Clinical tools to quantify torso flexion endurance: Normative data from student and firefighter populations

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Abstract. Given that torso muscle endurance is one of the few metrics that has been shown to be linked to having a history of back disorders together with predicting future back disorders, endurance tests for workers have been developed. While some data exists on the V-sit exercise for flexor endurance, some have specifically adopted the plank test. The primary objective of this study was to assess links between the two tests. Two data sets were collected. The first set was obtained from a convenience group of fire fighters where the plank endurance test scores, together with the Biering Sorensen test for extension endurance, were obtained over three years. The second data set was obtained from a tightly controlled cross-sectional study of university students that included scores for both flexor and extensor endurance. 620 fire fighters for the first data set and 181 university students for the second. While flexor endurance in the firefighters peaked when aged in their 40's, extensor endurance peaked in their 20's. In the study of university students, the plank scores were relatively higher than the V-sit scores in males but relatively lower than the V-sit in the females. A pearson correlation test between the paired plank and V-sit scores of each subject rendered a coefficient of r = 0.34. This means that the performance on one flexor test only predicted 11% of the score in the other. ANOVA comparison of scores based on their history of having had shoulder or back troubles showed no significant link between V-sit or plank scores. The plank scores are not well correlated with the V-sit scores suggesting that the two measure different variables. Since more data exists for the V-sit, measurement of flexor endurance in occupational settings using this test probably forms a stronger link to back injury.

Keywords: Endurance, back pain, muscle testing

1. Introduction

Both Biering-Sorensen [2] and Luoto and colleagues [4] suggested that while isometric strength was not associated with the onset of back troubles, poor static back endurance scores are. This motivated a study to quantify the endurance of torso muscles about three axes (flexion-extension, lateral bend, and twist) in a healthy group of young adults to establish a normal data base [5]. While it was difficult to choose simple tests that isolated these groups of muscles, the modified V-sit was chosen together with the side bridge and the Biering-Sorensen extension hold. The same study also found a high reliability coefficient, at least 0.98 or higher, when the tests were repeated over five consecutive days. Subsequently, using these tests, a link was found between poor torso endurance in those who have episodic back troubles compared

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with those who do not experience debilitating episodes [7]. Further, the same study found that the ratios of endurance between the torso flexors, extensors, and lateral musculature better discriminates those who have had back troubles from those who have not, in a matched population performing similar work. Others have used these tests for establishing fitness norms in working populations and in establishing training goals for those in back injury rehabilitation programs. However, other tests have been developed to quantify abdominal endurance, namely the prone plank posture. Schellenberg and colleagues [9] demonstrated that the prone plank activates the abdominals (52% MVC for the rectus abdominis and 59% MVC for the external oblique) and that those with chronic low back pain score more poorly.

The issue addressed in this study concerns the use of the "plank" exercise as a substitute for the V-sit test to test abdominal, or torso flexor, muscle endurance. The hypothesis tested in this study was that the plank score would correlate with the V-sit score, suggesting that it could act as a substitute and thereby linking existing data sets. Other objectives included obtaining a better understanding of the effects of age and gender on test scores, whether or not there were links to disorders of the back and shoulder, and whether similar ratios (between flexor and extensor musculature) that characterize those with pained backs exist between the plank and previously reported V-sit tests and the Biering Sorensen test for the back extensors. Two data sets form this study. The first set was obtained from a convenience group of fire fighters where the endurance test scores were obtained over three years. This was important since some occupational groups are using the plank as an endurance test. The second data set was obtained from a tightly controlled study of university students.

2. Methods

Two separate data collections were conducted. First, over 620 firefighters were tested for their endurance holding time performing the plank test. The second data collection involved a total of 181 university students (99 women and 82 men) who were tested for their scores in the original three torso endurance tests in addition to the plank test (see Fig. 1). All subject recruitment and data collection procedures were performed in accordance with the University of Waterloo Office of Research and Ethics guidelines, and written informed consent was received from each participant.

2.1. Description of the tests

2.1.1. V-sit – Flexor endurance test
Testing endurance of the flexors (rectus abdominis and the obliques) begins with the person in a sit-up posture with the back resting against a jig angled at $55°$ from the floor (i). Both knees and hips are flexed $90°$, the arms are folded across the chest with the hands placed on the opposite shoulder, and toes are secured under toe straps. To begin, the jig is pulled back 10 cm (4 in.) and the person holds the isometric posture as long as possible (ii). Failure is determined to occur when any part of the person's back touches the jig, or the participant request to stop, or they are unable to preserve form after one verbal warning (all testing postures are shown in Fig. 1).

2.1.2. Side bridge – Lateral musculature test
The lateral musculature is tested with the person lying in the full side-bridge position. Legs are extended, and the top foot is placed in front of the lower foot for support. Subjects support themselves on one elbow and on their feet while lifting their hips off the floor to create a straight line over their body length. The uninvolved arm is held across the chest with the hand placed on the opposite shoulder. Failure occurs when the person loses the straight-back posture and the hip returns to the ground, or the participant request to stop, or they are unable to preserve form after one verbal warning.
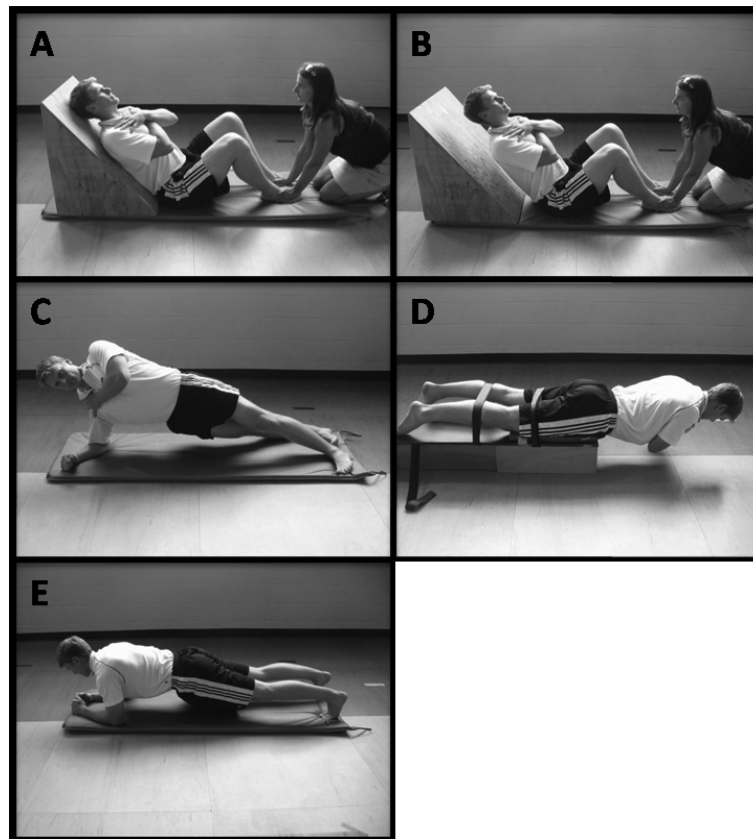
Fig. 1. The four endurance testing postures were the V-Sit (A – starting posture, B – test posture with the jig pulled pack 10cm), C) Side bridge, D) Biering-Sorensen extensor test, E) plank.

2.1.3. Biering-Sorensen – Back extensor test

The back extensors are tested in the "Biering-Sorensen position" with the upper body cantilevered out over the end of a test bench and with the pelvis, knees, and hips secured. The upper limbs are held across the chest with the hands resting on the opposite shoulders. Failure occurs when the upper body drops from the horizontal position, or the participant request to stop, or they are unable to preserve form after one verbal warning.

2.1.4. Plank – Flexor endurance test

An alternate approach for testing the flexors is to begin laying prone, elbows directly under the shoulders and hands together so that the forearms form a "V". Subjects then bridge off the ground with the torso straight. Failure occurs when a straight back can no longer be maintained and the hips drop toward the floor, or the participant request to stop, or they are unable to preserve form after one verbal warning.

2.2. Testing of firefighters to obtain plank scores

The firefighters formed a convenience group in that the data was collected as part of a fitness test. In 2006, 401 fire fighters volunteered to participate in a trial study to obtain some preliminary data on the

Table 1
In 2006, 401 firefighters were tested for their
plank scores and stratified for gender and age

Age	Average age	Plank time (s)
20'S (53)	25	115
30'S (142)	35	113
40'S (103)	45	124
50'S (98)	53	111
FEMALE(5)	35	92
($n = 401$)	40	118

Plank test. Later in 2007, data on the plank test together with the V-sit and the Biering-Sorensen back extensor test were collected on 287 fire fighters. Note that the Biering-Sorensen had a maximum cut-off time of 3 minutes as per the Canadian Physical Activity, Fitness and Lifestyle Approach protocol. In 2008, 390 Plank and Biering-Sorenson tests were conducted. Some of the participants were similar, and thus retested, in subsequent years. Age, height and weight were recorded during 2007 and 2008 and the Body Mass Index (BMI) was calculated. In total 1078 tests were conducted over the three year period, but since some fire fighters were re-tested each year, a total of 620 individual fire fighters participated.

2.3. Comparison testing of the V-sit and the plank tests

A more tightly controlled study was then conducted on a sample of university students. Data was collected on 181 first year Kinesiology students (99 women and 82 men) with ages ranging from 17 to 25 years (mean age 19 years). Their average Body Mass Index was 26 kg/m^2. Students also completed a form to indicate histories of either disabling back pain or shoulder pain. Forty-five reported having had back pain and 18 reported having had shoulder troubles. If the participant broke form when performing the isometric tests, they were warned and corrected. If they were too fatigued to make the correction the test stopped. Subjects were randomized into two equal groups where one group performed the plank first, then the V-sit two weeks later, while the other group performed the tests in the opposite order, again two weeks apart.

2.4. Statistical analysis

A Pearson correlation between the V-sit and plank endurance times on the university student scores was conducted. A Spearman correlation and an ANOVA tested whether endurance times were linked with having a history of either shoulder or back disorders.

3. Results

3.1. Study 1: Plank scores in firefighters together with scores in other endurance tests

The data is presented by year as additional data was collected in 2007 and 2008 compared to 2006. In 2006, 401 firefighters, average age 40 years, held the plank 118 seconds on average (see Table 1). In 2007, 287 fire fighters held the plank 129 seconds, and the Biering Sorensen 116 seconds (see Table 2). In 2008, both scores increased to 153 seconds for the plank and 121 seconds for the Biering Sorensen.

Table 2

In 2007, 287 firefighters were tested and 390 were tested in 2008. Plank and Biering-Sorensen scores were recorded as a function of age and gender together with more personal data to obtain their Body Mass Index. Note that the Biering-Sorensen test had an upper limit of 3 minutes (180 seconds)

2007							
(*n* = 287)	Female (7)	20's (38)	30's (114)	40's (62)	50's (66)	Average	N = 287
Age	33.29	26.6	34.5	44.7	53.3	Age	40
Weight (kg)	74.7	87.0	89.0	90.7	90.8	Weight (kg)	89.1
BMI	26	28	27	28	28	BMI	28
Sorensen (s)	135	131	116	114	108	Sorenson	116
Plank (s)	114	132	129	140	119	Plank	129
2008							
(*n* = 390)	Female (10)	20's (89)	30's (156)	40's (76)	50's (59)	Average	N = 390
Age	32.1	26	34.27	44.23	52.5	Age	40
Weight (kg)	73.8	87.9	88.6	89	91.2	Weight (kg)	88
BMI	25	27	27	28	28	BMI	28
Sorensen (s)	153	120	117	115	101	Sorenson	121
Plank (s)	145	138	143	155	143	Plank	153

3.2. Study 2: Comparison of traditional tests and the plank

The mean scores of the various endurance holds are shown in Table 3 while the data is re-stratified according to participants' history of having either back or shoulder disorders, or neither, in Table 4. The plank scores were relatively higher than the V-sit scores in males but relatively lower than the V-sit in the females.

A pearson correlation test between the paired scores of each subject rendered a coefficient of r=0.34. This translates to a r2 value of 0.11 meaning that 11% of the variance can be explained or that the performance on one flexor test only predicts 11% of the score in the other.

ANOVA comparison of scores based on their history of having had shoulder or back troubles showed no significant link between V-sit or plank scores.

4. Discussion

The hypothesis that the performance on the V-sit is comparable to that of the plank was rejected. It appears that the two tests are independent and measure different variables. Curiously the men are more endurable than the women in the both the V-sit and the plank yet different conclusions are reached when comparing the two tests within a gender. The men hold the plank longer than the V-sit suggesting some gender specific aptitude. The women hold the V-sit longer than the plank. Given that the plank requires more shoulder challenge, perhaps men have an advantage. Interpreting the scores in those with a history of shoulder troubles is interesting in that there was no difference in holding times based on having a history of back or shoulder disorders. We do not know the grade of the disorder but note that these were young people. Perhaps additional study of strength as opposed to endurance, would further understanding of the links with injury. Perhaps links grow as people age and gain work experience (with the associated body wear). Previous work on matched occupational populations containing people with and without a history of back troubles showed those that those with a history of back troubles had even stronger backs. They appear to have stronger backs because they overuse their backs, when performing similar tasks, compared to the matched controls with no back troubles [7].

The data obtained from incumbent fire fighters is interesting from several perspectives. It provides the first data base that we are aware of for plank scores stratified by age and gender. The Biering-Sorensen

Table 3
Endurance scores were obtained from 181 university students (99 female and 82 male). Ratios of flexion V-sit to the Biering-Sorensen extension test was also calculated given evidence that this is linked with back disorders. Other similar ratios were calculated for interpretation and comparison with other data sets (for example McGill, 2007)

Task	Men			Women			All		
	Mean	SD	Ratio	Mean	SD	Ratio	Mean	SD	Ratio
EXT	141	45	1.00	155	47	1.00	149	46	1.00
FLEX	132	62	0.94	116	56	0.75	123	59	0.83
PLANK	183	93	1.30	106	46	0.69	141	81	0.95
RSB	97	41	0.69	69	26	0.44	81	37	0.55
LSB	96	39	0.68	68	28	0.44	80	36	0.54
FLEX/EXT	0.95	0.38		0.79	0.39		0.86	0.39	
PLANK/EXT	1.35	0.73		0.74	0.38		1.02	0.64	
RSB/LSB	1.04	0.28		1.06	0.30		1.05	0.29	
RSB/EXT	0.71	0.27		0.47	0.20		0.58	0.26	
LSB/EXT	0.71	0.27		0.46	0.19		0.57	0.26	

Table 4
Endurance scores (together with relevant ratios) were obtained from 181 university students stratified based on having a history of either shoulder or back disorders, or neither

Task	No back troubles			History of disabling back			History of disabling shoulder		
	Mean	SD	Ratio	Mean	SD	Ratio	Mean	SD	Ratio
EXT	153	46	1.00	145	50	1.00	129	30	1.00
FLEX	126	62	0.82	118	56	0.81	118	50	0.91
PLANK	138	83	0.90	145	78	1.00	151	72	1.17
RSB	83	37	0.54	80	39	0.55	77	25	0.60
LSB	82	36	0.53	82	40	0.57	69	25	0.54
FLEX/EXT	0.85	0.40		0.85	0.38		0.94	0.41	
PLANK/EXT	0.96	0.59		1.11	0.78		1.19	0.56	
RSB/LSB	1.04	0.24		1.02	0.35		1.18	0.38	
RSB/EXT	0.57	0.26		0.58	0.29		0.62	0.22	
LSB/EXT	0.56	0.25		0.60	0.30		0.56	0.22	

scores are highest when the fire fighters are in their 20's, but then continually drops to their 50's. The peak plank holding times occur when they are in their 40's. We do not know how to interpret this although poorer endurance scores are associated with future back troubles [2,4] and with past histories of chronic back troubles [7]. Scores on the prone plank were noted by Schellenberg et al. [9] who reported shorter holding times in non-firefighters (93 seconds for men and 51 seconds for women compared to the firefighters (men and women combined) in the present study from the same age group of 113 seconds) compared to firefighters of a similar mean age. Their chronic back pained population held the posture for about one-third of time of their non-pained group.

Comparing the data of the two data collections in this study with other data sets that share the same protocol suggests that they are comparable. The absolute endurance scores are all slightly lower than those we published 10 years ago from the same student population [5]. Their BMI's have also increased over the 10 year period suggesting a general decline in fitness. Interpreting these scores in terms of back health and the formation of guidelines for clinical targets is outside the scope of this paper, although guidance is provided in McGill [8]. Techniques to enhance endurance are also provided in McGill [8].

While scores have been provided here for various endurance holds, it is emphasized that these are tests. Thus "training the test" to enhance endurance is not advocated given the prolonged spine load. There are preferable exercises and holding times to enhance endurance. For example, when training

extensor endurance the birddog exercise has been shown to be superior for sparing the spine with lower compressive loads when compared with the Biering-Sorensen posture, and in creating muscle activation patterns that ensure stability [3]. The modified curlup has been shown to be spine sparing with lower compressive loads as well [1] compared to the V-sit. Training to enhance endurance has been more fully addressed elsewhere McGill [8].

5. Conclusions

The plank scores are not well correlated with the V-sit scores suggesting that they measure other qualities. These may be due to the plank posture involving the entire abdominal chain from the shoulders to the feet given that the joint torques required to hold the posture are borne over the full length of the body. Those who choose to test the plank cannot assume that it is a substitute for the V-sit endurance score. Further, since more data sets exist for the V-sit, it would be a preferred measure of flexor endurance linking back disorders in occupational settings.

Acknowledgement

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