee angle, although they were required to perform all exercises with flexed knees and hips.

Each subject performed 10 repetitions of abdominal flexion and extension while being videotaped in the sagittal plane (Panasonic AG-450, Shuttered 1/250 s, S-VHS, Secaucus, NJ). A personal computer (Compaq Prolinea Net 1/33 s, Houston, TX) was programmed to produce an audible tone at 1-second intervals, to which the subjects were instructed to perform trunk flexion and extension at a cadence of 2 seconds per complete repetition.

The S-VHS videotapes were encoded and analyzed via the PEAK Performance Technologies Software (Version 5.0.0., 1992, Englewood, CO). The tapes were analyzed at 60 Hz and automatically digitized via the PEAK software. The markers identified 5 angles that were subsequently analyzed for ROM. The angles included (a) head (temple, auditory meatus, shoulder); (b) neck (auditory meatus, shoulder, hip); (c) trunk (lower sternum marker, shoulder, hip); (d) a noncontacting angle formed by the line from the temple to the auditory meatus and the line from the upper to the lower sternum markers; and (e) a noncontacting angle formed by the line between the 2 sternum markers and the line between the hip and shoulder. A sixth angle variable was calculated as the sum of the head, neck, trunk, and hip angles. Three consecutive trials were digitized, beginning randomly with either the second, third, or fourth repetition. Following digitization all files were checked for digitizing error by viewing the trials using the "stick figure" display capabilities of the PEAK software. All marker paths were smoothed by a recursive Butterworth digital filter provided with the PEAK software. All marker paths were smoothed at 6 Hz except the far sternum and temple markers, which were smoothed at 3 Hz to reduce digitizing noise when the sternum marker was sometimes confused with shiny tape and the temple marker was sometimes confused with the exposed region of the face.

Statistical Analyses

The data were checked for out of range values. The minimum and maximum angles for 3 repetitions was extracted for each defined angle by passing a cursor through the angle data display as provided by the PEAK software. The differences between the minimums and maximums of the angles during each repetition were then recorded for further analyses. The 3 repetitions (trials) were analyzed for stability via Cronbach's alpha statistic, and the mean of the trend-free trials was recorded for further analyses by inferential statistics (3). The maximum ROM, via the differences between minimum and maximum angles, were then analyzed by 6 (defined or summed angles) 2 × 5 (sex by equipment) repeated measures analyses of variance (ANOVAs). Experiment-wise statistical significance was set at $p \leq 0.05$, and type I error was controlled by the modified Bonferroni test, which resulted in a per comparison alpha-value of $p < 0.0083$ (4, 5, 9). If no main effect resulted for sex, then male and female data were collapsed and analyzed via 6 (angle or sum of angles) separate 1-way repeated measures ANOVAs testing for differences between the various devices. Following a statistically significant main effect, post hoc pairwise analyses were calculated using the Tukey's honestly significant difference statistic ($p \leq 0.05$) (2).

Table 1. One-way analysis of variance (ANOVA) results for range of motion (ROM) differences between abdominal exercises.

Angle	Exercise $F(4, 76)$	Exercise p
Neck	42.32	<0.001
Head	7.01	<0.001
Hip	15.63	<0.001
Sternum/head	14.04	<0.001
Sternum/trunk	28.79	<0.001
Sum 4 angles	47.26	<0.001

Table 2. Tukey's HSD: differences in neck angle between abdominal exercises.

	AB Trainer	ABS Health-Rider	ABS T45	AB Shaper	Crunch
Means	21.90	37.71	26.28	26.54	44.69
SD	6.84	8.27	7.72	6.93	5.87
AB Trainer		15.81*	4.38	4.64	22.79*
ABS HealthRider			11.43*	11.17*	6.98*
ABS T45				0.26	18.41*
AB Shaper					18.15*
Crunch					

* $p < 0.01$ (critical difference = 6.906).

Results

Ten men (29 ± 5.87 years, 177.5 ± 6.46 cm, 80.96 ± 11.72 kg) and 10 women (33.4 ± 10.16 years, 162.23 ± 3.83 cm, 56.99 ± 7.36 kg) subjects participated in the study. The stability of the trials was determined via Cronbach's alpha statistic and the mean of the trend-free trials was recorded for further analyses (3). Four angles were shown to be statistically different across repeated trials. However, because there was no discernible pattern to these differences and the alpha values were high (all alpha-values > 0.94), the average of the 3 repetition values on each device was used for further data analyses (3).

The initial six 2 × 5 (sex by device) repeated measures ANOVAs did not demonstrate a significant main effect for sex, with the exception of trunk angle. Therefore, the data were collapsed across sex for all angles except trunk and 1-way repeated measures ANOVAs were performed (Table 1). Due to the statistically significant sex by device interaction for trunk angle, data were not collapsed for this angle prior to post hoc testing. Table 2 displays the results of the 1-way repeated measures ANOVAs following collapsing data for the relevant angles across sex. Tables 2–8 display the results of the Tukey's post hoc analyses.

Table 3. Tukey's HSD: differences in head angle between abdominal exercises.

	AB Trainer	ABS Health Rider	ABS T45	AB Shaper	Crunch
Means	10.22	8.39	13.10	7.10	11.84
SD	3.40	1.85	6.40	2.05	5.87
AB Trainer		1.83	2.88	3.12	1.61
ABS HealthRider			4.71*	1.92	3.44
ABS T45				6.00*	1.27
AB Shaper					4.74*
Crunch					

* $p < 0.01$ (critical difference = 4.399).

Discussion

The neck angle ROM represents flexion of the neck and head about the shoulder. The traditional crunch showed the largest flexion ROM followed in order by ABS HealthRider, AB Shaper, ABS T45, and AB Trainer. The AB Trainer device has a unique feature involving an extra pivot axis attached to the head rest, which allows the head and neck movement to occur independent of the overall position of the device, which may have resulted in the smaller change in neck angle.

The traditional crunch showed considerably larger neck flexion ROM than any of the other devices. The traditional crunch was performed without grasping the head with the hands, which indicates that the neck angle change was due to neck flexor muscles. The AB Trainer device can allow the exerciser to extend, rather than flex, the neck during the trunk motion, but this was not observed in the subjects tested in this study. Allowing the head and neck to extend or remain still may be an unnatural movement with regard to raising the head and trunk from a lying position and may represent a qualitatively new movement pattern. By extending or hyperextending the neck, the exerciser increases the moment of inertia of the upper trunk and head, thus requiring a larger torque to raise these body areas (8). The AB Shaper is similar to the AB Trainer in that both are roller-type devices; however, the AB Shaper does not permit independent movement of the head and neck. The 2 pivot devices (ABS HealthRider and ABS T45) have a fixed radius in which the exerciser must move. It was noted that smaller subjects often flexed the neck more as the head rest moved slightly toward the occipital region of the head while rising in the trunk flexion action. This appeared to be due to the shortening of the trunk caused by the flexion action of the trunk (6), whereas the fixed radius of the pivot devices resulted in the head rest appearing to shift toward the top of the head. This could contribute to neck and head flexion as a result of movement of the head rest away from the indentation of the neck to the more protruding occipital region of the skull. Moreover, the shape of the head rest may have interacted with the neck movement in that 3 of the devices have a thicker section of head rest for placement on the subject's neck. Neck flexion has been shown to result in reduced torque about the lumbar vertebrae when performing full sit ups as compared to sit ups performed with a straight neck and trunk (8). A partial sit-up or crunch resulted in the lowest torque about the lumbar vertebrae in a model of various trunk flexion exercises (8).

The head angle was formed by the intersection of a line from the temple to the auditory meatus, and a second line from the shoulder to the auditory meatus. The post hoc analyses (Table 3) indicated that among the devices the AB Trainer and the ABS T45 showed the largest head movement, whereas the crunch showed the largest head movement of all exercises. In spite of the AB Trainer's pivoting head rest, all of the motions were of a flexion, rather than extension, nature. Significant differences were determined between the ABS T45 and the ABS HealthRider, the AB Shaper and the ABS T45, and the AB Shaper and the traditional crunch.

The trunk angle was formed by the near sternum marker (i.e., lowest sternum marker), shoulder, and hip. This angle was analyzed as an indicator of trunk flexion that was independent of the movement of the head and neck. The post hoc analyses showed that the female subjects tended to achieve a slightly smaller ROM on all devices except the traditional crunch, where the women showed a larger ROM compared to the men. This result may be due to differences in absolute strength between men and women because the devices do not provide an accommodating resistance, and some of the devices are quite heavy to raise in trunk flexion (especially the pivot devices). Although not measured in this study, women may also have demonstrated a greater ROM in the traditional crunch because of increased flexibility of the trunk as compared with their male counterparts.

The hip angle consisted of the angle between the shoulder, hip, and knee markers. Because the knee and hip were fixed, the hip angle reflected the movement of the shoulder upward while being somewhat independent of the trunk flexion motion. The post hoc analyses showed that the AB Shaper had a significantly smaller ROM than the AB Trainer, whereas the crunch had a significantly larger ROM than the AB Trainer. The AB Shaper also showed a smaller ROM than the ABS HealthRider. The crunch showed a larger ROM in the hip angle than any of the devices. The larger ROM of the crunch was somewhat surprising in that the various devices are considered to make the trunk flexion motion slightly easier, but this did not translate into a larger ROM as measured by the hip

Table 4. Tukey's HSD: differences in lower-trunk angle between abdominal exercises.†

	Men					Women				
	AB-T	AB-HR	AB-t45	AB-S	TC	AB-T	AB-HR	AB-T45	AB-S	TC
Means	12.01	15.00	10.02	14.25	16.76	10.90	13.16	8.54	11.90	18.38
SD	3.47	4.38	3.79	4.73	5.77	3.44	3.74	3.26	3.29	3.22
AB-T (men)		2.99*	1.99	2.24	4.75**	1.11	1.15	3.47*	0.12	6.37**
AB-HR (men)			4.98**	0.75	1.76	4.10**	1.84	6.46**	3.11*	3.38**
AB-T45 (men)				4.23**	6.74**	0.88	3.14*	1.48	1.87	8.38**
AB-S (men)					2.51	3.35*	1.09	5.71**	2.35	4.13**
TC (men)						5.86**	3.60**	8.22**	4.87**	1.62
AB-T (women)							2.26	2.36	0.99	7.48**
AB-HR (women)								4.62**	1.27	5.22**
AB-T45 (women)									3.36*	9.84**
AB-S (women)										6.49**
TC (women)										

† AB-T = AB Trainer; AB-HR = AB HealthRider; AB-T45 = ABS T45; AB-S = AB Shaper; TC = traditional crunch.
* $p < 0.05$ (critical difference = 2.953).
** $p < 0.01$ (critical difference = 3.375).

Table 5. Tukey's HSD: differences in hip angle between abdominal exercises.

	AB Trainer	ABS Health-Rider	ABS T45	AB Shaper	Crunch
Means	14.75	14.97	14.20	11.53	20.35
SD	5.51	4.49	5.44	4.32	8.19
AB Trainer		0.22	0.54	3.22*	5.61**
ABS HealthRider			0.76	3.44*	5.39**
ABS T45				2.67	6.15**
AB Shaper					8.82**
Crunch					

* $p < 0.05$ (critical difference = 3.208).
** $p < 0.01$ (critical difference = 3.866).

Table 6. Tukey's HSD: differences in sternum to head angle between abdominal exercises.

	AB Trainer	ABS Health-Rider	ABS T45	AB Shaper	Crunch
Means	17.17	25.66	25.25	13.02	26.49
SD	5.45	5.53	10.33	4.40	13.14
AB Trainer		8.50*	8.08*	4.14	9.32*
ABS HealthRider			0.42	12.64*	0.82
ABS T45				12.23*	1.24
AB Shaper					13.46*
Crunch					

* $p < 0.05$ (critical difference = 6.389).

angle. This may be because of the restriction of movement of the upper trunk to that of the device instead of allowing the trunk to more freely flex and shorten when it is unencumbered by the devices.

The sternum to head angle was formed by 2 noncontacting lines. The head line was composed of the temple and auditory meatus markers, whereas the sternum line was composed of the near and far sternum markers. The purpose of this angle was to determine if the head and trunk moved independently or together. If the sternum to head angle did not change, one could assume that the head basically followed the trunk. If the head moved independently of the trunk, then one should see the angle change more profoundly. Post hoc analyses of this angle (Table 6) showed a marked difference between pivot and roller devices. The roller devices (AB Trainer and AB Shaper) were not statistically different from each other, and neither were both pivot devices (ABS HealthRider and ABS T45). However, both pivot devices were statistically different from both roller devices. The crunch also showed statistical differences vs. the 2 roller devices. The crunch, like the 2 pivot devices, can move the head more independently than the 2 roller devices. This analysis appears to indicate that the roller devices allow the head and neck to "keep up" with the trunk more synchronously than the 2 pivot devices. All devices showed that the head and neck flexed and extended during the movement; however, the pivot devices resulted in head and neck movement most closely aligned with that of the traditional crunch.

The sternum to trunk angle also consisted of 2 noncontacting lines. The sternum line was formed by the near and far sternum markers, whereas the trunk line

Table 7. Tukey's HSD: differences in sternum to trunk angle between abdominal exercises.

	AB Trainer	ABS Health-Rider	ABS T45	AB Shaper	Crunch
Means	13.62	15.32	11.59	17.09	19.72
SD	3.81	5.35	4.14	5.16	4.85
AB Trainer		1.70	2.03	3.47*	6.10*
ABS Health-Rider			3.73*	1.77	4.40*
ABS T45				5.50*	8.13*
AB Shaper					2.63**
Crunch					

* $p < 0.01$ (critical difference = 2.778).
** $p < 0.05$ (critical difference = 2.305).

Table 8. Tukey's HSD: differences in sum of 4 angles between abdominal exercises.

	AB Trainer	ABS Health Rider	ABS T45	AB Shaper	Crunch
Means	58.33	75.15	62.87	58.25	94.45
SD	14.16	15.72	17.16	14.12	21.72
AB Trainer		16.82*	4.54	0.09	36.12*
ABS HealthRider			12.28*	16.90*	19.30*
ABS T45				4.62	31.58*
AB Shaper					36.20*
Crunch					

* $p < 0.01$ (critical difference = 10.801).

was formed by the shoulder and hip markers. The purpose of this angle was to assess the amount of flexion of the trunk that was independent of the head and neck. As the trunk flexes, the shoulder and hip markers move toward each other while the sternum line is inclined toward the hip and legs. The post hoc analyses (Table 7) revealed that the larger the ROM of this angle, the larger the trunk flexion that occurred. The crunch achieved the greatest trunk flexion followed by the AB Shaper, the ABS HealthRider, AB Trainer, and ABS T45. Assuming that exercising through a maximum ROM is desirable, the crunch, the AB Shaper, and the ABS HealthRider appear to be superior in trunk flexion. Some smaller subjects had difficulty, specifically with the ABS T45, because of an inability to properly fit the device, which may have been partially responsible for the lower ROM value. Recommendations to exercisers regarding any of these devices should include checking to ensure that the user can properly fit the device.

The head, neck, trunk, and hip angles were summed in an effort to determine an operational overall or total flexion movement. The sum of 4 angles showed that the crunch had a greater total ROM than any of the abdominal conditioning devices, whereas the ABS HealthRider ranked second. The ABS HealthRider was also statistically different from the ABS T45 and the AB Shaper. Again, the crunch movement performed by these subjects involved a larger ROM than any of the abdominal devices tested. Moreover, if the point of these devices is to simulate a crunch, then they all fall somewhat short with the pivot devices coming closer than the roller devices, although not always significantly closer (Table 8). The picture is somewhat complicated by the structure of the pivot devices, which appear to require more careful fitting to the size of the exerciser to avoid the sliding of the head on the head rest.

Practical Applications

Interestingly, although these devices and the traditional abdominal crunch are all touted to target trunk flexion and abdominal conditioning, the ROMs achieved by these devices indicated that considerable variation exists among the devices. Muscle involvement by virtue of electrical activity, magnitude of recruitment, and so forth were not addressed in this study because of the inherent problems of a shifting detection volume under the electrode, changing fat locations caused by skin wrinkling under the electrodes while performing the movement, and the problems of cross-talk between closely aligned muscles (1). As suggested by Smidt et al. (8), determining the typical ROMs of various trunk flexion exercises should be undertaken to determine what ROMs occur while performing such movements. Until the electromyography problems are solved, the muscle electrical activity magnitude values will be suspect. However, ROM assessments by traditional kinematics can be an important step in fully understanding these and other related movements. The popularity of abdominal conditioning devices has made them ubiquitous in health clubs and among home exercisers. Prescription of abdominal conditioning exercises for relief or prevention of back pain and for simple conditioning should be undertaken with a thorough knowledge of the magnitude of movement one achieves in these exercises. Prescribing these types of devices for those with cervical spine complications may need to be closely evaluated prior to implementation.

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Address correspondence to William A. Sands, Department of Kinesiology, California Lutheran University, 60 W. Olsen Road, Thousand Oaks, CA 91360.