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Effects of Instability on Core Muscle Activation in a Side Bridge

Erin E. Kishman
Western Michigan University

EFFECTS OF INSTABILITY ON CORE MUSCLE ACTIVATION IN A SIDE BRIDGE

by

Erin E. Kishman

A thesis submitted to the Graduate College
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Thesis Committee:

Timothy Michael, Ph.D., Chair
Nicholas Hanson, Ph.D.
Sangwoo Lee, Ph.D.

EFFECTS OF INSTABILITY ON CORE MUSCLE ACTIVATION IN A SIDE BRIDGE

Erin E. Kishman, M.S.

Western Michigan University, 2018

Training the musculature of the core continues to be perceived as an essential component of conditioning and rehabilitation settings (11). A popular way to train the core is with the use of instability devices, such as Swiss ball or suspension trainer. However, there is limited research on the effects of these devices on core muscle activity. The purpose of this study was to examine core muscle activity during side bridge variations with and without instability devices (Floor, Swiss Ball, and TRX) through electromyography (EMG) of the rectus abdominis, external oblique, erector spinae, and latissimus dorsi. 39 participants performed three variations of a side bridge; one on the floor, one with their feet elevated on a swiss ball, and one with feet suspend in a TRX suspension trainer. Each bridge variation was held for 5 seconds and repeated three times. Prior to performing the side bridges, participants completed a maximal voluntary isometric contraction (MVIC). Root mean square (RMS) values for each side bridge were normalized to the MVIC and reported as a percentage of MVIC. Significant increases in muscle activation occurred with the use of the instability devices. Mean ± *SD* %MVIC was significantly higher on the ball (B) and TRX (T) when compared to the floor (F) in the rectus abdominis (F: 21.77±11.86; B: 29.7±15.61; T: 31.73±18.52) external oblique (F: 32.92±13.64; B:40.09±24.44; T: 38.0±18.52), and latissimus dorsi (F: 7.03±4.49; B: 12.18±9.07; T: 12.18±7.26). It was concluded that instability devices may be beneficial in training the core musculature.

ACKNOWLEDGEMENTS

First, I would like to thank the members of my committee, Dr. Michael, Dr. Hanson, and Dr. Lee. Thank you for your feedback and support throughout the project. A special thank you to Dr. Michael for helping me decide on a research topic, running statistics, edits, and everything in-between. All of the support I received is greatly appreciated.

Secondly, I would like to thank my parents for their support through all of my academic endeavors. Their love and encouragement has kept me motivated to finish this project. I would also like to thank my classmates, coworkers, and friends that have helped me along the way.

Erin E. Kishman

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INTRODUCTION

The core has been described as the musculature of the spine and pelvis that are responsible for maintaining stability of the spinal column (4,13). Core stability is increasingly perceived as an essential component of conditioning and rehabilitation programs. A stable core allows for greater force generation, while also helping maintain balance and decreasing the risk of injuries. The benefits of increasing core stability can lead to improvements in sport performance, as well as help with rehabilitation of an injury (11). In activities of daily living and in sports, the core muscles usually co-contract and stiffen the core through isometric contraction. Suggesting that the core muscles should be trained in a different way than the limbs of the body. Research by McGill (11) has shown that the core should be a source of stabilization, and not an initiator of movement. Previous research has shown that training the core in a stabilized position with a load maintained against the natural curve of the spine (neutral) is the safest and most effective way to train the core (9).

As explained by McGill (11), there are three ways that core stiffness enhances performance: 1. Stiffening the torso transfers the full force and movement of muscles to the distal side of the ball and socket joints, of the hips and shoulders, thus creating greater limb strength and speed; 2. Load bearing capacity and prevention of buckling or bending, is enhanced by stiffening of the core; 3. Stiffness creates muscular turgor, which helps protect vital abdominal structures. In athletic training programs, core strengthening often involves movement-based exercises, such as a sit up or Russian twist. While these exercises place a challenge on the core muscles, their movement-based mechanisms can lead to spinal injury (6). Since the core plays such an important role in everyday life and in sports, it is important that exercise professionals know how to properly train their clients. This involves training the core for stability, not movement. Knowing how to regress and progress core exercises, while maintaining core safety, is essential to properly training individuals.

Approximately 85% percent of people will experience low back pain during their lifetime (9). This pain is commonly a result of spinal flexion and trunk instability (11). Core training should be done with the focus on stability and endurance. If exercises are done repeatedly without these qualities, there is an increased risk for injury. The side bridge is one of three major spine safe exercises suggested by McGill (11). The side bridge, along with the curl up and bird dog, produce stabilizing patterns, while maintaining a low spinal load making them a spine safe exercise. A study done by McGill (10), investigated different progressions of a side bridge, and the results demonstrated a clear progression for the side bridge exercise. Performing the exercise on the knees was the easiest variation while rolling from a right-side bridge to the left side created the greatest challenge. However, McGill's study only looked at bodyweight side bridge progressions.

Core exercises can also be progressed using a variety of equipment. The use of instability devices to train the core continues to be popular in all training settings. One of the most popular devices is a Swiss Ball. Previous research has shown that adding a Swiss ball to core exercise can increase muscle activation (2,7,8,13,14). Another device that is growing in popularity is a suspension trainer (TRX). Suspension trainers are anchored to a single point and have two mobile straps with handles. One study found that performing a pushup in a suspension device led to greater activation of the external oblique and rectus abdominis (1). However, Snarr et al. (13) compared a prone plank on a swiss ball to a prone plank in a suspension device and found there was greater activation on both instability devices when compared to the ground, but there were no significant differences between the ball and TRX. While Snarr et al. (13) looked at a traditional plank between the ball and TRX, the effects of these devices on a side bridge have not been investigated.

There is limited data on the use of instability devices in core training, but there is a large increase in the use of these devices in all physical activity settings. Therefore, the purpose of this study was to compare core muscle activity during side bridge variations with instability devices (Floor, TRX, and Swiss Ball), through electromyography (EMG) in the rectus abdominis, external oblique, erector spinae, and latissimus dorsi. It was hypothesized that activity in all four muscles would be significantly lower in the floor side bridge compared to the TRX and Swiss ball.

METHODS

Subjects

Recruitment and experimental procedures were approved by the Western Michigan University human subject institutional review board. Forty-two participants, with demographics seen in Table 1, volunteered for this study. Subject number was determined by a power analysis with an effect size of 0.4 and power level of 0.8. All subjects read and signed an informed consent form and completed a health and activity questionnaire prior to testing. The activity questionnaire asked participants how long they have been resistance training, how many days a week they train, and if they had any musculoskeletal injuries. Participants were moderately to highly active (exercise 3 or more days a week) and had at least six months of resistance training experience. Any participants with a musculoskeletal injury in the past 6 months were excluded from the study.

Table 1: Descriptive statistics of participants (Mean ± SD).

	Males (n=22)	Females (n=17)	Total (n=39)
Age (y)	23.5 ± 2.89	22.24 ± 2.02	22.95 ± 2.30
Height (cm)	178.72 ± 13.50	166.47 ± 6.24	173.38 ± 8.59
Mass (kg)	84.92 ± 13.5	65.37 ± 7.99	76.40 ± 14.97
BMI (kg/m^2)	26.50 ± 3.37	23.54 ± 2.29	25.21 ± 3.27

Procedures

Electromyography (EMG) Electrode Placement. Wireless EMG (Noraxon, AZ, USA) was used to collect values from four different muscles: rectus abdominis (RA), external oblique (EO), erector spinae (ES), and latissimus dorsi (LD). Data was sampled at 1500 Hz. Skin was prepped for electrode placement through exfoliation and alcohol cleansing. If needed, the skin site was also shaved to reduce impedance. Electrode placement followed the same placement as Snarr et al., (13) and Escamilla et al. (2). RA electrodes were placed vertically two centimeters right of navel. Electrodes for the EO were placed lateral to the iliac crest, at the same level as the RA, following the angle of the iliac crest. ES electrodes were placed 2 cm laterally to the L-3 vertebrae. The LD electrodes were placed 4cm below the scapula at a 25-degree angle.

Maximal Voluntary Isometric Contraction (MVIC). Once all electrodes were placed, an MVIC for each muscle was measured to normalize EMG signals. For the RA, participants laid supine with their knees bent and arms across their chest, in a sit-up position. They were instructed to crunch up while resistance was being applied to their shoulders. For EO, participants started while laying on their left side and performed a right lateral bend, while manual resistance was being applied to their shoulder. These MVICs followed the same protocol used by Snarr et al. (13). LD and ES MVIC followed the same protocol as McGill and Karpowicz (10). Participants then laid in a prone position and performed a back extension while resistance was applied to their shoulder to measure ES. The LD MVIC was measured while subjects laid prone with arms by their side and palms facing up. Participants were instructed to elevate their shoulders towards the ceiling while resistance was being placed on their forearms.

Exercise Trials. Participants performed multiple variations of a side bridge immediately after all MVIC data was collected (Floor, Swiss Ball, and TRX). Order of bridge variations was randomized. All participants were properly shown how to perform a side bridge following National Strength and Conditioning Association (NSCA) recommendations (3). Participants practiced all bridge variations prior to data collection. Each bridge was held for 5 seconds and was repeated three times. One minute of rest was allowed between bridges of the same condition and five minutes between bridge variations to prevent fatigue. After each bridge participants were asked to rate their perceived exertion using the Borg 6-20 scale. The technique of each bridge follows:

- Floor Side bridge: Participants laid on their right side, with legs fully extended and elbow flexed at 90 degrees. The left foot was placed in front of the right foot in a heel to toe position. Once instructed, participants lifted their hips off the floor being supported only by their feet and arm. Once in position the participants were in a straight line down their body and the left hand was extended straight, perpendicular to the floor.
- Swiss ball side bridge: Participants started in the same position as the floor, except with their feet and ankles placed on top of a swiss ball.
- TRX side bridge: The TRX straps were adjusted to mid-calf length for each participant. They started laying on their sides with their feet placed in the straps. The straps went around the arch of the foot. The TRX suspension trainer was anchored to a door. Participants were instructed to slide away from the door before getting into the bridge to

avoid their feet hitting the door and being able to use it for support. The position was the same as the floor side bridge, with feet in a heel to toe position.

Electromyography Analysis. EMG signals were processed using Noraxon MyoMuscle software (Noraxon USA, INC). Raw signals were full-wave rectified and smoothed with 100 milliseconds. MVICs were analyzed for 10 seconds. The peak value in the 10 seconds was used as the MVIC value. 5 seconds of each bridge was analyzed for the exercise trials. The participants were holding the bridge for the full five seconds being analyzed. EMG was not recorded until the participant was correctly in the bridge. The root mean square (RMS) value for each side bridge was normalized to the MVIC and reported as a percentage of MVIC (6).

Statistical Analyses

Analysis of the data was performed using SPSS v.24. For each variable, means and standard deviations were calculated. A repeated measures analysis of variance (ANOVA) of normalized EMG values was used to determine significance between muscle activation in the three side bridge conditions. In addition, analysis of sex differences in muscle activation, and RPE for each exercise condition was also assessed. Statistical significance was set a priori at $p \leq 0.05$.

RESULTS

39 out of the 42 participants successfully completed the trials. Data from one participant was removed due to errors in the EMG signal. Two participants were removed because their MVIC was not a true MVIC. The EO and RA MVIC was lower than the activation that occurred in the side bridge trials.

Rectus Abdominis

There was a significant main effect between the RA and side bridge conditions ($p < 0.001$). %MVIC for the floor was significantly lower than the ball ($p = 0.001$) and TRX ($p < 0.001$). No significant difference ($p > 0.05$) was found between the ball and TRX. (Figure 1). RA activity was significantly different between males and females ($p = 0.001$). Females had higher activation in all side bridge variations.

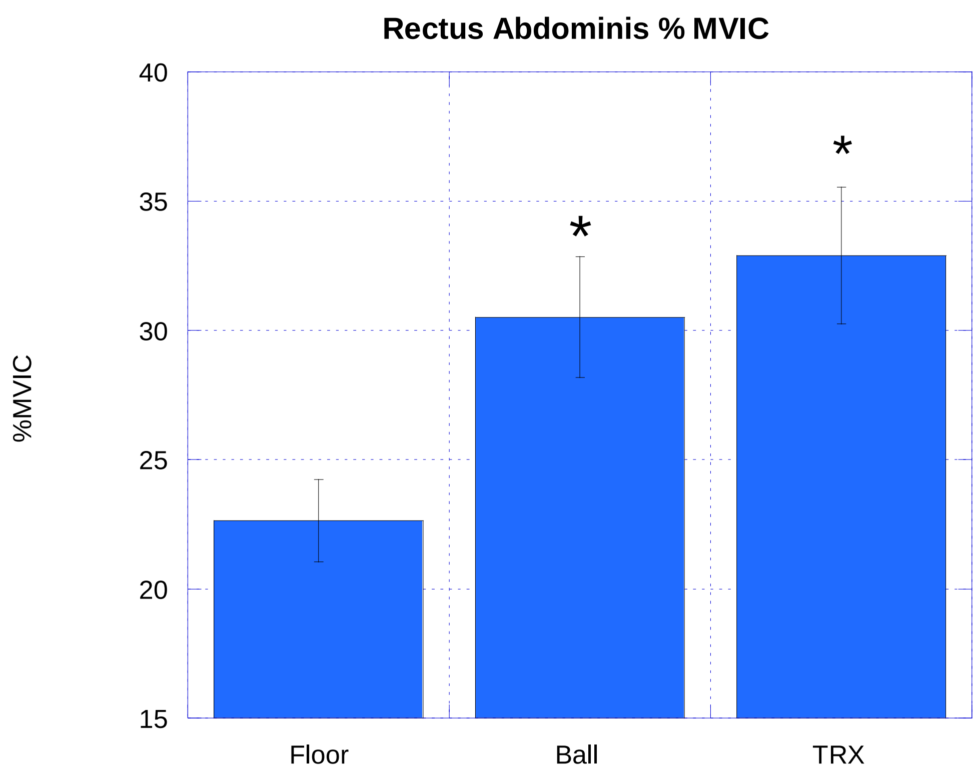

Figure 1: Mean and standard error comparison of normalized EMG activity, expressed as %MVIC, in the rectus abdominis during side bridges with and without instability devices.

External Oblique

When comparing %MVIC there was a significant main effect ($p < 0.01$) between the floor, ball, and TRX. The floor was significantly lower than both TRX ($p=0.032$) and ball ($p=0.035$). There was no difference ($p > 0.05$) in %MVIC between the ball and TRX. (Figure 2). For the EO, there were no significant differences between men and women ($p > 0.05$).

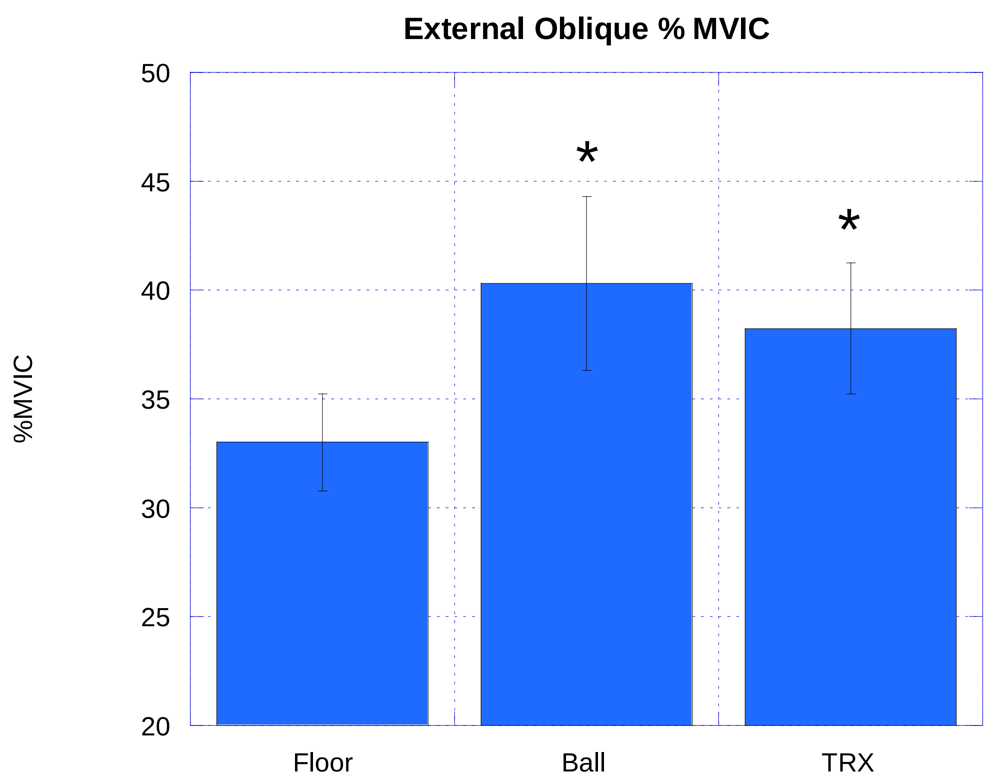

Figure 2: Mean and standard error comparison of normalized EMG activity, expressed as %MVIC, in the external oblique during side bridges with and without instability devices.

Erector Spinae

The main effect of side bridge condition on ES activity was significant (p=0.005). TRX %MVIC was significantly higher (p= 0.009) than the floor. Although the ball had a higher %MVIC than the floor, there was no significant difference between the two conditions (p>0.05). There was also no significant difference between the ball and TRX (Figure 3). There was also a significant main effect of gender and ES %MVIC (p=0.007). Females had higher ES activation than males in all conditions.

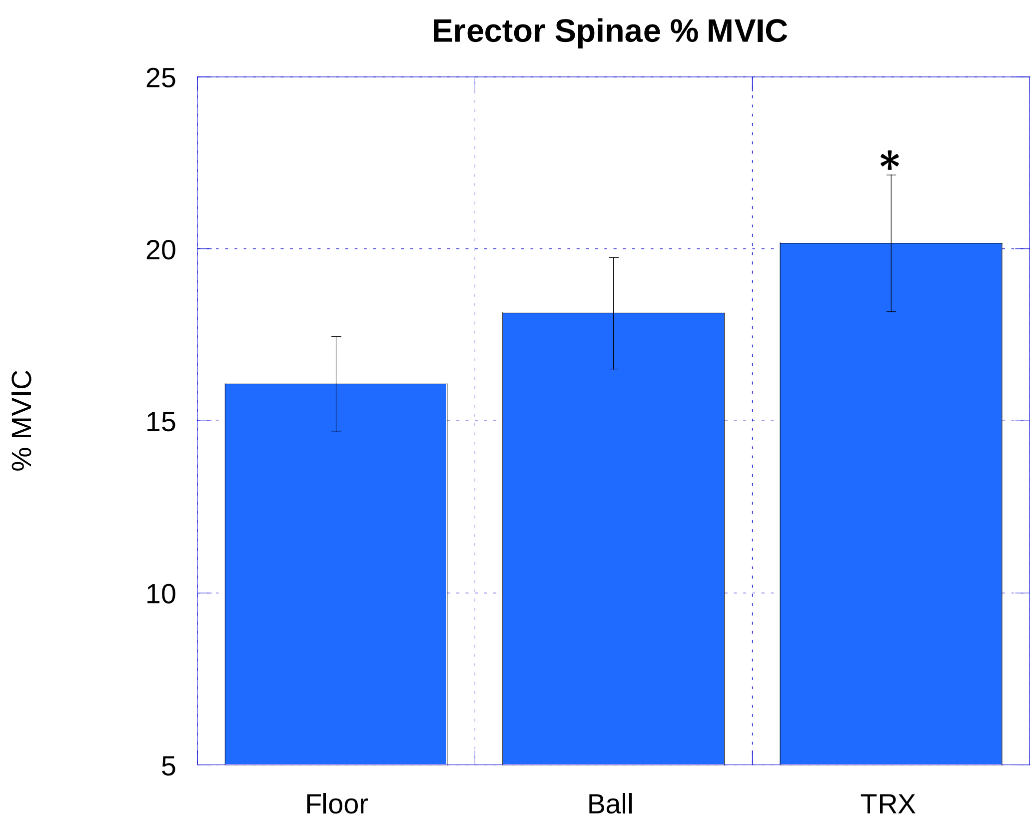

Figure 3: Mean and standard error comparison of normalized EMG activity, expressed as %MVIC, in the erector spinae during side bridges with and without instability devices.

Latissimus Dorsi

There was a significant main effect between LD activity and side bridge conditions ($p<0.001$). %MVIC was significantly lower in the floor when compared to the ball ($p<0.001$) and TRX ($p<0.001$). No difference was found between the TRX and ball ($p=1.0$). There was no significant difference ($p> 0.05$) between sexes in any condition

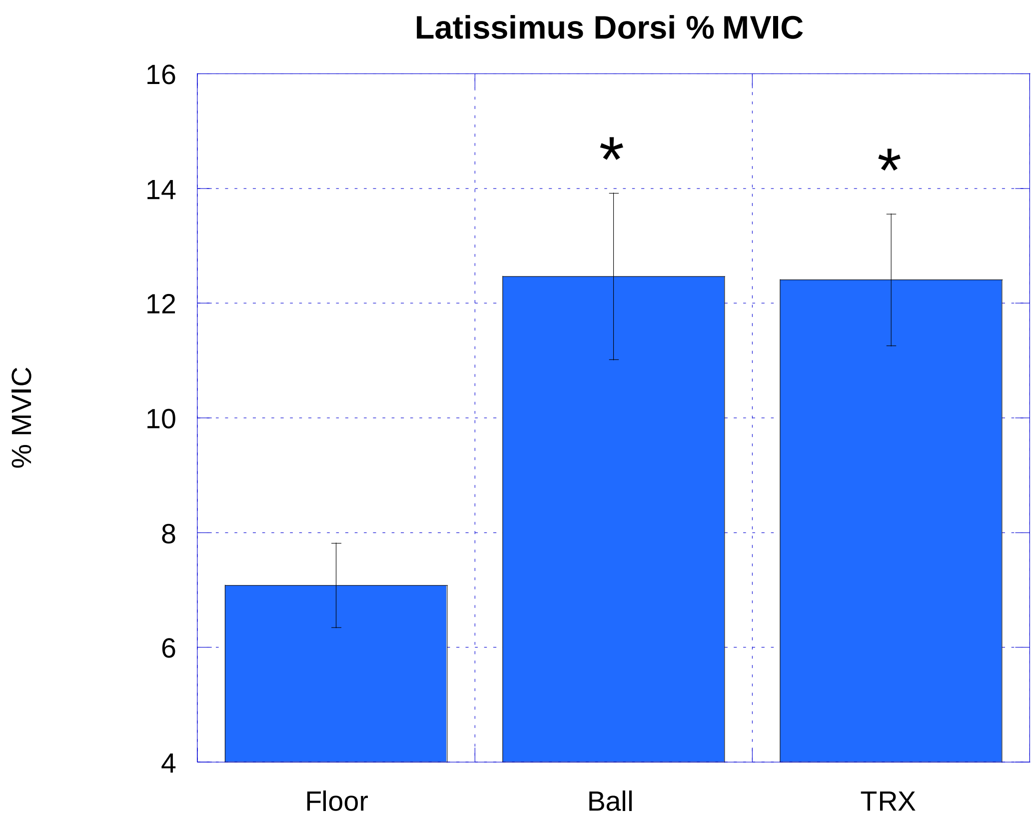

Figure 4: Mean and standard error comparison of normalized EMG activity, expressed as %MVIC, in the latissimus dorsi during side bridges with and without instability devices.

Rating of Perceived Exertion

The mean RPE for the floor was significantly lower ($p < 0.001$) than both the ball and TRX. However, there was no difference ($p > 0.05$) between the mean RPE of the ball and TRX (Table 2). There was no difference ($p > 0.05$) between males and females.

Figure 5: Mean and standard error of rating of perceived exertion (RPE) between side bridge variations

DISCUSSION

Incorporating instability devices has become a popular trend in fitness settings. However, there is limited research on the effectiveness of these devices. The purpose of the current study was to examine muscle activity in a side bridge on the floor, on a swiss ball, on a TRX suspension trainer. The main finding was the significantly higher muscle activity in the RA, EO, and LD in the side bridge on instability devices when compared to the floor.

The results of this study are similar to previous studies comparing different instability devices to stable exercises. When reviewing %MVIC, activation was higher in the RA, EO, and LD when the side bridge was performed on the ball and on the TRX. The greater activation may be due to instability devices creating more disturbances in the spinal column, requiring more activation of the core for stabilization (14) These findings are similar to what Snarr et al. (13) found when comparing a prone bridge on the floor to a ball and TRX. They found greater activation in the RA and EO on the ball and TRX. However, his results also found greater activation in the ES. In the present study, only the TRX %MVIC in the ES was significantly higher than the other conditions. This may be due to the difference in performing a prone bridge and a side bridge, as McGill has found a side bridge to be one of the top three spine safe exercises because of low spinal compression (10).

Increases in ES activity may indicate an increase in spinal loading and compression (12). The ES %MVIC was significantly higher than the floor and ball, but the percentage was still relatively low at 19.56%. The significantly higher %MVIC in the ES during the TRX side bridge may be due to some instances where the TRX swung side to side. This may have caused a greater disturbance in the spinal column, causing an increase in muscle activation to stabilize the core. Since the TRX is anchored to a door with two mobile straps, it allows for side to side movement. The ball is not anchored and this side to side movement would cause one to fall off the ball.

Marshall and Murphy (7) also found muscle activation to be higher in core exercises on unstable surfaces vs stable conditions. However, they found no significant difference between %MVIC in a roll out exercise, which is similar to a prone bridge. Feet were placed on a swiss ball and arms were straight with wrists directly under shoulders. The stable exercise even had slightly higher activity in the RA, EO, and ES. This could be due to the difference in the amount of contact in the roll out compared to a side bridge. It is suggested that the number of contact areas of the participants affect muscle activity. Previous research has shown that a decrease in contact areas increases EMG activity (8,13).

One interesting finding from the present study was the difference between sexes. Females had higher activation in the RA and ES. Few studies have compared core muscle activation between sexes. One study evaluated core activation during a jump landing (5) and found that males activate their internal oblique more than females. Internal oblique was not measured in this study, therefore future studies should consider examining this. It may be possible that males had greater internal oblique activation, which could have created more stability, and may have caused a lower RA and ES activation.

As with all studies there are limitations, the first being the sample of participants. Participants were ages 19-31 and healthy. EMG patterns may vary with an older population or for individuals with low back pain. MVIC may be distorted in patients with LBP (7). Patterns may differ in an older population due to sarcopenic effects on the neuromuscular system (14)

Another limitation was the collection of the MVIC. Only the EO MVIC was taken with participants lying on their side, the others were taken prone and supine. Activation patterns may have differed if the MVIC was taken in a similar position to the side bridge. Third, this study only looked at an acute bout of instability exercise. Future studies may be needed to look at the longer effects of instability training.

In conclusion, the use of instability devices may be beneficial to increasing muscle activity in a side bridge and progressing the exercise. While muscle activity increased in the RA, EO, and LD, there were no differences in the ES %MVIC between conditions. This suggests that progressing a side bridge with a ball or TRX device keeps the side bridge a spine safe exercise, due to low spinal compression.

Practical Applications

The results of this study suggest that when progressing a side bridge exercise, placing the feet on the ball or in a suspension device may elicit the same results. When evaluating cost, using a swiss ball (approximately $12) may be more practical than buying a suspension device, which can cost over $140. However, depending on the facility, a suspension device might be beneficial due to the number of exercises that can be performed on it. While in this study, the ball and TRX had similar results in muscle activation, getting into the side bridge on the ball was difficult for some and took multiple attempts before they could successfully hold the bridge. If someone is in a rehabilitation setting and has difficulty balancing, the ball may not be the best way to progress the side bridge, and the TRX may be more practical.

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Appendix A:

Informed Consent Document

Western Michigan University
H.S.I.R.B.
Approved for use for one year from this date:

OCT 31 2017

HSIRB Office

Informed Consent

Western Michigan University
Human Performance Health Education

Principal Investigator: Timothy Michael
Co-Investigators: Nicholas Hanson, & Sangwoo Lee
Student Investigators: Erin Kishman
Title of Study: Effects of instability on core muscle activation in a side bridge

You have been invited to participate in a research project titled "**Effects of instability on core muscle activation in a side bridge"** This consent document will explain the purpose of this research project and will go over all the time commitments, the procedures used in the study, and the risks and benefits of participating in this research project. Please read this consent form carefully and completely and please ask any questions if you need more clarification.

What are we trying to find out in this study?
Our goal is to examine the effects of different exercises on core muscle contraction. The main purpose of this study is to determine what side bridge variation (ground, TRX, and Swiss Ball) elicits the greatest core muscle activity, in the front abdominals, side abdominals, and two back muscles.

Who can participate in this study?
You must be between the ages of 18-45 years old. You may not have sustained a muscle or bone injury (i.e. sprained ankle etc.) or surgery within the last 6 months. You must have at least 6 months experience of resistance training and be moderately to highly active. You must be able to perform a side bridge with proper form and be able to hold it for at least 10 seconds. We will ask you to complete a health and resistance training questionnaire. If you have had an injury in the past 6 months you will not be able to participate in this study.

Where will this study take place?
This study will take place in the Human Performance Research Lab located on the first floor of Western Michigan University's Student Recreational Center.

What is the time commitment for participating in this study?
The total estimated time commitment will be about 2 hours. We will ask you to come to the lab for one visit. Approximately 30 minutes will be used for informed consent and baseline measurements and approximately 1 hour and 30 minutes will be used for practice of the exercises and muscle activity assessment of the side bridge exercises.

Western Michigan University
H.S.I.R.B.
Approved for use for one year from this date:

OCT 31 2017

x [signature]
HSIRB Office

What will you be asked to do if you choose to participate in this study?
The first session we will be measuring your height, weight, and ask you to practice the side bridge exercises. Skin surface electrodes will be placed on the four muscle locations. You will then be asked to contract each of the four muscles as hard as possible. You will be given time to rest. Next, three side bridge variations using a suspension trainer (TRX), Swiss ball, and the ground, will be performed. Three repetitions of each side bridge will last for 5 seconds and 1 minute of rest will be given in between reps, while 5 minutes of rest will occur between variations. You will also be asked your how you feel during each plank (rating of perceived exertion) using the Borg 6-20 scale after each side bridge.

You will still be able to participate in your normal exercise routine; we just ask you avoid any strenuous exercise 24 hours prior to your session. You can maintain your normal diet, but we ask that you keep the diet as similar as possible for the 24 hours leading up to the trial.

What information is being measured during the study?
Muscle activity will be measured for the four core muscles during the maximal contraction. Muscle activity will also be recorded for five seconds during each side bridge. Rating of perceived exertion will also be recorded after each side bridge.

What are the risks of participating in this study and how will these risks be minimized?
As in all research, there may be unforeseen risks to the subject. If an accidental injury occurs, appropriate emergency measures will be taken; however, no compensation or additional treatment will be made available to you except otherwise stated in this consent form. The risks in this study are considered minimal. These include muscle or bone injuries and general muscle soreness. We will provide you with proper instruction on how to perform each side bridge variation and allow sufficient rest time between each side bridge to minimize these risks.

What are the benefits of participating in this study?
You may not see a direct benefit from the exercises. The benefits of this research may be seen in gyms and rehabilitation settings. You will be helping to provide a potential benefit to the field of Exercise Science by participating, as we will gain useful knowledge on the effects of exercise equipment.

Are there any costs associated with participating in this study?
You will be accountable for paying for parking at the Student Recreation Center if need.

Is there any compensation for participating in this study?
No compensation will be provided for participating in this study.

Western Michigan University
H.S.I.R.B.
Approved for use for one year from this date:

OCT 31 2017

HSIRB Office

Who will have access to the information collected during this study?
The principal investigator, co-investigators, and student investigator will have access to the data collected during this study. The information will be coded with numbers and not the participant's' name. All information collected during the study will be locked in a file cabinet in the primary investigator's office.

What if you want to stop participating in this study?
You can choose to stop participating in the study at any time for any reason. You will not suffer any prejudice or penalty by your decision to stop your participation. You will experience NO consequences either academically or personally if you choose to withdraw from this study.

The investigator can also decide to stop your participation in the study without your consent.

Should you have any questions prior to or during the study, you can contact the primary investigator, Timothy Michael at 269-387-2691 or tim.michael@wmich.edu or the student investigator, Erin Kishman at 616-295-2521 or erin.e.kishman@wmich.edu. You may also contact the Chair, Human Subjects Institutional Review Board at 269-387-8293 or the Vice President for Research at 269-387-8298 if questions arise during the course of the study.

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this study if the stamped date is older than one year.

I have read this informed consent document. The risks and benefits have been explained to me. I agree to take part in this study.

Please print your name: ______________________________

______________________________ ______________________________
Signature Date

Appendix B:

Activity Questionnaire

Activity and Injury Questionnaire

1. Have you ever resistance trained before? Yes No

2. If your answer was "Yes" for the previous question, for how long did you resistance train?

   A. Currently resistance training

   B. Off and On for the past _________ number of years

3. Do you exercise on a regular basis? Yes No

4. If your answer was "Yes" for the previous question, how many days per week do you exercise?

   A. One day per week

   B. 2-3 days per week

   C. more than 3 days per week

5. When you exercise how much effort do you put into your exercise training?

   A. Hard enough that it is hard to talk while I am exercising.

   B. I exercise to the point that I am breathing heavy, but can still carry on a conversation.

   C. I do not exercise to the point that I am breathing heavy.

6. Have you had any musculoskeletal injuries in the past 6 months? Yes No

Appendix C:

HSIRB Approval Letter

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board

Date: October 31, 2017

To: Timothy Michael, Principal Investigator
Erin Kishman, Student Investigator for thesis
Nicholas Hanson, Co-Principal Investigator
Sangwoo Lee, Co-Principal Investigator

From: Amy Naugle, Ph.D., Chair

Re: HSIRB Project Number 17-10-28

This letter will serve as confirmation that your research project titled "Effects of Instability on Core Muscle Activation in a Side Bridge" has been **approved** under the **expedited** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may **only** be conducted exactly in the form it was approved. You must seek specific board approval for any changes in this project (e.g., ***you must request a post approval change to enroll subjects beyond the number stated in your application under "Number of subjects you want to complete the study***)." Failure to obtain approval for changes will result in a protocol deviation. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

Reapproval of the project is required if it extends beyond the termination date stated below.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: **October 30, 2018**

1903 W. Michigan Ave., Kalamazoo, MI 49008-5456
PHONE: (269) 387-8293 FAX: (269) 387-8276
CAMPUS SITE: 251 W. Walwood Hall