Relationship of Timed Sit-up Tests to Isokinetic Abdominal Strength

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Hall, G.L., Hetzler, R.K., Perrin, D.H., & Weltman, A. (1992). Relationship of timed sit-up tests to abdominal strength. *Research Quarterly for Exercise and Sport*, *63*, 80-84.

Key words: strength testing, sit-ups, isokinetic testing

Article:
Sit-up tests have been included in most youth and adult fitness test batteries. One logical reason for their inclusion is the possible relationship between poor abdominal strength and the incidence of low back pain. Therefore, a number of timed field tests have been proposed to measure abdominal function. However, the published data on the validity of field test measures are sparse. The sit-up test has been widely described as a test of abdominal muscular strength and endurance (DiNucci, McCune, &: Shows, 1990; Kendall &: McCreary, 1983; Kraus, 1965; Lipetz &: Gutin, 1970; Robertson &: Magnusdottir, 1987; Vmcent &: Britten, 1980).

To our knowledge, timed sit-up tests have not been validated against a criterion measure to determine if they actually measure abdominal strength. To study this relationship a reliable measure of abdominal strength must be obtained. However, strength per se is not measured; rather, power, average force, or torque is used to estimate strength. One valid measure of muscular strength involves the use of an isokinetic dynamometer that adequately isolates the musculature of interest. The purpose of the present study was to test the validity of timed sit-up tests as measures of isokinetic abdominal strength. Specifically, a modification of the Kraus-Weber (Kraus, 1965), Robertson Curl-Up (Robertson &: Magnusdottir, 1987), and American Alliance of Health, Physical Education, Recreation and Dance (AAHPERD, 1980) sit-up protocols was compared to concentric and eccentric abdominal peak torque as measured on an isokinetic dynamometer. The present study was not designed to determine if these tests were valid measures of dynamic muscular endurance.

Method

Subjects
Twenty-three men and 28 women volunteered to participate in the present study. The mean (± SD) age, height, and weight for the male subjects were 23.1 ± 7.4 years, 178.0 ± 7.5 cm, and 73.1 ± 5.9 kg, respectively. The mean (± SD) age, height, and weight for the female subjects were 22.2 ± 4.6 years, 165.1 ± 7.6 cm, and 61. 7 ± 8.2 kg, respectively. Informed consent documents were signed by each subject. The subjects performed concentric and eccentric isokinetic trunk flexion tests and the following sit-up tests: (a) Kraus-Weber (KW), (b) Robertson Curl-up (RCU) , (c) American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD) sit-up tests. Each subject was tested isokinetically prior to performing the sit-up trials. The order of performing the sit-up tests was randomly assigned. To avoid muscle fatigue and soreness, subjects were tested on alternate days.

Abdominal Muscular Strength Criterion Test
Muscular strength was determined using an isokinetic dynamometer (Kin-Com, Chattanooga, TN) because it can adequately isolate the abdominal muscles through an acceptable range of motion. Each subject was seated on a table with a stabilizing back attachment with the knees flexed to 90°. A pelvic pad was secured snugly around the waist with the lower surface of the anterior pelvic pad firmly against the proximal thigh. The apex of

the sacral pad contacted the subject's pelvis 1 cm above the posterior superior iliac spines. An adjustable T-bar force application pad was aligned with the chest wall and manubrium 3 cm below the clavicles. The subject's arms were crossed anteriorly. The dynamometer would not allow movement until a 50-Newton (N) force was applied on the T-bar pad. This preload prevented impulse loading and was a means of protecting the subject during eccentric exercise.

Subjects performed trunk flexion at a constant velocity of 15° s^{-1}, through a 35° range of motion (-15° to 20°, vertical = 0°). They performed practice trials prior to the actual measurement of abdominal strength. Strength was defined as peak torque produced in a single voluntary effort through the specified range of motion. After the practice trials, each subject performed a concentric, followed by an eccentric, abdominal contraction. Both concentric and eccentric measurements were obtained because performance of the sit-up requires both types of contraction. Peak torque (torque = the product of the force magnitude and its perpendicular distance from the axis of rotation) was determined during the three concentric and eccentric repetitions throughout the range of motion. Because the trials took place in a seated position, torque measurements were not corrected for the effect of gravity. This process was repeated until the subject could replicate the abdominal concentric and eccentric torque curves three times. The investigator visually inspected the torque curves for reproducibility to demonstrate maximal effort by the subject. If a computer- generated overlay of the torque curves revealed deviation of one of the curves, the subject was asked to continue until three curves approached an identical configuration. The same examiner provided verbal encouragement to each subject to promote maximal performance.

Muscular Fitness Tests

Kraus-Weber Test. The subjects were in a supine position, with knees extended and hands interlocked behind the neck. An examiner held the subject's feet on the floor, while the subjects rolled into a sitting position so their forearms touched their thighs. Therefore, the subjects moved through an approximate 90° range of motion. The original Kraus-Weber test was modified so that the score was the number of sit-ups performed correctly in 1 min. This test was included to represent sit-up tests performed with straight legs.

Robertson Curl-up Test. The subjects were positioned supine, with their knees flexed in a comfortable position. The knee flexion angles were not standardized because no specific angles were reported by Robertson and Magnusdottir (1987). The subject's feet were not held by an examiner during this test. They reached forward toward a frame positioned 7.62 cm away from their longest fingertip while lifting their upper back off the mat. The range of motion for this test was approximately the same as that tested isokinetically. The score was the number of times the subjects reached the frame in 1 min. Robertson and Magnusdottir (1987) reported acceptable levels of consistency between trials based on intraclass correlational analysis (R = .93 and .97 for men and women, respectively) .

AAHPERD. The subjects were positioned supine with knees flexed. An examiner held the feet on the floor 12-18 in. from the buttocks. The subject’s arms were folded across the chest with hands on opposite shoulders. The subject then curled to a sitting position by tucking the chin and allowing the elbows to touch the thighs. Therefore, the subjects moved through an approximate 90° range of motion. The score was the number of sit-ups performed correctly in 1 min. The intraclass reliability coefficient for college students has been reported to be $R = .91$ for both male and female subjects (DiNucci et al., 1990). Verbal encouragement was provided throughout each of the sit-up tests.

Statistical Analyses

Descriptive statistics were produced for all variables. The Pearson Product Moment correlation technique was used to determine the relationship among the isokinetic abdominal strength variables and the timed sit-up tests. A MANOVA was used to make gender comparisons between dependent variables. The level of statistical significance was set at $p < .05$.

Results

The MANOVA indicated significant differences between genders on the isokinetic muscular strength tests and the three timed sit-up tests by the Wilks's λ, $F(1,49) = 17.7$, $p < .05$. Therefore, male and female subjects were analyzed independently. Mean peak concentric (CON) and eccentric (ECG) abdominal strength measures were reported in Newton-meters (Nm) (see Table 1). Mean sit-up scores for the modified Kraus-Weber (KW), Robertson Curl-up (RCU) , and AAHPERD were reported in repetitions correctly performed in 1 min (see Table 1).

Table 1. Means for peak torque and sit-up tests

Variable	Females ($n = 28$) $M \pm SD$	Males ($n = 23$) $M \pm SD$
Trunk Flexion (Newton-meter)		
Concentric	94.9 ± 20.3	145.7 ± 24.6
Eccentric	110.7 ± 20.4	168.2 ± 25.4
Sit-up (reps·min^{-1})		
Kraus–Weber	32.4 ± 7.2	38.9 ± 5.1
Robertson	62.6 ± 16.6	75.5 ± 15.0
AAHPERD	41.7 ± 14.7	48.5 ± 7.2

Note. MANOVA revealed that the variables were significantly different between genders ($p < .05$).

The intercorrelations among the concentric and eccentric isokinetic strength measures (peak torque) and the timed sit-up scores for the male and female subjects are shown in Table 2.

Results show low correlations between each timed sit-up test and the criterion measures of concentric and eccentric abdominal strength. Additionally, relative measures of peak torque (peak torque/body weight) were generated and also appear in Table 2. These correlations were slightly higher for females, but relatively unchanged for males.

Discussion and Conclusions

The major finding of the present study was that a weak relationship existed between isokinetic measures of abdominal strength and the timed sit-up scores. These data suggest the use of timed sit-up tests is not a valid method of estimating isokinetic abdominal muscular strength. Therefore, if one accepts isokinetic peak torque values as a criterion measure of abdominal strength, the use of timed sit-up tests as estimates of abdominal muscular strength seems untenable. Hence, to describe a timed sit-up test as a measure of abdominal strength would be misleading. However, it should be pointed out that the timed sit-up tests are isotonic, whereas the Kin-Com test is an isokinetic measure of strength. Additionally, the length-tension relationship for the abdominal muscles may have been different for the sit-up tests and the criterion measure.

A delimitation of the present study was that a criterion measure of abdominal muscular endurance was not included. This is an important consideration because the sit-up is often described as a test of abdominal muscular strength and endurance. However, no attempt was made to see how timed sit-up scores were related to dynamic muscular endurance. Further study of this issue seems warranted. Until such studies are performed, perhaps it would be better to refer to timed sit-up tests as tests of "abdominal muscular power" rather than tests of "strength and endurance."

Table 2. Correlation among peak torque and sit-up test scores

	Females ($n = 28$)			Males ($n = 23$)		
Variable	KW	RCU	AAHPERD	KW	RCU	AAHPERD
CON	.42*	-.07	.27	-.18	-.41*	-.25
ECC	.40*	-.08	.32*	-.21	-.38*	-.28
CON/Body Weight	.59**	.10	.41	-.19	-.21	-.22
ECC/Body Weight	.54*	.05	.45*	-.24	-.20	-.26

Note. KW = Kraus–Weber Sit-up Test, RCU = Robertson Curl-up Test, AAHPERD = AAHPERD Sit-up Test, CON = Concentric Peak Torque, and ECC = Eccentric Peak Torque.
* $p < .01$.
** $p < .001$.

When examining the correlations between abdominal concentric and eccentric strength and timed sit-up tests, negative correlations were found for the male subjects. This finding further negates a direct relationship between timed sit-up performance and isokinetic abdominal strength in males. Perhaps the negative correlations existed because larger individuals (due to a correspondingly greater muscle mass) can produce greater peak torques but be at a biomechanical disadvantage when performing the timed sit-up test. Additionally, in the criterion strength test (Kin-Com) the subject was in a seated position in which the weight of the upper body may aid in the performance. However, in the timed sit-up tests, upper body weight is the resistance that must be overcome. The use of relative peak torques had little effect on the poor relationship observed between timed sit-up tests and isokinetic strength scores for males.

Although the modified Kraus-Weber test showed a stronger positive relationship for the female subjects ($r = .42$ and .40, $p < .05$, for CON and ECC, respectively), the strength of the relationship was not great ($r^2 = .18$ and .16 for CON and ECC, respectively). The use of relative peak torques increased the strength of the relationship, but it is still relatively low ($r^2 = .35$ and .29 for CON and ECC, respectively). When the feet are held down, as in the modified Kraus-Weber test, the hip flexors are given fixation and the exercise can immediately become a sit-up movement with flexion of the hip joints (Kendall & McCreary, 1983). The remaining two sit-up tests (RCU and AAHPERD) utilize the hook-lying position, which theoretically contributes to the isolation of the abdominal muscles by minimizing the potential of hip flexors to assist the movement (Gutin & Lipetz, 1971; Vincent & Britten, 19S0; Walters & Partridge, 1957). However, in the AAHPERD test a full sit-up is performed. Therefore, the hip flexors are active in the movement regardless if the feet are held or the knees bent. Once the end point of the range of motion of the spine is achieved in flexion, only the hip flexors are in position to move the trunk further (i.e., the abdominal muscles do not cross the iliofemoral joint). Therefore, the KW and AAHPERD tests allow for use of the hip flexors and do not adequately isolate the abdominal muscles. Why they correlate higher with abdominal peak torque scores than the RCV for females is unclear.

A variable that may have affected the relationship observed between peak torque and the timed sit-up scores was the velocity at which the testing procedure was performed. Although isokinetic dynamometers have been reported to be reliable and valid (Delitto, Crandell, & Rose, 1989; Johnson & Siegel, 1978; Perrin, 1986; Smith, Mayer, Gatchel, & Becker, 1985; Tredinnick & Duncan, 1988), the optimal velocity for testing the truncal muscles has yet to be established. The velocity used in the present study (15° s^{-1}) was chosen so that isokinetic abdominal strength could be assessed following manufacturer's recommendations. This was much slower than the velocity of performing a sit-up in a timed test situation. Smith et al. (1985) reported that speeds of 60° s^{-1} or less may not adequately represent functional truncal speeds, which may exceed 120° s^{-1}. However, when testing at a greater velocity the chance of injury due to the acceleration phase is increased. Therefore, a velocity of 15° s^{-1} was utilized in the interest of safety for the subjects.

The sit-up movement consists of a series of concentric and eccentric contractions. However, most of the research on truncal strength reported only concentric strength data at varying velocities (Hasue, Fugiwara, & Kikuchi, 1980; Langrana, Lee, Alexander, & Mayott, 1984; Nordin et al., 1987; Smidt et al., 1983; Thompson, Gould, Davies, Ross, & Price, 1985; Thorstensson & Nilsson, 1982). To date, little has been published concerning eccentric isokinetic abdominal muscle strength. However, it has been reported that an eccentric (lengthening) contraction produces greater tension than a concentric (shortening) contraction (Hageman, Gillaspie, & Hill, 1988; Seger, Westing, Hanson, Karlson, & Ekblom, 1988; Smidt et al., 1983). Thus, results from the present study were in agreement with previous research.

In summary, a poor relationship was observed between maximal isokinetic abdominal strength and timed sit-up test performance. However, how other sit-up tests (e.g., Canadian or YMCA) or other measures of abdominal muscular strength may relate to this finding is unknown. Additionally, no attempt was made to determine how timed sit-up tests are related to dynamic muscular endurance. It was concluded that the timed sit-up scores for KW, RCV, and AAHPERD are not valid predictors of isokinetic abdominal muscular strength.

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