2009-03-18

Development of a Prone Bridge Test as a Measurement of Abdominal Stability in Healthy Adults

Joel D. Reece
Brigham Young University - Provo

DEVELOPMENT OF A PRONE BRIDGE TEST AS A MEASUREMENT

OF ABDOMINAL STABILITY IN HEALTHY ADULTS

by

Joel Reece

A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

Department of Exercise Sciences

Brigham Young University

April 2009

BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

Joel Reece

This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

Date	James George, Chair
Date	Brent Feland
Date	J. William Myrer
Date	A. Wayne Johnson
Date	Ronald Hager

BRIGHAM YOUNG UNIVERSITY

As chair of the candidate's graduate committee, I have read the thesis of Joel Reece in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

Date

James George
Chair, Graduate Committee

Accepted for the Department

Larry T. Hall
Chair, Department of Exercise Sciences

Accepted for the College

Gordon B. Lindsay, Associate Dean
College of Health and Human Performance

ABSTRACT

DEVELOPMENT OF A PRONE BRIDGE TEST AS A MEASUREMENT

OF ABDOMINAL STABILITY IN HEALTHY ADULTS

Joel Reece

Department of Exercise Sciences

Master of Science

This study sought to develop an interval prone bridge fitness test to assess core stabilization in healthy adults (ages 18–39 years). Participants performed a prone bridge maneuver in alternating 15-sec work and 5-sec rest intervals with participants' RPE scores (0–10) recorded at the end of each work interval. The RPE score reported after 95 sec (RPE-95) was used to predict total interval prone bridge endurance time along with participants' self-reported level of physical activity (PA; sedentary = 0, low active = 1, active = 2, very active = 3). Multiple linear regression was employed to generate the following prediction equation (R = .86, SEE = 32.98 sec): Total time (sec) = 300.0 – (23.4 x RPE-95) + (17.7 x PA). Each predictor variable was statistically significant (RPE-95, $p < .0001$; PA, $p = 0.006$) and cross validation procedures using PRESS (predicted residual sum of squares) statistics revealed minimal shrinkage (R_p = .85 and SEE_p = 32.89 sec). The mean and standard deviation (±SD) for the total duration of the

interval prone bridge test and the RPE-95 data were 179.9 ± 65.2 sec and 6.3 ± 2.2, respectively. To assess test-retest reliability, a second test was completed about 48 hours after the first. The reliability study (n = 45) yielded an acceptable test-retest intraclass reliability coefficient (ICC = .95, SEM = 12.7 sec) when comparing total interval prone bridge endurance times across days. In summary, this interval prone bridge fitness test, and accompanying regression model, yields a relatively accurate estimate of total interval prone bridge test time in healthy men and women, using both RPE-95 and PA data.

ACKNOWLEDGMENTS

I would like to acknowledge and give my sincere thanks to God for the seen and unseen angels who strengthened and encouraged me to complete this project. In particular, Dr. Jim George gave much of his time, energy, and patience to guide me through this experience along with my committee members Dr. A. Wayne Johnson, Dr. Brent Feland, Dr. J. William Myrer, and Dr. Ron Hager.

I would also like to acknowledge God's tender mercies for allowing me to work with other faculty members, students, secretaries, and administration in the Department of Exercise Sciences. Their support and friendship brought light and hope throughout this journey.

Finally, I would like to acknowledge and express my deep gratitude to God for the wonderful family at my side every step of the way. The lessons taught by my parents, David and Rebecca, of hard work and dedication helped make this accomplishment possible. The pure love of Christ felt from my wife, Linda, and my son, Dallin, was a constant reminder of where I could turn for encouragement, strength, and peace.

Table of Contents

List of Tables

Tables

List of Figures

Figures

DEVELOPMENT OF A PRONE BRIDGE TEST AS A MEASUREMENT OF ABDOMINAL STABILITY IN HEALTHY ADULTS

Joel D. Reece, MS., James D. George, PhD.,

Brent Feland, PhD., Bill Myrer, PhD.,

Ronald L. Hager, PhD., Wayne Johnson, PhD.

Department of Exercise Sciences

Brigham Young University, Provo, Utah

Author Note

Address correspondence to James D. George, Ph.D., Department of Exercise Sciences, 228A Smith Fieldhouse, Brigham Young University, Provo, Utah 84602

Phone 801/422-8778, Fax: 801/422-0555, email: jim@byu.edu

Abstract

This study sought to develop an interval prone bridge fitness test to assess core stabilization in healthy adults (ages 18–39 years). Participants performed a prone bridge maneuver in alternating 15-sec work and 5-sec rest intervals with participants' RPE scores (0–10) recorded at the end of each work interval. The RPE score reported after 95 sec (RPE-95) was used to predict total interval prone bridge endurance time along with participants' self-reported level of physical activity (PA; sedentary = 0, low active = 1, active = 2, very active = 3). Multiple linear regression was employed to generate the following prediction equation (R = .86, SEE = 32.98 sec): Total time (sec) = 300.0 – (23.4 x RPE-95) + (17.7 x PA). Each predictor variable was statistically significant (RPE-95, $p < .0001$; PA, $p = 0.006$) and cross validation procedures using PRESS (predicted residual sum of squares) statistics revealed minimal shrinkage (R_p = .85 and SEE_p = 32.89 sec). The mean and standard deviation (±SD) for the total duration of the interval prone bridge test and the RPE-95 data were 179.9 ± 65.2 sec and 6.3 ± 2.2, respectively. To assess test-retest reliability, a second test was completed about 48 hours after the first. The reliability study (n = 45) yielded an acceptable test-retest intraclass reliability coefficient (ICC = .95, SEM = 12.7 sec) when comparing total interval prone bridge endurance times across days. In summary, this interval prone bridge fitness test, and accompanying regression model, yields a relatively accurate estimate of total interval prone bridge test time in healthy men and women, using both RPE-95 and PA data.

Key Words: Core Stabilization, Exercise Testing, Abdominal Fitness

Introduction

There are a number of assessments currently used in wellness and fitness centers to evaluate one's health-related physical fitness. Traditionally, measurements are taken to assess a client's cardiorespiratory fitness, muscular strength and endurance, body composition, joint range of motion, resting heart rate and blood pressure, and other biometric data. Recently, specific postural and movement assessments have become popular as a way to better document one's functional fitness, which shows whether or not a person has sufficient levels of joint mobility and stability necessary to maintain a healthy posture, prevent chronic pain, and enhance athletic performance. It is the on-going aim of wellness and fitness programs to find and use those fitness tests that can appropriately educate the client, enhance one's motivation to exercise, properly evaluate physical fitness levels, and provide meaningful data for exercise prescription (ACSM, 2006).

To date, a popular way to assess abdominal strength and endurance is the one-minute half sit-up test (ACSM, 2006; Diener, Golding, & Diener, 1985). The widespread use of this fitness test has emphasized the importance of abdominal strength and endurance. However, if this type of exercise is performed without first developing proper internal pelvic stabilization, excessively high compressive forces could put unwanted pressure on the intervebral disks and lumbar spine (Hodges, Richardson, & Jull, 1996; Hodges & Richardson, 1996, 1997; Norris, 1993). In addition, since the abdominal region is better designed for stabilization than it is for movement (Hodges & Richardson, 1996), it is logical that more emphasis should be placed on evaluating one's core stabilization. Thus, developing and using core stabilization tests in fitness and wellness centers may help more people become educated on the importance of developing a strong and stable core to improve their functional fitness and to possibly minimize or prevent low back pain (Akuthota, 2004; Biering-Sorensen, 1984; Hides, Richardson, & Jull, 1996; Hodges & Richardson, 1996; Saal & Saal, 1989; Stevans & Hall, 1998).

Some of the current core stabilization tests (Alaranta, Hurri, Heliovaara, Soukka, & Harju, 1994; Biering-Sorensen, 1984; McGill, Childs, & Liebenson, 1999; McIntosh, Wilson, Affleck, & Hall, 1998; Schellenberg, Lang, Chan, & Burnham, 2007) include the side bridge (McGill et al., 1999), supine bridge, and prone bridge (Schellenberg et al., 2007) which are relatively easy to administer and perform. Specifically the continuous prone bridge test appears to be well tolerated by asymptomatic and symptomatic (low-back pain) participants and is a valid measure of lumbar spine stabilization endurance (Schellenberg et al., 2007). This test does not involve an external load (other than body weight), and involves only a static (isometric) position placing minimal compression on the spine when it is performed with neutral spine alignment (Ekstrom, Donatelli, & Carp, 2007). Schellengerg et al. (2007) reported the average (±SD) prone bridge maneuver can be maintained continuously for 72.5 ± 32.6 sec in healthy adult males and females (ages 18–65 years) before fatigue or discomfort no longer allows the position to be held. However, holding a steady prone bridge position continuously with good form until volitional fatigue may be difficult for some participants, possibly resulting in a less than enjoyable testing experience.

The primary purpose of this study was to develop a reliable interval prone bridge test (for individuals 18–39 years of age) that includes both work and rest intervals. Ultimately we desired to create an interval prone bridge test that is convenient and time-efficient, realistic and enjoyable for participants to complete that emphasizes the importance of core stabilization.

Methods

Participants

A total of 92 healthy participants, free of low back pain, took part in this study. Participants were recruited from Brigham Young University and the surrounding local community. Before data collection, each participant read and signed a physical activity readiness questionnaire (PARQ) and an informed consent approved by the Brigham Young University Institutional Review Board for Human Subjects.

Procedures

Participants answered a series of questions regarding age, race, physical activity level, and weekly abdominal conditioning. Physical activity (PA) levels were estimated with the following self reported daily activity scale: sedentary = 0, low active = 1, active = 2, and very active = 3, as defined by the Institution of Medicine (2005). Specifically, participants select a *sedentary* daily activity score when PA levels consist of only performing activities of daily living with no exercise or other leisure activities. Participants select a *low active* PA rating when consistently performing light exercise and leisure activities such as walking (e.g., 2–3 mph) approximately 45 minutes a day. Participants select an *active* PA score when consistently performing a combined total of approximately 75 minutes of leisure activities (e.g., walking 2–3 mph) and moderate exercise such as cycling leisurely each day. Lastly, participants select a *very active* PA rating when performing heavy or vigorous exercises like aerobics, swimming, and jogging (e.g., 10 min miles) for approximately 60–75 minutes a day. In addition, weekly abdominal conditioning was self-reported regarding the frequency that participants performed sit-ups/crunches and core training activities (e.g., bridging, yoga, Pilates) with scores ranging from 0–5+ sessions each week.

After answering a brief questionnaire, participants were instructed to remove their shoes to measure body mass and body height using an electronic scale and stadiometer, respectively. Before performing the interval prone bridge test, participants were individually instructed on how to perform the interval prone bridge exercise and reminded to breathe regularly while performing the test.

Participants were then asked to lie in a prone position on a large Aeromat™ gym mat with a paper copy of the 0–10 rate of perceived exertion (RPE) scale (Borg, 1982) placed on the mat in front of them with zero representing no physical strain and ten signifying very, very strong physical strain. Once in a prone position on the mat, participants were asked to practice the prone bridge maneuver. This allowed the participants to learn how to correctly perform the exercise and also allowed the testing administrator to measure the height of the participants' buttocks while correctly performing the test. To measure this height, wooden dowels, acting as rulers, were secured vertically on each side of the participant using blocks of wood as anchors. A string was tied to each ruler which stretched over the top of participants' buttocks when assuming a proper prone bridge position. The string was positioned level with the floor and was set during the practice prone bridge maneuver and remained at this height until the completion of the test. This positioning of the string helped to ensure that participants stayed at the correct height without dropping or elevating their hips (see Figure 1).

To assume the proper prone bridge position, participants' feet were placed close to each other forming a narrow base with the upper body resting on the elbows and forearms. Each arm formed a 90-degree angle (upper arm to lower arm) and remained shoulder width-apart. The entire body was held in a rigid line with the shoulders, hips, and ankles forming a straight line. This position was maintained for a 15-sec work interval followed by a 5-sec rest interval. During the rest interval participants lowered their body to the mat and immediately reported their RPE score for the previous work interval by referring to the 0–10 RPE scale (RPE; 0 = nothing at all, 1 = very weak, 2 = weak/light, 3 = moderate, 4 = somewhat strong, 5 = strong/heavy, 7 = very strong, 10 = very, very strong/almost max). At the end of the 5-sec rest interval, the testing administrator instructed the client to again assume the prone bridge position for another 15-sec work interval. This work-rest cycle was repeated with RPE scores being reported during each rest interval until participants could no longer maintain the proper prone bridge position. The total duration of the test (including the sum of all work and rest intervals) and each RPE score (reported at the end of each work interval) were recorded.

Before data collection it was decided to drop participants who could continue the interval prone bridge assessment beyond 295 sec (5 min) so that these very fit individuals (n = 7) would not bias the prediction model. Following data collection we also elected to drop any participant (n = 12) who completed the interval prone bridge test with a maximum RPE (RPE_{max}) of 8 or less to ensure that all participants analyzed in the regression model achieved a maximum (or near-maximal) level of exertion.

To assess the reliability of the prone bridge, participants were asked to volunteer and perform a second interval prone bridge test at least 48 hours after the initial test.

Statistical Analysis

To determine the contribution and statistical significance of the possible predictor variables (e.g., gender, age, body mass, height, RPE scores, physical activity level, and abdominal conditioning) a stepwise model selection tool was used to evaluate the data. After this, multiple linear regression was employed to generate a prediction model using the statistically significant predictor variables. The relative accuracy of this regression model was evaluated using Pearson correlation coefficients, standard error of estimates (SEE), and the percent SEE (SEE ÷ mean total time). In addition, predicted residual sum of squares (PRESS) statistics (Holiday, Ballard, & McKeown, 1995) were calculated to estimate the degree of shrinkage or generalizability one could expect when the total time prediction equation is used across similar but independent samples. Lastly, a one-way ANOVA model was used to derive an intraclass correlation coefficient (ICC [3, 1]) to evaluate the test-retest reliability of total time estimates involving the interval prone bridge test across days. The level of statistical significance was set at $p < .05$.

Results

Descriptive statistics of the participants (N = 73) are presented in Table 1. Participants' age, weight, and height ranged from 18–39 years, 43.5–114.3 kg, and 1.55–

1.96 m, respectively. The total interval prone bridge test time and ending RPE_{max} score ranged from 75–295 sec and 9–10, respectively. The RPE scores reported after five work intervals (95 sec; RPE-95) were statistically significant in predicting total interval prone bridge test time and provided the highest level of accuracy as compared to RPE scores collected after three work intervals (55 sec; RPE-55) or after four work intervals (75 sec; RPE-75). The mean (±SD) RPE-95 equaled 6.3 ± 2.2. In addition, the only other variable found to be statistically significant in predicting total interval prone bridge test time was self-reported PA levels (0 = sedentary, 1 = low active, 2 = active, 3 = very active) with a mean (±SD) of 1.7 ± 0.6.

Multiple linear regression generated the following prediction equation to estimate total interval prone bridge test time (R = .86, SEE = 32.98 sec, N = 73, see Table 2): Total time (sec) = 300.0 – (23.4 x RPE-95) + (17.7 x PA). Of the two predictor variables, RPE-95 explained the largest amount of variance for total prone bridge time as compared to PA based on the beta-weight (see Table 2). Regression models were also generated separately for females and males using the RPE-95 and PA data (females; n = 37, R = .88, SEE = 32.19 sec: males; n = 36, R = .86, SEE = 31.07 sec) indicating similar accuracy across both groups in predicting total interval prone bridge test time.

The cross-validation PRESS statistics (R_p = .85 and SEE_p = 32.89 sec) demonstrated minimal shrinkage in the accuracy of the full regression model (see Table 2). Figure 2 provides a scatter plot of estimated versus measured total time scores. The reliability study (n = 45) yielded acceptable test-retest reliability (ICC [3,k] = .95, SEM = 12.7 sec) for total time estimates involving the interval prone bridge test across days.

Discussion

The interval prone bridge regression model developed in this study provides an additional testing option when evaluating one's core stabilization. Most importantly, the test provides a relatively accurate (*R* = 0.86; SEE = 32.98 sec; see Table 2) prediction of total elapsed interval prone bridge endurance time using RPE-95 and PA, and may provide a more enjoyable testing experience in a time-efficient manner. Fitness and wellness programs could easily include this test as part of their comprehensive fitness evaluation as a way to enhance and improve the participants' testing experience.

One of our main purposes in conducting this research was to develop a core stabilization test that was interval-based rather than continuous in nature. Traditionally, intervals are used in weight training activities where the participant moves through a series of work and rest intervals. This appears to have both physiological and psychological benefits. For example, after each work interval the muscle has a chance to rest and recover, making possible additional exercise at the beginning of the next work interval. In addition, switching between work and rest intervals add variety to the exercise and minimize the problem of boredom that usually accompanies prolonged static (isometric) muscle contractions. Future research is needed to compare how participants respond to interval vs. continuous prone bridge exercise testing in terms of overall satisfaction and level of enjoyment.

The regression equation developed in this study allows participants to perform a prone bridge test in a series of five 15-sec work intervals and four 5-sec rest intervals for a total of 95 sec. Similarly, the average (±SD) duration of the current continuous prone bridge test (where participants hold a static position until exhaustion) equaled 72.5 ± 32.6 sec (Schellenberg et al., 2007). Consequently, our interval prone bridge test takes about the same amount of time as the current continuous prone bridge test, making either type of test time-efficient and suitable for use in fitness and wellness programs. In contrast, the major difference between the two testing options is that the interval prone bridge test does not require that the participant continue exercising to the point of volitional fatigue; rather, the test is completed at a submaximal level of exertion at the end the fifth work interval (95 sec).

It is not surprising that the RPE-95 score explained the largest amount of the interval prone bridge total time variance (based on the standardized β-weights; Table 2) since RPE data provide relatively accurate estimates of exercise intensity (Borg, 1982). Along with RPE-95, PA also explained a significant amount of variance (based on the standardized β-weights; see Table 2). This is also reasonable to expect since PA generally requires core activation during all types of common body movements (e.g., walking, jogging, swimming, lifting weights, etc.). Interestingly, age was not found to be statistically significant in estimating total prone bridge time in our sample of 18–39 year-olds. Schellenberg et al. (2007) reported the same finding in their study involving participants (aged 18–65 years) who performed a continuous prone bridge test. Thus, it appears on average that participants in these age ranges have not begun to experience a statistically significant age-related drop in abdominal stabilization at this point in their lives.

Notably, this appears to be the first core stabilization test that provides participants the opportunity to report RPE scores throughout the prone bridge test. This offers several possible advantages. For example, the testing administrator can become aware of how clients feel when performing the test and can then make specific suggestions on how hard a given participant might work during a training routine. Similarly, the reporting of RPE scores may help clients to introspectively consider the intensity caused by this type of movement. This reflection on intensity may help participants become more aware of the progression of fatigue during the test, improve their ability to understand and comprehend their physical limitations, and possibly help them in appropriately adjusting their intensity level during training routines involving core stabilization. In addition, fitness and wellness professionals can use various test data to monitor clients' progress during a given training program. The easiest way to do this is to simply compare RPE-95 scores pre- and post-training. Another obvious way is to calculate estimated interval prone bridge time using the regression equation found on Table 2 or to simply identify a client's score with the use of a conversion table (see Table 4).

The cross-validation PRESS statistics (R_p = .85 and SEE_p = 38.2 sec) demonstrated minimal shrinkage in the accuracy of the regression model suggesting that the regression model should provide acceptable accuracy when it is applied to similar samples. Future research needs to confirm these cross-validation results and evaluate how various predictor variables (e.g., gender, age, body mass, height, RPE scores, and physical activity level) affect the predictive accuracy of the interval prone bridge test.

Interestingly, the test-retest reliability (intraclass reliability coefficient [ICC 3,k] = .95, SEM = 12.7 sec) for the interval prone bridge test was somewhat higher than the continuous prone bridge test developed by Schellenberg et al., (2007) (*R* = .78). However, this may be the case because their sample involved older individuals who may have not had adequate rest between the two test sessions. Compared with other types of muscular fitness tests, the test-retest reliability in this study was similar to or better than the core muscle endurance test (ICC range, .93–.99) developed by McGill et al. (1999); the active sit-up and active straight leg raise tests (κ = .48 and κ = .77, respectively) developed by Waddell et al. (1992); and by Hicks et al. (2003) involving a prone lumbar instability test (κ = .87).

The present study was not without limitations, however. Customarily, before a comprehensive fitness testing evaluation participants are asked to drink ample amount of water, refrain from vigorous exercise the day of the test, and abstain from consuming such items as food, alcohol, caffeine, or using any tobacco products for at least 3 hours (ACSM, 2006). In contrast we followed the example of other similar studies involving abdominal exercise testing (Alaranta et al., 1994; McGill et al., 1999; Schellenberg et al., 2007) and did not instruct our participants to adhere to these pre-test control recommendations. However, in the current study we 1) asked our participants to remove their shoes before testing, 2) performed all tests on a consistent testing surface, and 3) required all participants to maintain their buttocks at the appropriate, pre-determined height (using the apparatus described earlier, see Figure 1) during each work interval.

Future research involving abdominal exercise testing may benefit from a more thorough observation of the additional pre-test guidelines recommended by ACSM (2006).

Conclusion

In conclusion, the interval prone bridge test, and accompanying multivariate regression model, developed in the current study provide relatively accurate estimates of total interval prone bridge time using RPE-95 and PA in healthy adults 18–39 years of age. Completing the prone bridge test in intervals and reporting RPE scores during the test may provide a more enjoyable testing experience and serve as an educational tool to teach clients how to appropriately train the core stabilization muscles of the body. In addition, the test is reliable, time-efficient, simple to administer, cost-effective, and poses a low risk of injury to healthy adults. The estimated total interval prone bridge time provides meaningful test results, reflecting one's ability to activate and use core stabilization muscles. Based on the cross-validation results, the predictive accuracy of the regression model should be comparable to other similar samples of healthy adults.

References

American College of Sport Medicine. (2006). *ACSM's Guidelines for Exercise Testing and Prescription (7th edition)*. Philadelphia, PA: Lippincott Williams & Wilkins.

Akuthota, V. (2004). Core strengthening. *Archives of Physical Medicine and Rehabilitation, 85*(3 Suppl 1), S86-S92.

Alaranta, H., Hurri, H., Heliovaara, M., Soukka, A., & Harju, R. (1994). Non-dynamic trunk performance tests: Reliability and normative data. *Scandinavian Journal of Rehabilitation Mededicine, 26*, 211-215.

Biering-Sorensen, F. (1984). Physical measurements as risk indicators for low-back trouble over a one-year period. *Spine, 9*, 106-119.

Borg, G. A. V. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise, 14*(5), 377-381.

Diener, M. H., Golding, L. A., & Diener, D. (1985). Validity and reliability of a one-minute half sit-up test of abdominal strength and endurance. *Sports Medicine, Training, and Rehabilitation., 6*, 105-119.

Dietary Reference Intakes (2005). *DRIs for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids.* Washington, DC: Institute of Medicine. *pp 880-935.*

Ekstrom, R. A., Donatelli, R. A., & Carp, K. C. (2007). Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation exercises. *Journal of Orthopaedic & Sports Physical Therapy, 37*(12), 754-762.

Hides, J. A., Richardson, C. A., & Jull, G. A. (1996). Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. *Spine, 21*(23), 2763-2769.

Hicks, G. E., Fritz, J. M., Delitto, A. & Mishock, J. (2003). Interrater reliability of clinical examination measures for identification of lumbar segmental instability. *Archives of Physical Medicine and Rehabilitation,84* (12), 1858-1864.

Hodges, P. W., Richardson, C., & Jull, G. (1996). Evaluation of the relationship between laboratory and clinical tests of transverse abdominus function. *Physiotherapy Research International, 1*(1), 30-40.

Hodges, P. W., & Richardson, C. A. (1996). Inefficient muscular stabilization of the lumbar spine associated with low back pain. *Spine, 21*(22), 2640-2650.

Hodges, P. W., & Richardson, C. A. (1997). Contraction of the abdominal muscles associated with movement of the lower limb. *Physical Therapy, 77*(2), 132.

Holiday, D. B., Ballard, J. E., & McKeown, B. C. (1995). PRESS-related statistics: Regression tools for cross-validation and case diagnostics. *Medicine and Science in Sports and Exercise, 27*(4), 612-620.

McGill, S. M., Childs, A., & Liebenson, C. (1999). Endurance times for low back stabilization exercises: Clinical targets for testing and training from a normal database. *Archives of Physical Medicine and Rehabilitation, 80*(8), 941-944.

McIntosh, G., Wilson, L., Affleck, M., & Hall, H. (1998). Trunk and lower extremity muscle endurance: Normative data for adults. *Journal of Rehabilitation Outcomes Measurement, 2*(4), 20-39.

Norris, C. M. (1993). Abdominal muscle training in sport. *British Journal of Sports Medicine, 27*(1), 19-27.

Saal, J. A., & Saal, J. S. (1989). Nonoperative treatment of herniated lumbar intervertebral disc with radiculopathy. *Spine, 14*(4), 431-437.

Schellenberg, K. L., Lang, J. M., Chan, K. M., & Burnham, R. S. (2007). A clinical tool for office assessment of lumbar spine stabilization endurance: Prone and supine bridge maneuvers. *American Journal of Physical Medicine & Rehabilitation, 86*(5), 380-386.

Stevans, J., & Hall, K. G. (1998). Motor skill acquisition strategies for rehabilitation of low back pain. *Journal of Orthopaedic & Sports Physical Therapy, 28*(3), 165-167.

Waddell, G., Somerville, D., Henderson, I., & Newton, M. (1992). Objective clinical evaluation o fphysical impairment in chronic low back pain. *Spine, 17*(6), 617-628)

Table 1

Descriptive Statistics for Total, Female, and Male Participants

	Total (n = 73)		Females (n = 37)		Males (n = 36)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age	27.9	5.8	26.9	5.5	29.0	6.0
Weight (kg)	71.1	14.7	62.2	9.4	80.2	13.5
Height (m)	1.74	0.1	1.66	0.07	1.81	0.07
RPE-95[a]	6.3	2.2	6.5	2.4	6.2	2.0
PA level[b]	1.7	0.6	1.7	0.6	1.8	0.7
Situp/crunch Freq[c]	1.5	1.5	1.5	1.5	1.5	1.5
Bridging Freq[d]	0.5	0.9	0.7	1.0	0.3	0.6
Total Interval Prone Bridge Time (sec)[e]	179.9	65.2	172.3	68.3	187.8	61.8
RPE_{max}	9.9	0.3	9.9	0.3	9.9	0.4

[a] RPE-95 = the submaximal RPE score reported at 95 sec during the interval prone bridge test

[b] Physical activity coded as sedentary = 0, lightly Active = 1, active = 2, very active = 3

[c] Situp/crunch exercise sessions completed each week

[d] Core stabilizing exercise sessions completed each week

[e] Total duration of the test to volitional fatigue

Table 2

Interval Prone Bridge Total Time Regression Equation *(N = 73)*

Variable	β	β-weight	*p* value
Intercept	300.0		
RPE-95	-23.4	-0.80	<.0001
PA level	17.7	0.18	0.006
R^2	.74		
R	.86		
SEE (sec)	32.98		
% SEE (% of total time)	18.3		
R_{PRESS}	.85		
SEE_{PRESS}	32.89		

β-weights = standard multiple regression coefficients

$R_{PRESS} = (1-(PRESS/SS_{total}))^{1/2}$

$SEE_{PRESS} = (PRESS/n)^{1/2}$

Table 3

Interval Prone Bridge Endurance Time Predictions[a]

	Sedentary (score = 0)	Low active (score = 1)	Active (score = 2)	Very Active (score = 3)
RPE-95				
0	300	318	335	353
1	277	294	312	330
2	253	271	289	306
3	230	248	265	283
4	206	224	242	260
5	183	201	218	236
6	160	177	195	213
7	136	154	172	189
8	113	131	148	166
9	***	107	125	143
10	***	***	101	119

[a]Calculated using the full regression model; see Table 2

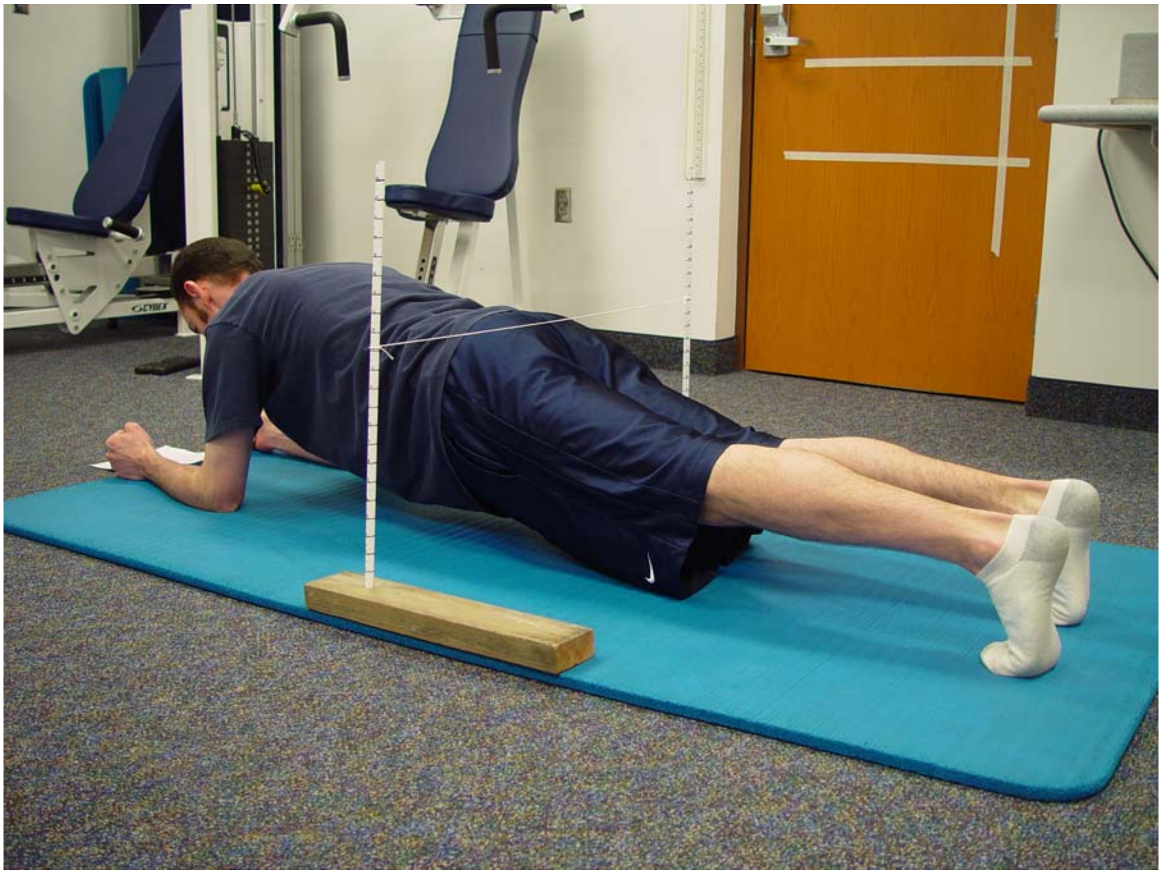

Figure 1. Prone Bridge Testing Position

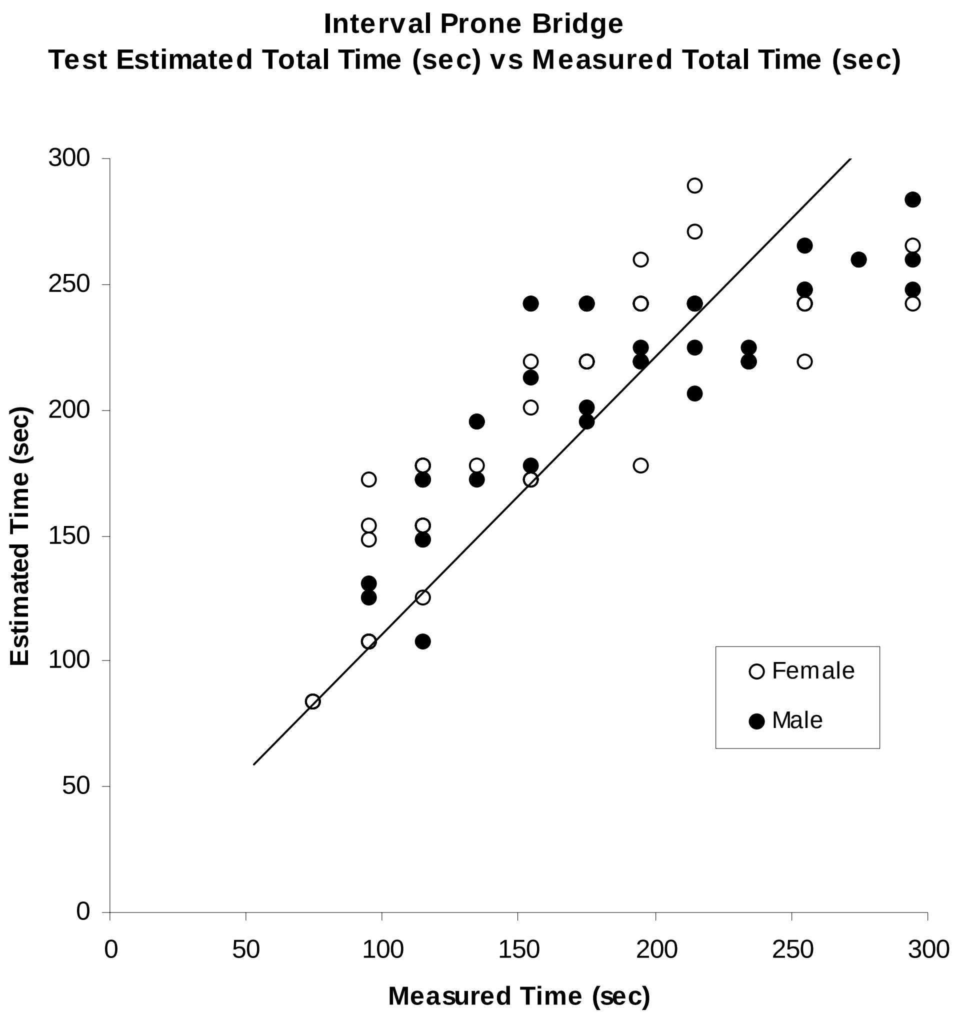

Figure 2. Estimated Time (sec) vs Measured Time (sec)

Appendix A

Prospectus

Chapter 1

Introduction

The muscles of the core are essential because of their important role in stabilizing and mobilizing the spine, hips, and torso of the body. The "core" as it is commonly called, is the genesis of function, transferring force to every limb movement. For this reason it is often called the "powerhouse" of the body.[1] Strengthening the core is one way to help prevent disabilities, rehabilitate injuries, and enhance athletic performance.[1] Richardson et al.[2] define the core as a box. The roof of the box is the diaphragm and the base is the pelvic floor and hip girdle musculature. The front of the box consists of the abdominal walls and the back is made up of the paraspinals and gluteals. In all, the musculature makeup of the core includes 29 pairs of muscles that support the lumbo-pelvic-hip complex and stabilize the spine, pelvis, and kinetic chain during movement.[3]

Bergmark[4] originally divided the muscles of the core into two categories known as the local system and global system. Since then others[1, 5, 6] have made slight changes to reorganize these systems. For example, the National Academy of Sports Medicine (NASM) identifies these categories as the stabilization (local) system and movement (global) system.[6] Examples of stabilizer muscles include the transverse abdominis, internal oblique and multifidus.[6] Norris[5] describes stabilizer muscles as generally deep, slow twitch in nature, and activated by low resistance levels of 30–40% maximum voluntary contraction (MVC). Mobilizing muscles are typically superficial, fast twitch in nature, and better activated with resistance levels above 40% MVC.[5] Examples of these include the rectus abdominis, external oblique, and erector spinae.[2, 5, 6]

By identifying and understanding both the stabilization system and the movement system, it is obvious to see the need for multiple core exercises to improve both systems. Professionals can now select from a variety of exercises to target improvement in each system or desired core muscles within a system. For this reason, over the past several decades many core exercises have been developed.[1, 7-16]

Exercises suggested by Faries and Greenwood[8] to improve the movement system are mainly dynamic, such as the t-rotation, twist on ball, cable wood chop, cable reverse wood chop, skier crunch, overhead press functional progression, and the two arm/single arm chest press functional progression. Exercises more isometric in nature such as dying bug, marching, side bridge, prone bridge, and prone bridge hip extension focus more on improving the stabilization system.[8] These are only a few of the exercises developed for core muscle training differentiating the movement system and stabilization system.

In particular, the prone bridge maneuver is currently prescribed to improve the stabilization system of the core[8] as a component of an exercise program, and can be used to evaluate lumbar spine stabilization endurance as a field test.[11] It is validated as a surrogate measure of lumbar spine stabilization endurance[11] and requires the use of at least the rectus abdominis,[9, 11] external obliques,[9, 11] and internal obliques.[10] Although more research is needed to validate the use of other muscles, face validity suggests the use of the prone bridge as a stabilizing exercise. Some of the early advocates and researchers of the prone bridge include Ekstrom et al.,[9] Lehman et al.,[10] Schellenberg et al.,[11] and Jemmett.[12]

In 2007, Schellenberg et al.[11] measured the test-retest reliability for a continuous prone bridge maneuver as a field test in asymptomatic participants with a correlation of 0.78 and average endurance times for male and female at 92.9 sec (SD $\pm$ 29.3) and 51.2 sec (SD $\pm$ 19.9), respectively. Male and female participants with low-back pain had endurance times of 33.4 sec (SD $\pm$ 26.0) and 24.3 sec (SD $\pm$ 27.5), respectively.[11] Even though some participants discontinued the test because of pain and not fatigue, it did not have a significant effect on mean endurance times.[11]

The prone bridge maneuver does not involve an external load (other than body weight) and appears to have little compression on the spine when it is performed with a neutral spine alignment.[9] The prone bridge maneuver is well tolerated by asymptomatic and symptomatic (low-back pain) participants.[11] These benefits make the prone bridge an attractive maneuver as a core exercise and a field test without the risk of low back pain or injury.[17]

However, the current continuous prone bridge maneuver field test does not follow the recommendation for performing core stabilization training. It is recommended when training the core stabilization system to perform multiple repetitions of sustained contractions for only 6 to 20 secs.[6] The continuous prone bridge test measures sustained contractions far beyond the recommended 20 sec.

Statement of the Problem

The primary purpose of this study is to develop a reliable 15/5-sec work/rest interval prone bridge test, similar to prescribed training routines for the core stabilization system,[6, 12] for individuals 18–29 and 30–39 years of age. A secondary purpose is to evaluate how the sit-up test, continuous prone bridge test, and 15/5-sec work/rest interval prone bridge test compare in terms of total number of sit-ups and total endurance times. Rate of perceived exertion (RPE) and test preference will be compared between the continuous prone bridge test and the 15/5-sec work/rest interval prone bridge test.

Hypothesis

The 15/5-sec work/rest interval prone bridge test will be a reliable field test and preferred by participants over the continuous prone bridge test. Both the 15/5-sec work/rest interval prone bridge test and the continuous prone bridge test will elicit near maximum RPE scores by the termination of each test. The sit-up test, continuous prone bridge test, and 15/5-sec work/rest interval prone bridge test will be correlated.

Null Hypothesis

The 15/5-sec work/rest interval prone bridge test will not be a reliable field test. There will be no difference in preference between the continuous prone bridge test and 15/5-sec work/rest interval prone bridge test. RPE scores for the continuous prone bridge test and the 15/5-sec work/rest interval prone bridge test will not elicit near maximum RPE scores by the termination of each test. The sit-up test, continuous prone bridge test, and 15/5-sec work/rest interval prone bridge test will not be correlated.

Significance of the Study

This study will develop a new field test that involves evaluating the abdominal stabilization system with a normative rating system to rank participants according to their muscular endurance times in healthy adults, aged 18–29 and 30–39 years. A 15/5-sec work/rest interval prone bridge test will be more specific to training protocol of commonly prescribed routines. Developing a more preferred endurance stabilization test may motivate additional people to assess fitness levels more frequently and engage in stabilization training.

Chapter 2

Review of the Literature

A common abdominal exercise and fitness test is the standard sit-up. However, McGill[18] determined that the compressive load of both dynamic and quasi-static sit-up positions on the spine is above 3000 N and suggests that anyone with low back pain or anyone desiring to prevent low back injury may wish to avoid these specific types of exercise. In search for better ways to strengthen and test abdominal muscles without the risk of low back pain, many professionals have sought to improve and promote safe abdominal exercises.[7-12, 17]

The purposes of abdominal and low back exercises are mainly for low back rehabilitation, injury prevention, athletic performance, and fitness.[1, 17] Determining which exercise is best to use depends on which of these reasons one is engaging in abdominal and low back exercises. For example, exercises that place little load on the spine but cause substantial muscle activation may be better for rehabilitation, injury prevention, and general conditioning. However, trained athletes that want to improve athletic performance may do so by including exercises which require a greater load on the spine.[17]

McGill[17] suggests that the abdominal muscles are not all challenged by any one particular abdominal exercise. Thus, there is a need for abdominal training regimens and fitness testing to incorporate various exercises in order to strengthen and test the different abdominal muscles. Researchers[7, 9, 10, 17, 19] have shown different levels of muscle activation across a large variety of abdominal exercises using intramuscular and surface electromyographic (EMG) analysis, assisting fitness professionals to select the best exercise(s) for their participants involved with abdominal fitness testing and training.

For example, if someone wants to focus training on the obliques a fitness professional could suggest an exercise such as the isometric side support exercise which highly activates these muscles.[17, 19] Furthermore, if a patient is just beginning to train it may be better to begin strengthening the stabilizer muscles such as the transverse abdominis, internal oblique and multifidus.[6] This can be accomplished by prescribing exercises such as the prone bridge,[10] isometric hand-to-knee,[7] or unilateral bridge.[9]

Before prescribing and performing abdominal and low back field tests or training regimens, it is important to understand how the muscles of the core are categorized into different systems. Most commonly, the core is separated into two systems know as the stabilization (local) system and the movement (global) system.[2, 4-6] The stabilization system is made up mainly of the transverse abdominis, multifidus, internal oblique, and the quadratus lumborum.[2, 5, 6] The movement system of the core is primarily comprised of the rectus abdominis, external oblique, and the erector spinae.[2, 5, 6]

After categorizing the core into two systems, stabilization and movement, different abdominal and lower back exercises can be selected to focus training regimens for a specific system or muscles. For instance, the back extensor exercise of leg extension from a four-point stance with opposite arm extension, can be used to focus training the multifidus, external oblique, and internal oblique from the stabilization system and both the thoracic erector spinae and lumbar erector spinae from the mobilizing system.[17, 20] This back extensor exercise influences muscles in both systems and puts minimal load on the spine, while maintaining adequate muscle activation for endurance and strength training.[20]

Other abdominal exercises focus on muscles such as the rectus abdominis, external oblique and internal oblique. Both the straight-leg and bent-leg sit-up protocols have high muscle challenge using the rectus abdominis, but also a high compression on vertebrae L4 and L5, highlighting why these two exercises may not be the safest exercises to train the movement system of the core.[19] However, in search for the safest abdominal challenge, Axler and McGill,[19] discovered a number of abdominal exercises with a high challenge-to-compression ratio. These exercises include the Canadian Standardized Test of Fitness (CTSF) curl-up feet anchored, CTSF curl-up feet free, dynamic cross-knee curl-up, and hanging straight-leg raise. These exercises are now recommended as safe abdominal exercises for the rectus abdominis and external oblique.[19]

When focusing more on the stabilization system of the core, Lehman et al.,[10] McGill,[17] and Axler and McGill,[19] support the isometric side bridge as an exercise that emphasizes both the external oblique and internal oblique with low compression between vertebrae L4 and L5.

Among other recommended abdominal exercises for the stabilization system is the prone bridge.[12] Ekstrom et al.,[9] Lehman et al.,[10] and Schellenberg et al.[11] all performed specific research identifying abdominal muscle activation for the prone bridge through surface EMG analysis. Their results show the prone bridge appears to engage the external oblique,[9-11] rectus abdominis,[9-11] and internal oblique[10] enough for endurance training. However, the gluteus medius[9] is only lightly activated by the prone bridge. Although activation of the transverse abdominus, a primary muscle of the stabilizing system, appears to have not been directly studied with the prone bridge exercise, Jemmett[12] suggests the prone bridge is a good exercise for stabilization, activating the transverse abdominus.

Among these researchers, Schellenberg et al.[11] validated the prone bridge test by measuring the abdominal anterolateral muscle activity, specifically, external oblique and rectus abdominus activation. Test-retest reliability for the continuous prone bridge test was measured at 0.78.[11] This test-retest reliability correlation may have been somewhat low due to inadequate resting time between tests as suggested by the authors (although the specific amount of rest time was not mentioned).[11] Also, isometric endurance tests seem to have greater variability than dynamic strength tests.[21]

Ekstrom et al.[9] also suggest the prone bridge exercise provides moderate stimulus on the rectus abdominus and the external oblique. This stimulus should improve endurance and stabilization, especially in people who initially have lower endurance or stabilization ability.[9] The prone bridge may also be important to help prepare a rehabilitation program because it does not externally load (other than body weight) the spine. The effect of the prone bridge maneuver on the shoulder girdle and glenohumeral joint does not appear to have been studied. The prone bridge test is now used as a tool to assess lumbar spine stabilization endurance,[11] and is prescribed for rehabilitation measurements and as a component of exercise programs.[9, 12]

The actual prone bridge maneuver appears to be safe and can be used as a spine stabilization endurance exercise and test.[9-12] However, the actual prone bridge test is continuous and may not be the best approach compared to an interval test. This is because a 15/5-sec work/rest interval test is more specific to the recommended training programs by professionals.[6, 12] For example, Jemmett[12] suggests that the prone bridge maneuver may only be able to be held for 5–10 sec performing up to 10 repetitions, when beginning a stabilization program. NASM specifically requires core training for the stabilization system to include 6–20 sec sustained repetition contractions.[6]

The purpose of this study is to develop a new field test for core muscle stabilization endurance using the prone bridge exercise in 15/5-sec work/rest intervals. This new type of interval testing will be in line with how professionals recommend training the stabilization system and can become a training tool to perform the prone bridge maneuver. This new 15/5-sec work/rest interval test may also result in a more desirable test compared to a continuous prone bridge test. Even more, it may prove to be a better method of abdominal exercise testing with less test-retest variability than the continuous prone bridge test.

Chapter 3

Methods

The design of this study will be a randomized block design and consist of two phases. Specific details of the methods in each phase will be given below in the phase sections. A general description of phase 1 and phase 2 is as follows:

The first phase will include three different abdominal tests comparing multiple measurements from each test. These tests include a one-minute sit-up test, a continuous prone bridge test, and a 15/5-sec work/rest interval prone bridge test. Each test will be administered at least 48 hours apart. Measurements will involve total endurance time/number of sit-ups, rate of perceived exertion (RPE), reason for discontinuing the test, and preference between the continuous and 15/5-sec work/rest interval prone bridge tests.

The second phase will involve two different age groups, 18–29 and 30–39 years of age. These participants will perform the 15/5-sec work/rest interval prone bridge test two times in a laboratory setting, where better control of body positioning during the prone bridge tests can be monitored. Test-retest reliability of the 15/5-sec work/rest interval prone bridge test will be measured in both phases including field and laboratory settings.

Before testing, participants will read, complete, and sign a physical activity readiness questionnaire (PARQ) and an IRB informed consent. Participants will also report their demographics, including physical activity level, on their record sheet. Each abdominal exercise test will be explained and demonstrated immediately before testing. All participation is voluntary and participants may withdraw from the study at any time.

Phase 1: One Minute Sit-Up vs. Continuous Prone Bridge vs. 15/5-sec work/rest Interval Prone Bridge

Participants in this phase will be recruited from physical activity classes at Brigham Young University. Approximately 120 students (60 male, 60 female) about 18–29 years of age will perform the one-minute sit-up test, continuous prone bridge, and 15/5-sec work/rest interval prone bridge test. Testing in this phase will last approximately two weeks, spacing each test at least 48 hours apart. The testing order for each of these three tests will be randomized.

While performing both the 15/5-sec work/rest interval prone bridge test and the continuous prone bridge test participants will report their RPE every 10 or 15 seconds. This will be done by placing a perceived exertion Borg Scale[22] from 1 to 10 on the ground visibly in front of the participants. Throughout the duration of the continuous prone bridge test the testing administrator will ask participants how they feel every 10 seconds until discontinuing the test. Participants will respond with an exertion score which will be recorded by the testing administrator. During the 15/5-sec work/rest interval prone bridge test participants will be asked for a RPE score at the end of each 15/5-sec work/rest interval.

Immediately after completing each of the continuous prone bridge test and the 15/5-sec work/rest interval prone bridge test, participants will answer two questions regarding their overall opinion of the test they performed and whether each test was discontinued because of abdominal fatigue or discomfort, shoulder fatigue or discomfort, back discomfort, or other. Once both the continuous prone bridge test and the15/5-sec work/rest interval prone bridge test are complete, the participants will be asked which of the two tests they would rather perform. In addition, willing participants who completed the 15/5-sec work/rest interval prone bridge as their final test will also be asked to complete a second 15/5-sec work/rest interval prone bridge test after 48 hours to measure test-retest reliability in a non-laboratory setting.

One-Minute Sit-up Test. The procedures from the Canadian Standardized Test of Fitness (CSTF) operations manual third edition[23] will be used to administer the one-minute sit-up test. Testing materials include a mat and stop watch. After lying on the mat in a supine position, the participants will flex their knees to 90 degrees with feet hip-width apart. Hands will be positioned on each side of the head over the ears. A partner will hold down the participant's ankles during the test to ensure the heels remain in constant contact with the mat during testing. On the "go" command the participant will be instructed to sit up far enough that the elbows touch the knees and then lower the back until the shoulders touch the mat again. This movement should be a controlled body motion of "curling up" and "curling down" not a "rocking" or "bouncing" movement.

Curling up emphasizes rolling the upper back and shoulders off the mat. Curling down emphasizes the lower back coming in contact with the mat before the upper back and shoulders. Avoiding rocking and bouncing movements will keep participants from using momentum to bounce back up after making contact with the mat. The participant's buttocks will remain in contact with the mat, and the fingers in contact with the sides of the head throughout the entire test.

The complete sit-up motion will be repeated as many times as possible in one minute. Rest is permitted at any time during the test and all participants will be advised not to hold their breath, but to exhale when curling up and inhale while curling down. The testing administrator will count the total number of properly performed repetitions. Improper repetitions including rocking, bouncing, or not maintaining contact with the mat or sides of the head will not be counted. The number of properly performed repetitions will be recorded upon completion of the test.

Continuous Prone Bridge Test. Participants will begin the prone bridge test by getting in a prone position on the floor after removing their shoes. On the go command, participants will lift their body off the ground, resting their body weight on the forearms/elbows and the toes. The feet will form a narrow base about 12 inches apart. The upper arms will be perpendicular to the ground forming a 90-degree angle with the forearms. Elbows will be shoulder-width apart (spacing between the forearms and hands will also be shoulder-width apart). The trunk should be in a neutral spine alignment with the shoulders, hips, and ankles maintained in a straight line. This is the prone bridge testing position.

The test will be terminated when at least one of the following conditions is met: (1) participants are unable to maintain a neutral spine alignment with the shoulders, hips, and ankles in a straight line after two reminders; (2) participants return to the start position, or request to end the test; and (3) 5 minutes is reached while maintaining a proper testing position.

15/5-sec work/rest Interval Prone Bridge Test. This test will begin the same as the continuous prone bridge test with participants resting on the floor in a prone position after removing their shoes. Before starting the test, participants will be informed that a rest period of 5 seconds will be given between each 15-sec interval (during each 5-sec rest period participants will return to the start position).

On the go command, participants will raise their body into the prone bridge testing position as described for the continuous prone bridge test. After each 15-sec interval the testing administrator will instruct the participant to drop down or rest for 5-sec. The 5-sec rest period will begin as soon as the administrator says down or rest. The timer will be continuously running so the up and down movements will be quick. Immediately following the 5-sec rest, the participant will again be instructed to return to the go or up position.

Termination of the test will be determined when at least one of the following conditions is met: (1) participants are unable to maintain a neutral spine alignment with the shoulders, hips, and ankles in a straight line; (2) participants return to the start position or request the test be stopped; and (3) a total of 5 minutes is reached following the test protocol. At the completion of the test, total time (combined testing and resting position times) will be recorded.

Phase 2: 15/5-sec work/rest Interval Prone Bridge (laboratory setting)

Approximately 100 participants (50 male, 50 female) will be tested in this phase of the study. The 100 participants will make up two different age groups (18–29 years of age and 30–39 years of age) comprised of 25 males and 25 females in each group. This phase will last approximately three weeks in order to obtain the needed number of participants in this phase. Each participant will perform the 15/5-sec work/rest interval prone bridge test twice in order to measure test-retest reliability. Participants will be recruited from both Brigham Young University and the surrounding BYU community. The surrounding BYU community will include fitness and wellness centers.

To minimize muscle fatigue and training effect, at least 48 hours will separate each test. Total times for each test will be recorded and evaluated between age groups. In order to help ensure consistent results and proper prone bridge positioning in a laboratory setting, a string will be held across participants' buttocks at a constant level independent to each participant. To do this several hooks, an inch apart, will be placed vertically on a wall. The string will be attached to a hook at the appropriate height and then pulled across the buttocks of the participants (while in the up prone bridge position). The other end of the string will be secured to a stationary vertical measuring stick, keeping the string at a constant height, based on the stature of the participant. This technique will allow the testing administrator to more precisely determine if the hips rise or sink. The hook number and height where the string attaches to the ruler will be recorded. Two warnings will be given if needed to encourage participants to maintain a constant body height during the tests. If a third warning is necessary the test will immediately stop and the total time will be recorded.

Statistical Analysis

The design of this study will be a randomized block design and consist of two phases. In phase 1 the independent variable is the total endurance time for the 15/5 sec work/rest interval prone bridge test and the dependant variables are the total endurance time for the continuous prone bridge test and 1 minute sit-up test. A Pearson correlation will be calculated between these variables. Also, in phase 1 a Pearson correlation will be calculated from approximately 20 participants completing two 15/5 sec work/rest interval prone bridge tests. A t-test will be used on the mean differences between RPE scores of the continuous prone bridge test and the 15/5 sec work/rest interval prone bridge test and with mean differences of test preference between these two tests. Phase 2 will include a Pearson correlation for test-retest reliability for the 15/5 sec work/rest interval prone bridge in a laboratory setting. To determine a normative data chart for the 15/5 sec work/rest interval prone bridge test, endurance times in phase two will be categorized into excellent, good, average, fair and poor.

References

1. Akuthota V. Core strengthening. *Arch Phys Med Rehabil* 2004;85 (3 Suppl 1):S86-92.

2. Richardson C, Jull G, Hodges P, Hides J. *Therapeutic Exercise for Spinal Segmental Stabilization in Low Back Pain: Scientific Basis and Clinical Approach*. Edinburgh NY: Churchill Livingstone; 1999.

3. Fredericson M, Moore T. Core stabilization training for middle-and long-distance runners. *New Stud Athletics* 2005;20:25-37.

4. Bergmark A. Stability of the lumbar spine: A study in mechanical engineering. *Acta Orthop Scand* 1989;230:20-4.

5. Norris CM. Functional load abdominal training: part 1. *Journal of Bodywork and Movement Therapies* 1999;3:150-8.

6. Clark MA, Lucett S, Corn RJ. *NASM Essentials of Personal Fitness Training*. 3rd ed. Baltimore: Lippincott Williams & Wilkins; 2008.

7. Juker D, McGill S, Kropf P, Steffen T. Quantitative intramuscular myoelectric activity of lumbar portions of psoas and the abdominal wall during a wide variety of tasks. *Med Sci Sports Exercise* 1998;30(2):301-10.

8. Faries MD, Greenwood M. Core training: Stabilizing the confusion. *Strength and Conditioning Journal* 2007;29(2):10-25.

9. Ekstrom RA, Donatelli RA, Carp KC. Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation exercises. *Orthop Sports Phys Ther* 2007;37(12):754-62.

10. Lehman GJ, Hoda W, Oliver S. Trunk muscle activity during bridging exercises on and off a swissball. *Chiropractic & Osteopathy* 2005;13(14).

11. Schellenberg KL, Lang JM, Chan KM, Burnham RS. A clinical tool for office assessment of lumbar spine stabilization endurance: prone and supine bridge maneuvers. *Am Phys Med Rehabil* 2007;86(5):380-6.

12. Jemmett R. *Spinal Stabilization- The New Science of Back Pain*. Halifax: RMJ Fitness & Rehabilitation Consultants; 2002.

13. McGill SM, Childs A, Liebenson C. Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. *Arch Phys Med Rehabil* 1999;80(8):941-4.

14. Faulkner RA, Springings EJ, McQuarrie A, Bell RD. A partial curl-up protocol for adults based on an analysis of two procedures. *Can J Spt Sci* 1989;14(3):135-41.

15. Alaranta H, Hurri H, Heliovaara M, Soukka A, Harju R. Non-dynamic trunk performance tests: reliability and normative data. *Scand J Rehab Med* 1994;26:211-5.

16. Sparling PB, Millard-Stafford M, Snow TK. Development of a cadence curl-up test for college students. *Res Q Exerc Sport* 1997;68(4):309-16.

17. McGill SM. Low back exercises: evidence for improving exercise regimens. *Phys Ther* 1998;78(7):754-65.

18. McGill SM. The mechanics of torso flexion: situps and standing dynamic flexion manoeuvres. *Clin Biomech* 1995;10(4):184-92.

19. Axler CT, McGill SM. Low back loads over a variety of abdominal exercises: searching for the safest abdominal challenge. *Med Sci Sports Exerc* 1997;29(6):804-11.

20. Callaghan JP, Gunning JL, McGill SM. The relationship between lumbar spine load and muscle activity during extensor exercises. *Phys Ther*1998;78(1):8-18.

21. Mayer T, Gatchel R, Betancur J, Bovasso E. Trunk muscle endurance measurement: isometric contrasted to isokinetic testing in normal subjects. *Spine* 1995;20(8):920-6.

22. Borg GAV. Psychophysical bases of perceived exertion. Medicine and Science in Sports and Exercise 1982;14(5):377-81.

23. Sport GoCFaA. Candadian standardized test of fitness (CSTF) operations manual. 3 ed.; 1986.

24. Health BCMo. Physical Activity Readiness Questionnaire (PAR-Q) Validation Report. 1978.

Appendix A-1a

PARA-Q and Consent Forms

Modified Physical Activity Readiness Questionnaire (PARQ)

For most people physical activity should not pose any problem or hazard. The PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check the appropriate line.

YES	NO	
____	____	1. Do you suffer from lower back pain?
____	____	2. Do you frequently have pains in your heart and chest?
____	____	3. Has your doctor said you have heart trouble?
____	____	4. Do you often feel faint or have spells of severe dizziness?
____	____	5. Has a doctor ever said your blood pressure was too high?
____	____	6. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?
____	____	7. Is there a good physical reason not mentioned here why you should not participate in this activity program even if you want to?

______________________________ ______________________
SIGNATURE OF PARTICIPANT DATE

______________________________ ______________________
WITNESS DATE

If you answered "yes" to any question, please visit with the test administrator.

*References
Health BCMo. Physical Activity Readiness Questionnaire (PAR-Q) Validation Report. 1978. [24]
Sport GoCFaA. Candadian standardized test of fitness (CSTF) operations manual third edition. 3 ed.; 1986. [23]

Development of a Core Fitness Test
Consent to be a Research Subject

Introduction
This research study is being conducted by Joel Reece, BS, James George, PhD, Brent Feland, PhD, Wayne Johnson, PhD, Ron Hager, PhD and Bill Myrer, PhD, at Brigham Young University to develop a new core fitness test. You were selected to participate because you are currently taking a physical activity class or are part of the Brigham Young University community.

Procedures
This research includes two phases. During Phase 1 you will be asked to complete three different core fitness tests (1 min. sit-up test, continuous prone bridge test, interval prone bridge test) approximately 48 hours apart from each other. The continuous prone bridge test will require you to hold the prone bridge position (push-up position, but supported by elbows and forearms instead of palms and wrists) until fatigue while the interval prone bridge test allows a 5 sec rest from the prone bridge position every 15 sec. In phase 1 you may volunteer to perform a second interval prone bridge test after completing the three different core fitness tests. Also during phase 1, while performing the continuous prone bridge and interval prone bridge tests you will be asked your rate of perceived exertion (RPE), why you discontinued the test, and which of the prone bridge tests you would rather perform. During phase 2, only the interval prone bridge test will be tested and only qualified participants will be asked to complete a second interval prone bridge test. Each test will take place approximately 48 hours apart from each other. Before actual testing in either phase you will be asked questions regarding your demographics including name, age, gender, race, height, weight, and physical activity level. Researchers will contact those who volunteer with more information regarding the time and place. Each fitness test will last for approximately 5 minutes. Because you will complete one of the three tests on three separate days over a three week period, your total time of commitment of Phase 1 will be about 15 minutes (5 minutes/day, 2-3 days/week, lasting approximately 2 weeks).

Risks/Discomforts
There are minimal risks associated with participation in this study. However, you may feel abdominal muscle, shoulder, or low back fatigue/discomfort after testing. When participating in a fitness test, it is possible that you may feel embarrassed when performing in front of others. The moderator will be sensitive to those who may become uncomfortable.

Benefits
There are no direct benefits to subjects. However, it is hoped that through your participation researchers will learn more about core fitness testing.

Confidentiality
All information provided will remain confidential and will only be reported as group data with no identifying information. All data, including demographics, fitness test scores, RPE scores, and posttest questions will be kept in storage cabinets and only those directly involved with the research will have access to them.

Compensation
Those who complete Phase 1 of the study will receive 5 extra credit points. If you choose not to participate in this study you may receive 5 extra credit points by reviewing an article of interest from a peer reviewed journal or by assisting in data collection. All those who complete Phase 2 of the study will receive a $5 gift certificate after completing two 15/5 sec work/rest interval prone bridge tests. This compensation is given to participants who complete their participation either on or off campus. The $5 gift certificate will only be given after completing the second test. Participants in Phase 2 may not be asked to perform a second test. If this occurs no compensation will be provided. No partial compensation will be provided for those who do not complete the study.

Participation
Participation in this research study is voluntary. You have the right to withdraw at anytime or refuse to participate entirely without jeopardy to your class status, grade or standing with the university. The researchers may terminate your participation due to lack of compliance with the research expectations or an inability to schedule appointments.

Questions about the Research
If you have questions regarding this study, you may contact Joel Reece MS, at 422-9156, joelhead82@hotmail.com or James George, PhD, at 422-8778, jim@byu.edu.

Questions about your Rights as Research Participants
If you have questions regarding your rights as a research participant, you may contact Christopher Dromey, PhD, IRB Chair, 422-6461, 133 TLRB, Brigham Young University, Provo, UT 84602, Christopher_Dromey@byu.edu.

I have read, understood, and received a copy of the above consent and desire of my own free will to participate in this study.

Signature:____Date:_____________

Appendix A-1b

Data Collection Forms

Phase 1 Data Sheet

Name:______________________________ ID:________________ Date:___________

Age:_________________yr Gender: Male / Female Race:___________

Weight:______________lbs Height:_____inches PA level: S LA A VA

Do you do abdominal exercises? Sit-ups/Crunches Bridging/Yoga/Pilates

How often (per week)? 1x 2x 3x 4x 5x+ 1x 2x 3x 4x 5x+

Test Order (1 2 3)

_____ 1 minute sit-up test _____ Continuous Prone Bridge _____ 10/5-sec interval Prone Bridge

# of sit-ups:_______ Total time:_______(sec) Total time:_______(sec)

Why was the test discontinued?

1 minute sit-up test	**Continuous Prone Bridge**	**10/5-sec interval Prone Bridge**
Abdominal fatigue/ discomfort	**Abdominal fatigue/ discomfort**	**Abdominal fatigue/ discomfort**
Shoulder fatigue/ discomfort	**Shoulder fatigue/ discomfort**	**Shoulder fatigue/ discomfort**
Back Pain	**Back Pain**	**Back Pain**
Other	**Other**	**Other**

Which of the two prone bridge tests would the participant rather perform when evaluating abdominal endurance?

Continuous Prone Bridge 10-sec Int. Prone Bridge

The Borg Scale of Perceived Exertion

0- Nothing at all

1- Very Weak

2- Weak (light)

3- Moderate

4- Somewhat Hard

5- Hard (heavy)

6-

7- Very Hard

8-

9-

10- Very, Very Hard (almost max)

Borg GAV. Psychophysical bases of perceived exertion. Medicine and Science in Sports and Exercise 1982;14(5):377-81. [22]

Rate of Perceived Exertion Record Form

Continuous Prone Bridge Test RPE (0-10)

Name:______________________________ ID:________________

10 sec:_____

20 sec:_____

30 sec:_____

40 sec:_____

50 sec:_____

60 sec:_____

70 sec:_____

80 sec:_____

90 sec:_____

100 sec:_____

110 sec:_____

120 sec:_____

130 sec:_____

140 sec:_____

150 sec:_____

160 sec:_____

170 sec:_____

180 sec:_____

190 sec:_____

200 sec:_____

210 sec:_____

220 sec:_____

230 sec:_____

240 sec:_____

250 sec:_____

260 sec:_____

270 sec:_____

280 sec:_____

290 sec:_____

300 sec:_____

Rate of Perceived Exertion Record Form

15/5-sec work/rest interval Prone Bridge Test RPE (0-10)

Name:______________________________ ID:________________

0 sec-

end of 1st interval (15 sec):______

end of 2nd interval (35 sec):______

end of 3rd interval (55 sec):______

end of 4th interval (75sec/1:15):______

end of 5th interval (95 sec/1:35):______

end of 6th interval (115 sec/1:55):_____

end of 7th interval (135 sec/2:15):_____

end of 8th interval (155 sec/2:35):_____

end of 9th interval (175 sec/2:55):_____

end of 10th interval (195 sec/3:15):_____

end of 11th interval (215 sec/3:35):_____

end of 12th interval (235 sec/3:55):_____

end of 13th interval (255 sec/4:15):_____

end of 14th interval (275 sec/4:35):_____

end of 15th interval (295 sec/4:55):_____

Phase 2 Data Sheet

Name:______________________________ ID:________________ Date:__________

Age:________________yr Gender: Male / Female Race:__________

Measured Weight:_____lbs Measured Height: inches PA level: S LA A VA

Do you do abdominal exercises? Sit-ups/Crunches Bridging/Yoga/Pilates

How often (per week)? 1x 2x 3x 4x 5x+ 1x 2x 3x 4x 5x+

Test (1, 2)

____ **____**

<u>10-sec Int. Prone Bridge</u>

Total time:_______(sec)

<u>10-sec Int. Prone Bridge</u>

Total time:________(sec)

Ruler Height:_________

Appendix A-1c

Flyer and Business Consent Forms

Abdominal Stability Research Project:
Phase 2

Male and female participants 18–39 years of age are needed.

Qualified participants will receive a $5 gift certificate for lunch. Each abdominal stability test only takes about 5 minutes to complete. You can complete two abdominal stability tests in about 10 minutes and receive $5.

Participants must complete a brief questionnaire about their health and have no low back pain. After completing the first assessment participants will be immediately informed if they qualify for a second assessment and a $5 gift certificate. The second assessment will take place at least 48 hours after the first. When both assessments have been completed the gift certificate will be given to the participant. If you are not asked to complete a second assessment you will not qualify for the compensation.

Those interested should call 801-234-0973 for further information and details about location to make an appointment.

Consent forms will be provided at the time of the first appointment.

Call 801-234-0973

Joel Reece
Brigham Young University (EXAMPLE LETTER)
106 SFH
Provo, UT 84602

June 11, 2008

Gold's Gym
460 North 900 East
Provo, UT 84606

Dear Gold's Gym Manager,

Currently I am working on my thesis project at Brigham Young University. The purpose of my thesis is to develop an abdominal fitness test using the prone bridge maneuver. Specifically, the study population includes healthy adults from 18–39 years of age.

To administer the actual abdominal fitness test takes less than five minutes and requires very minimal equipment (a timer and a couple of measuring sticks). The test will need to be completed two times, separated by approximately 48 hours. The prone bridge maneuver is demonstrated by the picture below.

Participants must sign consent before participating. After completing both tests, participants will receive a $5 gift certificate to your business, purchased by funding for this research. With your consent, I would like to find participants at your establishment willing and anxious to be a part of this study.

Sincerely,

Joel Reece

Development of a Core Fitness Test
Consent to allow research at ______________________
(name of facility)

Introduction
This research study is being conducted by J. Reece, BS, J. George, PhD, B. Feland, PhD, W. Johnson, PhD, R. Hager, PhD and B. Myrer, PhD, at Brigham Young University to develop a new core fitness test.

Procedures
Participants will be asked to complete two 15/5 sec work/rest interval prone bridge tests approximately 48 hours apart from each other. Before actual testing, participants will be asked questions regarding their demographics including name, age, gender, race, height, weight, and physical activity level. Researchers will contact those who volunteer with more information regarding the time and place. The fitness tests will last for approximately 5 minutes.

Risks/Discomforts
There are minimal risks for participation in this study. However, participants may feel abdominal muscle fatigue/discomfort, shoulder fatigue/discomfort, or low back fatigue/discomfort after testing. When participating in a fitness test, it is possible that they may feel embarrassed when performing in front of others. The moderator will be sensitive to those who may become uncomfortable.

Benefits
There are no direct benefits to subjects. However, it is hoped that through your participation researchers will learn more about core fitness testing.

Confidentiality
All information provided will remain confidential and will only be reported as group data with no identifying information. All data, including demographics and fitness test scores will be kept in storage cabinets and only those directly involved with the research will have access to them.

Compensation
Participants will receive a $5 gift certificate to your establishment.

Participation
Participation in this research study is voluntary. Participants have the right to withdraw at anytime.

Questions about the Research
If you have questions regarding this study, you may contact J. Reece MS, at 422-9156, jdr87@email.byu.edu or J. George, PhD, at 422-8778, jim@byu.edu.

Questions about your Rights as Research Participants
If you have questions regarding your rights as a research participant, you may contact Christopher Dromey, PhD, IRB Chair, 422-6461, 133 TLRB, Brigham Young University, Provo, UT 84602, Christopher_Dromey@byu.edu.

I have read, understood, and received a copy of the above consent and desire of my own free will to allow participation in this establishment ______________________________ for this study.

Signature:____Date:_________________