4-2022

INCREASE IN 1RM BACK SQUAT AFTER ABDOMINAL STABILIZING MANEUVERS

Caro Els
cels@nmu.edu

INCREASE IN 1RM BACK SQUAT AFTER ABDOMINAL STABILIZING MANEUVERS

By

Caro Inge Els

THESIS

Submitted to
Northern Michigan University
In partial fulfillment of the requirements
for the degree of

MASTERS OF EXERCISE SCIENCE

Office of Graduate Education and Research

April 2022

SIGNATURE APPROVAL FORM

Increase in 1RM Back Squat after Abdominal Stabilizing Cues

This thesis by Caro Els is recommended for approval by the student's Thesis Committee and Department Head in the Department of Health and Human Performance and by the Dean of Graduate Studies and Research.

3-31-2022

Committee Chair: Dr. Randall Jensen — Date

Matthew Kilgas — 4/1/2022

First Reader: Dr. Matt Kilgas — Date

4/1/2022

Second Reader (if required): Jenna Bruttomesso — Date

Elizabeth Wuorinen — 4-1-2022

Department Head: Dr. Elizabeth Wuorinen — Date

Lisa Schade Eckert — 5/3/22

Dr. Lisa Schade Eckert — Date

Dean of Graduate Studies and Research

ABSTRACT

INCREASE IN 1RM BACK SQUAT AFTER ABDOMINAL STABILIZING MANEUVERS

By Caro Inge Els

Increasing intra-abdominal pressure (IAP) during free weight exercises can protect the lumbar spine from excess movement; a cause of lower back pain. Abdominal bracing (AB) and abdominal hollowing (AH) are two stabilizing maneuvers that increase IAP. Previous literature primarily compared AH and AB in therapy settings on bodyweight single joint movements. The effect of AB and AH during a multi-joint movement involving a maximum or near maximum external load is unknown. The purpose of this study was to compare the effect of AB and AH on lower limb muscle activity and the maximum amount of external weight lifted during a 1RM back squat protocol. Mean-normalized surface electromyography of the rectus femoris, biceps femoris, gluteus maximus, rectus abdominis, external oblique and erector spinae were analyzed in well trained individuals (n=13). A 1RM back squat protocol was performed under three conditions: control session, AB and AH. A significant difference was found between maximum external load lifted during both AB (124.39kg ± 8.77) and AH (123.46kg ± 8.84) conditions compared to the control day (120.53kg ± 8.71). No significant differences for the muscle activity were found under the conditions at the same weight, however, analyzing the max weight at every condition showed a significant difference of BF during AH ($p=0.04$). In summary, abdominal stabilizing maneuvers, AB and AH, increases 1RM back squat weight. As the increase in weight lifted cannot be accounted for by an increase in prime mover muscle activity, more research is needed to establish what caused the increase.

This thesis is dedicated to my Mom, Dad and Sisters.
I would not be where I am today if it was not for your endless love and support through all my endeavors.
Oneindig dankbaar, en oneindig life vir julle.

This thesis is further dedicated to my loving husband and his whole family, who continue to motivate me to be the best version of myself and have supported me through every step of my Master's degree.

ACKNOWLEDGEMENTS

I would first like to thank my thesis director, Dr. Randall Jensen, for his unwavering support and commitment to help me succeed. His patience and encouragement throughout have been instrumental to the successful completion of my master's thesis. I have become a better writer, data analyst, and critical thinker by virtue of Dr. Jensen. I would also like to thank Dr. Sarah Breen, my academic advisor, for their support and knowledge that helped me successfully conduct my research and collect my data.

I would like to thank my first reader Dr. Matt Kilgas for stepping in and volunteering his time and expertise. Further, I would like to thank my second reader, Jenna Bruttomesso, who has contributed to my critical thinking in the field of strength and conditioning, solidified my love for the field, and has encouraged me through every step of the way.

I would like to thank the Northern Michigan Strength and Conditioning department and Northern Michigan University Athletics Departments for allowing me to conduct my testing in their collegiate facilities. I extend a thank you to The Department of Health and Human Performance for their support and assistance throughout.

Finally, I would like to thank all the participants who volunteered their time to be pushed to do a maximal squat three times. A further thank you to all my classmates for their support throughout this process. Lastly, I would like to thank all my friends and family for their support, encouragement and dedication to help me succeed. This experience would not have been possible without the best support crew.

Thank you to you all,

Caro Inge Els

This thesis follows the formatting prescribed by the Journal Strength and Conditioning Research (https://edmgr.ovid.com/jscr/accounts/ifauth.htm) and the School of Health and Human Performance at NMU.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Excess spinal or pelvic movement during exercise is a common cause of lower back pain (1-4). Increasing intra-abdominal (IAP) pressure enhances spinal stability and stiffness which has been found to decrease lower back pain during exercise (1,2). Two common methods used to increase IAP are abdominal bracing (AB) and abdominal hollowing (AH). AB is the voluntary co-contraction of the abdominal muscles and AH involves drawing the belly button into the spine (5). AB is more commonly used in practice, but both maneuvers are documented to be effective in reducing spinal movement during various lower limb motions (5-9). The National Strength and Conditioning Association (NSCA) stresses the importance of engaging the core in all of their learning materials (6). Coaches have been taught to teach core bracing for years. The result is that most of the professionals in the field have adapted to coach abdominal bracing during all free weight exercises.

Investigation of the effect of AH and AB on single limb movements, e.g. prone hip extension (PHE) and side lying abduction, has concluded that both maneuvers are effective for increasing spinal stability and decreasing lumbopelvic motion (3,5). Various studies have shown that participants with lower back pain showed a higher activity of the erector spinae, gluteus maximus, and biceps femoris during various tasks (9-11). Dominant erector spinae activity may contribute to excessive anterior pelvic tilt during prone hip extension (PHE) (12). Several studies have found that AB and AH can decrease erector spinae muscle activity during PHE (8-9). Suehiro et al compared AB and AH during PHE and found that there was no difference in muscle activity between AB and AH when compared to a control group (7). However, AH had lower external oblique (EO) activity, suggesting that AH can reduce lumbopelvic movement without resulting in global muscle activation. To date, literature has mainly compared the effects of AB and AH on single limb movements with no external weight.

To the best of our knowledge, there have been no studies that compared the effect of AB and AH on multi-joint movements; as majority of the published research has been done with single-joint bodyweight movements in therapy settings. As stated, AB and AH are very commonly instructed in practical settings, like a collegiate weight room, but the use of AB and AH have, to date, not been compared in a sports performance setting.

The barbell squat would be a beneficial exercise to investigate the effect of AB and AH since it is a functional multi-joint movement that requires a large degree of spinal stability and is commonly used in athletic preparation of various disciplines. A maximum back squat protocol is a very popular performance testing method for assessing lower body muscular strength. It has also been found that maximal squat strength can improve sprinting and jumping capabilities in competitive athletes (14). It thus seems worthwhile to investigate the effects of AB and AH on lower limb muscle activity and squat performance during a maximum squat protocol.

The purpose of the current study was to assess the effect of the different abdominal stabilizing maneuvers, AB and AH, on lower limb and abdominal muscle activity and the total amount of external weight lifted during a max squat protocol in trained individuals. On the basis of previous findings, we firstly hypothesize that the maximal external load will be higher with both AB and AH conditions compared to the control session, and that AH will be higher than AB. Secondly, we believe that due to the increase in external load, the mean muscle activity will also be higher with both AB and AH, and AB will also have a greater mean when compared to AH.

METHODS

Experimental approach to the problem

All participants performed three conditions; control session, abdominal hollowing (AH) and abdominal bracing (AB) during a 1RM back squat protocol. The testing took place in a collegiate strength and conditioning facility over the span of three consecutive weeks. The day and time for each testing session was kept consistent each week. All participants completed the controlled session first, followed by AB and AH in a randomized order. The participants were blinded to the instruction of stabilization maneuvers until after they completed the control session. Maximum external load lifted as well as muscle activity were recorded during each session.

Subjects

Participants (male = 5, female = 8, 25 ± 5 years) were recruited from Northern Michigan University's (Marquette, MI, USA) student, athlete and faculty population. The Institutional Review Board at Northern Michigan University (NMU; HS 17-868) granted permission. To ensure eligibility to participate, participants had to be self-classified as intermediate or advanced weightlifters with more than 2 years of weightlifting experience and a self-reported 1RM in the back squat, be able to efficiently squat to a knee flexion angle of 90 degrees or less, and have no history of lower back pain. Participants currently participating in collegiate athletics were in off-season. Prior to testing, participants completed an informed consent (Appendix A) and shortened version of the International Physical Activity Questionnaire (Appendix B). Within the testing population, 7 were collegiate athletes (women's lacrosse, Olympic weightlifting, and alpine ski), 3 were retired college athletes (long distance swimming, volleyball, and track and field) and 3 were recreational weightlifters.

Procedures

Muscle Activity*:* Muscle activity of the back squat prime movers, as well as abdominal muscles used to stabilize the core, were measured by a wireless electromyography (EMG) system (Noraxon, Scottsdale, AZ, USA). The muscle sites that were analyzed for muscle activity differences included the rectus femoris, biceps femoris, gluteus maximus, erector spinae, rectus abdominis and external oblique. Surface EMG electrodes were connected to the 6 muscle sites on the right side of the body according to guidelines by seniam.org. The skin was cleaned, shaved and abraded before attaching the electrodes. The two abdominal muscle sites, rectus abdominis and external oblique, were used as a live feedback system when the participants were instructed to practice the maneuver before testing with it.

Maximum Voluntary Isometric Contraction (MVIC): For the rectus femoris, biceps femoris, gluteus maximum and erector spinae MVIC, a barbell was loaded with more than double of the participant's bodyweight in order for it to be immovable. The height of the barbell was determined by a barbell-only squat where the safety pins were set at 135 degrees of knee flexion (15). The participant performed three 5-second isometric contractions against the immovable barbell. For the rectus abdominis and external oblique MVIC, the participant was asked to perform a resisted sit up. The participants were instructed to lift their head and shoulders off the ground and perform an isometric contraction against the researcher. A further three 5-second contractions were recorded and repeated in a side crunch position.

1RM testing: The first day of testing was the control session. Participants completed the maximum back squat protocol without the introduction of any stabilization maneuver. Stabilization maneuvers were introduced and randomized between participants for the second and third day of testing. A general strength and conditioning warm up was completed and the participant performed personal additional warm ups as necessary (Appendix C).

The 1RM protocol was followed according to the NSCA guidelines and performance was assessed for correct form by a certified strength and conditioning specialist (CSCS) (6). For the repetition to be counted, a squat depth of 90 degrees or lower had to be achieved. To prepare for the maximum effort squat, participants picked a light resistance about 30-50% of their estimated 1RM that they could easily complete for 5-10 reps. A 1-minute rest period followed. The next load was calculated by adding 14-18 kg or 10%-20% to the chosen warm up weight so the athlete could successfully complete 3-5 reps followed by a rest period of 2 minutes, A conservative near maximal load was calculated by adding another 14-18 kg or 10-20% for a completion of 2-3 reps. This load was about 80-90% of the estimated 1RM and concluded the warm up.

After 3 minutes of rest the athlete added another 14 -18 kg or 10-20% and completed a single rep. If the repetition was successful, they rested another 3 minutes and then increased the load by 5-10% for their first attempt at their 1RM. If the repetition was unsuccessful, the load was decreased by 5-10%. The athlete's 1RM was reached within 3-5 attempts of adding 5-10%. This procedure was continued until failure to achieve a higher lift.

Stabilization Maneuvers: During the AB maneuver, participants were instructed to contract all the abdominal muscles while maintaining normal breathing. The cue 'contract the abdominal muscles' was used before the participant completed the repetition. AH required the participant to draw the navel into the spine without contracting the abdominal wall with the cue 'pull the navel into the spine'. These coaching cues were used and repeated before all appropriate trials. The participant also had an opportunity to see the live feedback from the EMG system as they practiced the two maneuvers. Muscle activity from RA and EO would notably increase when AB is done correctly and be lower for AH.

Data Analysis

Firstly, the squat trial that was used for the comparison analysis was the heaviest weight completed during the control day. The EMG muscle activity data for all three conditions were then analyzed at this weight for the first analysis. The second analysis involved comparing muscle activity at the heaviest weight completed during each condition. The EMG signals were amplified and a Butterworth fourth order 20-450Hz bandpass filter was applied to the data; while an RMS of 125ms was set normalized to MVIC (13). For data analysis, the mean value of a 5-second window backwards from the final hip extension at the end of the squat was exported through Noraxon myoMuscle (MR3.310, Noraxon, Scottsdale, AZ, USA). All six muscle sites were used for the analysis. Secondly, an additional table of data was recorded in Microsoft Excel, listing the weights the participant did from warm up to their final trial following the testing sheet (Appendix D). The heaviest weight from each of the conditions were used to calculate an overall mean weight lifted per maneuver.

Statistical Analysis

All statistics were analyzed using SPSS (v28.0, International Business Machines Corporation, Armonk, New York). A repeated measures ANOVA (α=0.05) was conducted to examine the effect of abdominal stabilizing maneuvers, AB and AH, on the maximum external load lifted. All of the mean muscle activity results were reported in percentage of MVIC. A repeated measures ANOVA (α=0.05) was used to compare the effect of AB and AH on the muscle activity during the 1RM protocol. A post hoc pairwise comparison using Bonferroni correction was performed and a Greenhouse-Geisser correction was used for violations of sphericity. Effect sizes using partial eta^2 (η^2_p) were obtained for each muscle using the formula: $\eta^2_p = SS_{effect}/ (SS_{effect} + SS_{crror})$, where SS_{effect} = effect variance and SS_{error} = error variance. Interpretation of effect size was based on the scale for effect size classification of Hopkins (2002). This scale is based on ***f***- values for effect size and these were converted to η^2_p using the formula: $\boldsymbol{f} = (\eta^2_p /(I - \eta^2_p;))^{0.5}$. Consequently, the scale for classification of η^2_p was < 0.04 = trivial, 0.041 to 0.249 = small, 0.25 to 0.549 = medium, 0.55 to 0.799 = large, and > 0.8 = very large.

RESULTS

Comparison of the maximum weight lifted during each maneuver showed an increase during the AB (124 ± 8.77kg) and AH (123 ± 8.84kg) maneuvers when compared to the control day (121 ± 8.71kg). The post hoc demonstrated that the load lifted during AH and AB were not different ($p=0.260$), but both were significantly higher than the control ($p<0.05$). The effect size for the maximum external load lifted across Control, AB and AH was medium ($\eta^2_p = 0.536$) and the observed power of 0.797 confirmed the significant difference found.

As shown in Table 1, there were no significant differences between the muscle activities for Control, AB, or AH for any of the prime movers of the squat; rectus femoris, biceps femoris, gluteus maximus and erector spinae ($p > 0.05$). Similarly, the muscle activity of the abdominal muscles, rectus abdominis and external oblique, did not differ across the three conditions ($p >0.05$) (see Table 1). However, when comparing the muscle activity at the heaviest weight in each condition, similar results were found, except BF activity during the AH condition was higher and statistically significant from AB and the control day ($p<0.05$) (See Table 2). Effect size for all muscle activity comparisons across Control, AB, and AH were trivial to small as shown in Tables 1 and 2.

Table 1 – Normalized mean (SD) of lower limb and abdominal muscle surface electromyography during a back squat at the same weight control, abdominal hollowing (AH) and abdominal bracing (AB).

	Control %	**AH %**	**AB %**	**Effect Size**	**Observed Power**
RF	72.58 (17.35)	73.85 (21.92)	68.24 (25.15)	0.065	0.177
BF	94.93 (39.82)	113.62 (39.29)	106.82 (51.80)	0.100	0.259
GM	79.74 (57.34)	82.20 (64.18)	83.20 (62.73)	0.008	0.641
RA	11.22 (9.59)	18.29 (24.31)	14.73 (13.79)	0.174	0.456
EO	14.56 (9.37)	15.85 (8.56)	16.98 (9.11)	0.061	0.167
ES	64.93 (21.75)	62.88 (16.09)	64.60 (21.64)	0.006	0.059

Table 2 – Normalized mean (SD) of lower limb surface electromyography during a back squat at the maximum weight completed control, abdominal hollowing (AH) and abdominal bracing (AB).

	Control %	AH %	AB %	Effect Size	Observed Power
RF	72.58 (17.35)	83.08 (19.95)	75.06 (25.10)	0.170	0.446
BF	94.93 (39.81)	137.66 (54.14) *	129.81 (66.71)	0.267	0.562
GM	79.74 (57.34)	76.45 (49.58)	86.87 (48.21)	0.041	0.124
RA	11.22 (9.59)	18.63 (22.34)	15.97 (17.48)	0.172	0.451
EO	14.56 (9.37)	16.33 (9.64)	17.322 (7.87)	0.075	0.199
ES	64.93 (21.75)	72.99 (19.27)	73.98 (23.50)	0.091	0.236
* Significantly different from control (p<0.05)					

DISCUSSION

The purpose of the current study was to examine the effect of abdominal stabilizing maneuvers, AB and AH, on lower limb muscle activity and maximum external load during a 1RM back squat. Our first hypothesis was accepted as the maximum external load during the AB and AH conditions were significantly higher than the control day, but AB did not have a significantly higher mean weight lifted than AH. Our second hypothesis was rejected. AB and AH did not elicit more muscle activity and they also did not differ from each other; except for the biceps femoris in the AH condition when comparing muscle activity at the maximum weight.

Maximum External Load

Abdominal stabilizing maneuvers, AB and AH, increased the maximum amount of load that the participants were able to lift. Due to 1RM testing being highly reliable regardless of resistance training experience, number of familiarization sessions, exercise selection, and sex or age of participants (16); we theorize that the increases in external load are due to the instruction of the abdominal stabilizing cues. Both abdominal stabilizing cues were found to be equally effective to increase maximum external load. The abdominal stabilizing cues did not elicit any increases in muscle activity, so additional research is necessary to determined what might have caused the increase in external load.

AB and AH both increase IAP effectively which cause increases in spinal stability (1-4). The increase in spinal stability can prevent unwanted thoracic flexion and extension, which is identified as a cause of biomechanical deficit in during the back squat. Deficits can be identified as either inefficient neuromuscular coordination, muscle weakness, strength asymmetry, joint instability, joint immobility, or muscle tightness (17). Biomechanical deficits during the back squat cause an increase in injury risk, and a decrease in performance and strength (18). Excess pelvic and lumbar movement is also seen as a biomechanical deficit, which increased spinal stability can prevent (7). The increase in external load is therefor likely to be caused by the decrease in back squat biomechanical deficits when spinal stability is increased by AB and AH.

Another possible explanation for the increase in external load may be that the abdominal stabilizing cues effected the psychology of the participant. It has been found that task-specific activation strategies can lead to increases in strength performance (19). Psychological strategies like instructing the participant to focus on the execution of either AB or AH, can remove negative and distracting thoughts that may impact the lift negatively, and allow the participant to focus on cues that can improve performance.

Muscle Activity

Similar to our EMG findings, Suehiro and colleagues found no difference in muscle activity between AH and AB during a prone hip extension (PHE), but lower external oblique activity during the AH condition, which disagrees with our findings (7). Previous studies also found during prone hip extension (PHE) that AH and AB independently decrease erector spinae activity and increase gluteus maximus and biceps femoris activity when compared to no intervention (8,9). ES activity has also been found to be significantly different between AB and AH during isometric trunk flexion and extension (2). We did not find any difference in ES, gluteus maximus and biceps femoris muscle activity during a back squat at the same weight; however, when muscle activity was compared at the maximum amount of weight lifted, an increase in biceps femoris muscle activity was found during the AH condition. The increased biceps femoris activity could be due to reduced anterior tibial translation, which is associated with increased hamstring activation (20,21). However, as assessment of tibial translation was not done in the current study, the exact cause remains unknown.

It was expected that the two maneuvers would activate trunk musculature differently. It is known that AB increases global muscle activation of the core with increased rectus abdominis, external oblique, transverse abdominis and internal oblique activation when compared to AH during various tasks such as side lying hip abduction, prone hip extension and trunk flexion and extension (7-9,22). We did not measure the transverse abdominis and internal oblique activity as they are relatively difficult to measure with surface EMG due to them be located deep to the external oblique and rectus abdominis (9,23).

Our study certainly has limitations that need to be addressed; firstly, we did not control our subjects' nutrition and training regimes outside of testing. We didn't because we wanted to mimic a real life 1RM testing scenario as closely as we could, which is more applicable in a practical setting. Secondly, our statistical power was very low. This could indicate a Type 2 error in the EMG data collection which may impact our results and findings. Future research can differentiate between using abdominal stabilizing cues as a task specific activation cue compared to a different activation cue like "push through the knees". This will give clarification if the increase in external load is caused by abdominal stabilizing specifically or any task-specific activation cue. This study should also be replicated to repeat the EMG muscle activity data collection to observe if a greater statistical power can be achieved.

PRACTICAL APPLICATIONS

Instructing abdominal stabilizing cues like AB and AH can increase the amount of external load an athlete can lift during a 1RM back squat protocol. Although no differences in muscle activity was found, we can confidently say that AB and AH caused the increases in external load. These increases may be explained through the increase in spinal and trunk stability that the abdominal stabilizing cues provide. This may have allowed the participants to complete a heavier squat with AB and AH. Cueing right before the athlete attempts a heavy squat can possibly cause task-specific activation which can mitigate negative self-talk and can help the athlete improve their focus during the lift. On the basis of our findings, we recommend that strength and conditioning coaches teach their athletes to brace or hollow. Any abdominal stabilizing instruction appears to be better than no instruction.

CHAPTER II: LITERATURE REVIEW

Introduction

Abdominal bracing (AB) and abdominal hollowing (AH) are lumbopelvic stabilization maneuvers used in both clinical and practical settings for rehabilitation and exercise training programs. (1-5,23,24). These maneuvers are used to stabilize the lumbar spine to reduce the risk of lower back pain and injury (1-3,11). Abdominal bracing activates more superficial muscles, while abdominal hollowing activates deeper abdominal muscles (23). AB, as defined by Marshall and colleagues, is the coactivation of the abdominal and lower back muscles without drawing the abdomen in; whereas AH is achieved by drawing the navel into the spine without consciously contracting the abdomen (24).

Abdominal bracing (AB)

As stated, AB involves contracting the superficial muscles in the abdominal region and it is used to increase intra-abdominal pressure needed to stabilize the spine (24). Kim and Kim found that AB increases the muscle activity of the quadratus lumborum and external and internal obliques. It can also reduce the angle of pelvic hip rotation more so than AH during side lying hip abduction (22). However, both conditions were found to be more effective than a control group with no intervention. These findings disagree with Suehiro and coworkers, who found that spine motion, lumbar extension and the anterior pelvic tilt degree did not differ between AH and AB groups (7). Similarly, when examining the effects of bracing on general lifting tasks, there are no clear advantages when comparing it to non-braced lifting (1). Conversely, Ishida and colleagues found that expiration and abdominal bracing maneuvers promoted torso contraction, reduced lumbar acceleration in response to a sudden trunk loading, and increased spinal stability (24).

Abdominal hollowing (AH)

Abdominal hollowing consists of drawing in the navel to the spine to create increased intra-abdominal pressure. AH primarily activates the deep trunk muscles, specifically the internal obliques and transverse abdominis, to help maintain a neutral position in the lumbar spine (24). Unlike AB, AH decreases erector spinae muscle activity during prone hip extension (7). Similarly, Kim and Kim noted that hollowing minimizes facilitation of global muscle activity when compared to AB during side lying hip abduction (22). The authors noted that AB can reduce pelvic lateral rotation more than AH in a side lying hip abduction. Kim and Kim concluded that AH can improve anteroposterior stability of the lumbo-pelvic region more by posteriorly lifting the pelvis and reducing the lordotic curve of the lumbar spine (22). In contrast, Suehiro and colleagues' results comparing AH and AB showed no significant difference in terms of kinematics during a prone hip extension. Dupeyron and coworkers found that AH was superior for increasing lower pelvic hip complex stability and leg stiffness in hopping tasks (25). However, Reeve and Diley found that maintaining a neutral spine and belly breathing will optimize muscle activation while performing abdominal hollowing (26).

In the majority of the research found, the difference between AB and AH has only been tested in conditions that involve one joint and/or a single action; such as prone hip extension or side lying abduction (1-5,22). The studies that do involve multi-joint movement only allowed participants to squat to 60 degrees with no external load or tested muscle activity with the different abdominal maneuvers during landing tasks (7,13).

To the author's knowledge, there have been no studies comparing AH and AB during a squat protocol with an external load doing full range of motion. The main goal of using either intervention is to increase lumbar stability to prevent lower back pain and possible injury when performing exercises with a heavy external load, especially within an athletic population. However, no studies to date have used the squat with a maximum external load to compare the differences between AH and AB. Thus, there is a prevalent gap in the published research when using these techniques for the squat.

1RM testing in the Back Squat

The 1RM method can be defined as the maximal weight that can be lifted with correct technique (16,28). This test is widely used in the strength and conditioning field to assess muscular strength, indicate imbalances, and evaluate efficiency of prescribed training programs. The 1RM test is a very diverse method, meaning it is not limited to one exercise and can be conducted using nearly any exercise involving an external load. This testing method is a safe and reliable way to measure strength in healthy trained and untrained adults (18-36 years) (16,28-31). In practical settings, the one-repetition maximum (1RM) test is considered the "gold standard" test for assessing muscular strength (16)

The loaded barbell squat is very popularly used in preparation programs for athletes in many disciplines. The main reason is that the squat is a very functional multi-joint movement; it has a unique ability to overload the prime mover muscles of the knee and hip, it also mimics many muscle actions during athletic movements, such as sprinting and jumping, and is safe when it is performed in a squat rack or cage (33). Because of its popularity, the squat has been the subject of a wide variety of research. Studies have examined the impact of the barbell squat on training adaptations such as maximal strength and power changes (34-41). These adaptations have been reported to impact performance parameters such as countermovement jumps, acceleration, and running speed (28,40,41). Other published research has established that there is a definite relationship between sprint performance and the 1RM squat (40,41).

As mentioned previously, most of the published research that examined the difference between AH and AB used single joint movements and one muscle action such as side lying hip abduction or prone hip extension (1-5). Barbosa and coworkers did use the squat while testing the different maneuvers, but only to 60 degrees of knee flexion and with no external load (13). This may be sufficient for therapy and older populations, but likely not for sport performance testing of athletes. Considering the relationship between performance parameters and the squat within the athletic population, it would be beneficial to use the back squat and the 1RM method to compare the effect of AB and AH.

Muscle activity measured via electromyography (EMG)

Electromyography (EMG) is the most popular method of measuring muscle activity and is used in nearly all the studies examined for this review. Barbosa and colleagues were the only researchers to measure the differences between AB and AH during a squat (13). The authors measured the muscle activity of the rectus femoris, biceps femoris, gastrocnemius medialis, and tibialis anterior during knee flexion and extension phases of the 60-degree squat under normal breathing, AH, and AH with Pilates breathing conditions. The authors noted significant differences between the conditions as muscle activity seemingly increased from the first to the last condition (13). They concluded that muscle activity in the rectus and biceps femoris as well as tibialis anterior is at the highest during the flexion phase under AH with Pilates breathing. This can be beneficial in a physical therapy setting; neuromuscular stress can be enhanced through breathing instead of adding an external load. Furthermore, AB may also influence 1RM performance of athletes.

Prone hip extension (PHE) is a test commonly used to evaluate the muscular recruitment pattern and test the stability of the lumbopelvic muscles in patients with chronic low back pain (CLBP) (1-4,42). Various studies have also shown an increase in erector spinal (ES), gluteus maximus (GM) and biceps femoris (BF) activity in patients with CLBP (42-48). That is why Kahlaee and colleagues compared the activation pattern of the GM, BF and ES muscles during PHE in participants with and without CLBP while performing AB and AH maneuvers during PHE. Central erector spinae activity during PHE was found to be significantly lower for AH than AB. There were no significant differences between EMG activity of the GM or BF muscles. In addition, the CLBP group showed higher levels of activity in all muscles (22).

In a similar study, Suehiro and colleagues also compared AH and AB during PHE; they examined spine motion as well as trunk muscle activity (7). A surface electromyography system was set to biofeedback mode to control the pattern and intensity of the lumbopelvic stabilization maneuvers. The right lower part of the internal oblique (IO) was monitored because it resembles the activity of the transverse abdominis, which cannot be measured on surface EMG (7). The external obliques (EO) were also monitored to differentiate between AH and AB because AH is supposed to activate deeper abdominal muscles with a minimum level of EO activation. The ratio of activation between the right IO and EO was calculated to ensure the stabilization maneuvers were performed correctly. This study did not measure any lower body muscle activity. The authors concluded that AH did effectively stabilize the lumbopelvic region as lumbar extension and pelvic tilt degree did not differ between AB and AH. However, global muscle activity such as EO was lower in AH than in AB. The researchers suggest that AH is recommended to effectively stabilize the lumbopelvic region during PHE without increasing global muscle activation.

Summary

The current literature review demonstrated that AB and AH are both sufficient to stabilize the lumbopelvic region. Although opinions differ on which maneuver is best to prevent LBP, a case can be made for both. The conclusions surrounding the maneuvers generally have been task specific. Limited research has been done comparing AH and AB during practical functional movements such as the back squat. Currently, most strength and conditioning professionals are trained to use core bracing but as this review has stated, AB causes more global muscle activation and may lead to undue stress on the spine and therefor cause LBP. The effects of these maneuvers on a complex maximal exertion movement such as the back squat, is unknown. Therefore, a comparison of the effect of AH and AB during a maximum squat protocol should be assessed via muscle activity on the abdominal muscles responsible for AH and AB and on the squat prime mover muscles.

CHAPTER III: CONCLUSIONS AND RECOMMENDATIONS

The current study found that AB and AH both increase the maximum amount of external weight lifted during a 1RM back squat protocol. There was no difference in muscle activity found when comparing control, AB and AH. Increases in external load can likely be accounted to the abdominal stabilizing cues ensuring proper squat mechanics by limiting pelvic and spinal movement. Another likely explanation is that the cueing of abdominal stabilizing maneuvers caused an increase in awareness of task-specific activation. This could have shifted the athletes focus from the weight to the task at hand. Either explanation is viable. The main finding of this study is that instructing abdominal stabilization cues before attempting a heavy back squat appears to increase maximum external load lifted.

The main limitation for this study was that the statistical power for the muscle activity data was very low. It is likely that a Type 2 error occurred during the EMG data collection, which makes the findings questionable and can explain why no increases in muscle activity were found. Future research should replicate the study with a larger sample size errors to assess if a higher statistical power will yield a significant difference in muscle activity. Additionally, researchers can look at instructing different task-specific activation cues to observe if the increase in external load will persist with any cue or just abdominal stabilization cues.

REFERENCES

1. Cholewicki, J, Juluru, K, & McGill, SM. Intra-Abdominal Pressure Mechanism for Stabilizing the Lumbar Spine. *J Biomech*, 32: 13-17, 1999.
2. Cholewicki, J, Juluru, K, Radebold, A, Panjabi, MM, & McGill, SM. Lumbar Spine Stability Can Be Augmented with An Abdominal Belt and/or Increased Intra-AbdominalPressure. *Eur Spine J,* 8: 388-395, 1999.
3. O'Sullivan, PB., Phyty, GDM, Twomey, LT & Allison, GT. Evaluation of Specific Stabilizing Exercise in The Treatment of Chronic Low Back Pain with Radiologic Diagnosis ofSpondylolysis or Spondylolisthesis. *Eur Spine J*, 22: 2959-2967, 1997.
4. H-S Jung, S-Y Kang, J-H Park, H-S Cynn, H-S Jeon. EMG Activity and Force During Prone Hip Extension in Individuals with Lumbar Segmental Instability. *Man Ther*, 20, pp. 440-444, 2015.
5. Tayashiki, K., Takai, Y., Maeo, S., & Kanehisa, H. Intra-Abdominal Pressure and Trunk Muscular Activities During Abdominal Bracing and Hollowing. *Int J Sports Med* 37(02), 134-143, 2016.
6. Triplett, NT. *Essentials of Strength Training and Conditioning*. FourthEdition. Champaign, IL: Human Kinetics, 2016.
7. Suehiro, T., Mizutani, M., Watanabe, S., Ishida, H., Kobara, K., & Osaka, H. Comparison of Spine Motion and Trunk Muscle Activity Between Abdominal Hollowing and Abdominal Bracing Maneuvers During Prone Hip Extension. *J Bodyw Mov Ther18*(3), 482-488, 2014

8. Ghamkhar, L. Effect of The Abdominal Bracing Maneuver on Muscle Activity Pattern During Prone Hip Extension. *PTJ*, 3(3): 16-21, 2013.
9. Oh, J. S., Cynn, H. S., Won, J. H., Kwon, O. Y., & Yi, C. H. Effects of Performing an Abdominal Drawing-In Maneuver During Prone Hip Extension Exercises on Hip and Back Extensor Muscle Activity and Amount of Anterior Pelvic Tilt. *Journal of Orthop Sports Phys Ther 37*(6): 320-324, 2017.
10. Murphy, D. R., Byfield, D., McCarthy, P., Humphreys, K., Gregory, A. A., & Rochon, R. Interexaminer Reliability of The Hip Extension Test for Suspected Impaired Motor Control of The Lumbar Spine. *J Manip Physiol Ther 29*(5): 374-377, 2016.
11. Harris-Hayes, M., Van Dillen, L.R.., Sahrmann, S.A. Classification, Treatment and Outcomes of a Patient with Lumbar Extension Syndrome. *Physiother. Theory Pract* 21: 181-196, 2005
12. Comerford MJ, Mottram SL. (2001) Movement and Stability Dysfunction--Contemporary Developments. *Man Ther*. Feb;6(1):15-26. doi: 10.1054/math.2000.0388. PMID: 11243905.
13. Barbosa, AC., Martins, FM., Silva, AF et al. (2017). Activity of lower limb muscles during squat with and without abdominal drawing-in and Pilates breathing. *J Strength CondRes*, 31: 3018-3023
14. Stone MH, O'Bryant HS, McCoy L, Coglianese R, Lehmkuhl M, Schilling B. (2003) Power and Maximum Strength Relationships During Performance of Dynamic And Static Weighted Jumps. *J Strength Cond Res* 17: 140–147
15. Burden, A. M., Trew, M., & Baltzopoulos, V. (2003). Normalisation of gait EMGs: A re-examination. *Journal of Electromyography and Kinesiology*, 13, 519–532.

16. Grgic, J., Lazinica, B., Schoenfeld, B. J., & Pedisic, Z. (2020). Test–retest reliability of the one-repetition maximum (1RM) strength assessment: a systematic review. *Sports Med. Int. Open*, *6*(1), 1-16.

17. Schoenfeld BJ. Squatting kinematics and kinetics and their application to exercise performance. *J Strength Cond Res* 24: 3497–3506, 2017.

18. Lamontagne, M., Kennedy, M. J., & Beaulé, P. E. The effect of cam FAI on hip and pelvic motion during maximum squat. *Clin. Orthop. Relat. Re* 467(3): 645-650, 2009

19. Mellalieu, S. D., & Shearer, D. *Mental skills training in strength and conditioning.* United Kingdom: Routledge, 2012.

20. Pasquet B, Carpentier A, Duchateau J. Specific Modulation of Motor Unit Discharge for A Similar Change in Fascicle Length During Shortening and Lengthening Contractions in Humans. *J Physiol* 577: 753–765, 2006.

21. Bryanton MA, Carey JP, Kennedy MD, Chiu LZF. Quadriceps Effort During Squat Exercise Depends on Hip Extensor Muscle Strategy. *Sport Biomech* 14:122–38, 2015.

22. Kim, D. W., & Kim, T. H. Effects of Abdominal Hollowing and Abdominal Bracing During Side-Lying Hip Abduction on The Lateral Rotation and Muscle Activity of the Pelvis. *J Exerc Rehabil* 14(2): 226–230, 2018.

23. Amir H. Kahlaee, Leila Ghamkhar, Amir M. Arab. Effect of The Abdominal Hollowing and Bracing Maneuvers on Activity Pattern of The Lumbopelvic Muscles During Prone Hip Extension in Subjects with or Without Chronic Low Back Pain: A Preliminary Study, *Manip Physiol Ther* 40(2):106-117, 2017.

24. Ishida H, Suehiro T, Kurozumi C, Watanabe S. Comparison Between the Effectiveness of Expiration and Abdominal Bracing Maneuvers in Maintaining Spinal Stability Following

Sudden Trunk Loading. *J Electromyogr Kinesiol* 26: 125–129, 2016.

25. Dupeyron, A., Hertzog, M., Micallef, J. P., & Perrey, S. Does an Abdominal Strengthening Program Influence Leg Stiffness During Hopping Tasks? *J Strength Cond Res 27*(8): 2129-2133, 2013.
26. Reeve, A., & Dilley, A. Effects of Posture on The Thickness of Transversus Abdominis in Pain-Free Subjects. Man Ther 14(6): 679-684, 2009.
27. Slater LV, Hart JM. Muscle Activation Patterns During Different Squat Techniques. *J Strength Cond Res* 31: 667–676, 2017.
28. Buckner, Samuel L., et al. Determining Strength: A Case for Multiple Methods of Measurement. *Sports Med* 47.2: 193-195, 2017.
29. McBride, JM, Skinner, JW, Schafer, PC, Haines, TL, & Kirby, TJ. Comparison of Kinetic Variables and Muscle Activity During A Squat Vs. A Box Squat. *J Strength Cond Res*, 24: 3195-3199, 2010.
30. Levinger, I., Goodman, C., Hare, D.L., Jerums, G., Toia, D. and Selig, S. The Reliability of the 1RM Strength Test for Untrained Middle-Aged Individuals. *J. Sports Sci. Med* 12(3): 310-316, 2009.
31. English, K. L., Loehr, J. A., Laughlin, M. A., Lee, S. M., & Hagan, R. D. Reliability of Strength Testing Using the Advanced Resistive Exercise Device and Free Weights. *NASA Tech. Pap*, 2008.
32. Ribeiro, A.S., Nasimento, M.A., Salavador, E.P., et al. Reliability of One-Repetition Maximum Test in Untrained Young Adult Men and Women. *Isokinet Exerc Sci* 22: 175-182, 2013.
33. Wisloff U, Castagna C, Helgerud J, Jones R, Hoff J. Strong Correlation of Maximal Squat

Strength with Sprint Performance and Vertical Jump Height in Elite Soccer Players. *Br J Sports* Med 38: 285–288, 2004.

34. Urquhart, BG, Moir, GL, Graham, SM, and Connaboy, C. Reliability Of 1RM Split-Squat Performance and The Efficacy of Assessing Both Bilateral Squat and Split-Squat 1RM In A Single Session for Non–Resistance-Trained Recreationally Active Men. *J Strength Cond Res* 29(7): 1991-1998, 2015
35. Stone MH, Potteiger JA, Pierce KC, Proulx CM, O'Bryant HS, Johnson RL, Stone ME. Comparison of The Effects of Three Different Weight-Training Programs on One Repetition Maximum Squat. *J Strength Cond Res* 14: 332–337, 2000.
36. Anderson K, Behm DG. Trunk Muscle Activity Increases with Unstable Squat Movements. *Can J Appl Physiol* 30: 33–45, 2005
37. Brown, LE & Weir, JP. ASEP Procedures Recommendation I: Accurate Assessment of Muscular Strength and Power. *J. Exerc. Physiol Online* 49(3), 2001.
38. Hoff J. Training and Testing Physical Capacities for Elite Soccer Players. *J Sports Sci* 23: 573–582, 2005.
39. Cormie P, McGuigan MR, Newton RU. Adaptations in Athletic Performance After Ballistic Power Versus Strength Training. *Med Sci Sports Exerc* 42: 1582–1598, 2010.
40. McBride, Jeffrey M; Blow, Daniel; Kirby, Tyler J; Haines, Tracie L; Dayne, Andrea M; Triplett, N Travis. Relationship Between Maximal Squat Strength and Five, Ten, and Forty-Yard Sprint Times. *J. Strength Cond. Res* 23(6): 1633-1636, 2007.
41. de Hoyo, M; Gonzalo-Skok, O; Sañudo, B; et al. Comparative Effects of In-Season Full-Back Squat, Resisted Sprint Training, and Plyometric Training on Explosive Performance In U-19 Elite Soccer Players. *J. Strength Cond. Res 30(2):* 368-377, 2016.

42. Steffens, D, Maher, CG, Pereira, LS et al. Prevention of Low Back Pain: A SystematicReview and Meta-Analysis. *JAMA Intern Med* 176: 199-208, 2016.

43. Marshall PW, Desai I, Robbins DW. Core Stability Exercises in Individuals with and Without Chronic Nonspecific Low Back Pain. *J Strength Cond Res* 25(12):3404-11, 2011.

44. Vaičienė, G., Berškienė, K., Slapsinskaite, A., Mauricienė, V., & Razon, S. Not Only Static: Stabilization Maneuvers in Dynamic Exercises - A Pilot Study. *PloS one 13*(8), 2018.

45. Bezerra, E. S., Simão, R., Fleck, S. J., Paz, G., Maia, M., Costa, P. B., & Serrão, J. C. Electromyographic Activity of Lower Body Muscles During the Deadlift and Still-Legged Deadlift. *J. Exerc. Physiol. Online* 16(3): 30-39, 2013.

46. K.N. Park, C.H. Yi, H.S. Jeon, W.H. Lee, S.M. Ha, S.J. Kim, O.Y. Kwon. Effects of Lumbopelvic Neutralization on The Electromyographic Activity, Lumbopelvic And Knee Motion During Seated Knee Extension in Subjects with Hamstring Shortness. *J. Phys. Ther*. Sci 24(1): 17-22, 2012.

47. Ross M. Therapeutic Exercise for Spinal Segmental Stabilization in Low Back Pain: Scientific Basis and Clinical Approach. *Physc Ther* 79(8):801, 1999.

48. Hodges PW, Richardson CA. Altered Trunk Muscle Recruitment in People with Low Back Pain with Upper Limb Movement at Different Speeds. *Arch Phys Med Rehabil* 80(9):1005-12, 1999.

APPENDIX A

CONSENT TO ACT AS HUMAN SUBJECT
Research Study by Caro Els in the Masters of Exercise Science Program
Northern Michigan University

ACTIVITY OF LOWER BODY MUSCLES DURING MAX SQUAT PROTOCOL WITH DIFFERENT ABDOMINAL STABILIZING TECHNIQUES

Subject Name (print): ______________________________ Date:
____

1. I hereby volunteer to participate as a subject in maximum effort exercise testing. I understand that I will undergo this testing as part of the study entitled "Activity of Lower Body Muscles During Max Squat Protocol with Different Abdominal Stabilizing Techniques". The purpose of this study is to determine the difference between lower limb muscle activity under different abdominal stabilizing cues.

2. I hereby authorize Randall L. Jensen, Caro I Els and/ or assistants, as selected by them, to take me through the following testing procedures:

    a. I understand that I am being asked to complete a max back squat protocol under different
    abdominal stabilizing cues.

    b. I understand that I will be testing once a week, on the same day and at the same time, for three consecutive weeks.

    c. I understand that the testing will take place in the Exercise Science lab and the Superior Dome Weight room.

    d. I understand that I will have 6 electrodes placed on the skin, and all on the left side of the body: one on each of the rectus abdominis (center abdominal), external oblique (outer abdominal), erector spinae (center lower back), rectus femoris (center quad), biceps femoris (center hamstring), and the gluteus maximus (glute) to assess muscle activity, via electromyography, while completing a 1RM squat protocol. For the application of each EMG, the site of attachment will be shaved and lightly abraded to allow for maximal contact.

3. The procedures outlined in the first paragraph has been explained to me.

   I understand that the procedure described involve the following risks and/ or discomforts: temporary muscle fatigue, pain and soreness is expected. I understand that there are risks of failing, falling, and musculoskeletal injury during the testing. Skin irritation may occur from EMG electrodes, although it is very unlikely.

   I am also aware that I can withdraw from this study at any time at my own discretion. I should cease any test if I experience abnormalities like dizziness, light-headedness or shortness of breath. To avoid any such risks, I understand that the examiners shall adopt the necessary measures to prevent these risks such as monitoring my movement during the exercise.

4. I understand that the following benefits will be derived from my participation: The benefits of this study include a better understanding of abdominal muscle activity with different stabilizing cues during a maximum effort back squat. No compensation will be given to participating athletes, but the study could benefit the strength and conditioning and the athletic community by providing results that can be used to increase performance and working maxes while providing the adequate lumbar stabilization. This study will benefit athletes and coaches alike. Results could alter coach's way of instruction to increase results and maximize performance.

5. I understand that Randall L. Jensen, Caro I Els and assistants, as selected by them, will answer any inquiries that I may have concerning any of the procedures.

6. I understand that my personal data will be kept confidential and only available upon my written request. I also understand that if the data were to be published, there will be no association between myself and the reported data.

7. I understand that I will not be compensated for my participation in this study.

8. I understand that if physical injury were to occur during my participation, compensation will not be provided. If injury occurs, emergency first aid will be provided and the EMS system will be activated.

9. I understand that I may terminate participation in this study at any time without prejudice to future care or any possible reimbursement of expenses, compensation, employment or team status.

10. I understand that if I have any further questions regarding my rights as a participant in a research project I may contact Dr. Eckhardt, Dean of Graduate Education and Research at Northern Michigan University (906-227-2300) leckert@nmu.edu. Any questions I have regarding the nature of this research project will be answered by Dr. Randall Jensen (906-227-1184) rajensen@nmu.edu or Caro Els (906-373-9660) cels@nmu.edu.

I have carefully read the above "Informed Consent Statement". The nature, risks, demands, and benefits have been explained to me. I understand that I can ask questions at any time and withdraw from participating without any consequences. I also understand that this consent form will be kept separate from data collection in this project to maintain anonymity and confidentiality. Access to this document is restricted to principle investigator.

X ______________________________ ______________________

Participant

Date

X ______________________________ ______________________

Principal Investigator

Date

APPENDIX B

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE
(August 2002)

SHORT LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data onhealth–related physical activity.

Background on IPAQ

The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ

Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this willaffect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation

Translation from English is supported to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methodsavailable on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website.

Further details on translation and cultural adaptation can be downloaded from the website.

Further Developments of IPAQ
International collaboration on IPAQ is on-going and an ***International Physical ActivityPrevalence Study*** is in progress. For further information see the IPAQ website.

More Information
More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective*. Research Quarterly for Exerciseand Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your sparetime for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathemuch harder than normal. Think *only* about those physical activities that you did for atleast 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physicalactivities like heavy lifting, digging, aerobics, or fast bicycling?

______days per week

☐ No vigorous physical activities ➡ ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on oneof those days?

______**hours per day** ______**minutes per day**

☐ Don’t know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you didfor at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis?Do not include walking.

______**days per week**

☐ No moderate physical activities ➡ ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on oneof those days?

______**hours per day**________**minutes per day**

☐ Don’t know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and athome, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutesat a time?

______**days per week**

☐ No walking ➡ ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

______**hours per day**________**minutes per day**

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisuretime. This may include time spent sitting at a desk, visiting friends, reading, or sitting orlying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

______hours per day **______minutes per day**

☐ Don't know/Not sure

This is the end of the questionnaire, thank you for participating.

APPENDIX C

General strength and conditioning warm up:

Leg swings x 10 each way

Forward lunge with rotation x 5 each side

Forward lunge with lean x 5 each side

Bodyweight squat x 10

Walking hamstring stretch x 10 each side

Low lunge holds on bench x 5 each side

Runners lunge with rotation x 5 each way

APPENDIX D

Name: ______________________	Date: ________	Control | AH | AB

Estimated 1RM: ________

Warm up

1	50%	*Weight:* ________	*Reps:* ________ *(5-10)*
		1 min rest	
2	70%	*Weight:* ________	*Reps:* ________ *(3-5)*
		2 min rest	
3	85%	*Weight:* ________	*Reps:* ________ *(2-3)*
		3 min rest	

1RM Trials

1	(+10-20%)	*Weight:* ________	Fail/Pass
		3 min rest	
2	(+5-10%)	*Weight:* ________	Fail/Pass
		3 min rest	
3	(+-5-10%)	*Weight:* ________	Fail/Pass
		3 min rest	

4	(+-5-10%)	*Weight:* ________ *3 min rest*	Fail/Pass
5	(+-5-10%)	*Weight:* ________ *3 min rest*	Fail/Pass

APPENDIX E

NORTHERN MICHIGAN UNIVERSITY

Graduate Studies and Research
Marquette, MI 49855-5301
906-227-2300
www.nmu.edu/graduatestudies/

Memorandum

TO: Randall Jensen
Caro Els
School of Health and Human Performance

DATE: April 4, 2022

FROM: Lisa Schade Eckert
Dean of Graduate Studies and Research

SUBJECT: **IRB Proposal** HS21-1203
IRB Approval Date 4/13/2021
Proposed Project Dates: **4/1/2021 – 4/30/2022**
"ACTIVITY OF LOWER BODY MUSCLES DURING MAX SQUAT PROTOCOL WITH DIFFERENT ABDOMINAL STABILIZING TECHNIQUES"

Your proposal "ACTIVITY OF LOWER BODY MUSCLES DURING MAX SQUAT PROTOCOL WITH DIFFERENT ABDOMINAL STABILIZING TECHNIQUES" has been approved by the NMU Institutional Review Board. Include your proposal number (HS21-1203) on all research materials and on any correspondence regarding this project.

A. If a subject suffers an injury during research, or if there is an incident of non-compliance with IRB policies and procedures, you must take immediate action to assist the subject and notify the IRB chair (dereande@nmu.edu) and NMU's IRB administrator (leckert@nmu.edu) within 48 hours. Additionally, you must complete an Unanticipated Problem or Adverse Event Form for Research Involving Human Subjects.

B. Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding. Informed consent must continue throughout the project via a dialogue between the researcher and research participant.

C. If you find that modifications of investigators, methods, or procedures are necessary, you must submit a Project Modification Form for Research Involving Human Subjects before collecting data. Any changes or revisions to your approved research plan must be approved by the IRB prior to implementation.

Until further guidance, per CDC guidelines, the PI is responsible for obtaining signatures on the COVID-19 Researcher Agreement and Release and COVID-19 Research Participant Agreement and Release forms for any in person research.

All forms can be found at the NMU Grants and Research website:
http://www.nmu.edu/grantsandresearch/node/102