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Postactivation Potentiation Effects from Maximal Isometric Contractions Performed at Different Hip Joint Angles

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POSTACTIVATION POTENTIATION EFFECTS FROM MAXIMAL ISOMETRIC CONTRACTIONS PERFORMED AT DIFFERENT HIP JOINT ANGLES

by

Kyle DeRosia

A thesis submitted to the Graduate College
in partial fulfillment of the requirements
for the degree of Master of Science
Human Performance and Health Education Western
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Thesis Committee:

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ACKNOWLEDGEMENTS

I would like to begin by acknowledging Dr. Lee for his guidance and support throughout my academic career and this project. Allowing me to help with his research during my time as an undergraduate is what inspired me to continue research on my own and eventually led to the work in this thesis.

Secondly, I would like to thank the other members of my committee, Dr. Hanson and Dr. Michael for their help throughout my project. Dr. Hanson made sure I kept working even when issues arose with the equipment. Dr. Michael for helped clear up any confusion I had with the entire thesis process.

Finally, I would like to thank my fiancé, Ireland, for being supportive when I was up late writing or in the lab for hours at a time. Listening to me read, rewrite, and re-read paragraphs over and over must have been frustrating, but she never seemed to mind. All in all, the help I received from everyone, no matter how small, was greatly appreciated and I will always be grateful for it. Thank you.

Kyle DeRosia

POSTACTIVATION POTENTIATION EFFECTS FROM MAXIMAL ISOMETRIC CONTRACTIONS PERFORMED AT DIFFERENT HIP JOINT ANGLES

Kyle DeRosia, M.S.

Western Michigan University, 2019

The purpose of this study was to investigate the differences in vertical ground reaction force (VGRF) production and myoelectric activity after performing maximal isometric contractions at different hip joint angles. 10 healthy, experienced participants reported to the lab on two separate occasions where they performed 3 power cleans at baseline, then 4 maximal isometric deadlifts at either ~50˚ hip flexion angle (Max) or ~90˚ hip flexion angle (Min). Following the isometric deadlifts, another 3 power clean trials at 70% 1 repetition maximum were performed and used as a post-test. The isometric deadlifts served as the conditioning contraction (CC) to induce Postactivation Potentiation (PAP). Repeated measures analysis of variance revealed no significant changes VGRF from pre to post testing for either condition. No significant differences were observed in electromyography (EMG) for any muscle, regardless of time or condition. Maximal isometric contractions with minimal rest following may not be an optimal protocol for inducing PAP prior to power cleans. Furthermore, potentiation effects may not be observed during power cleans performed at 70% 1RM since only submaximal effort is required for successful execution of the exercise.

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INTRODUCTION

Postactivation potentiation (PAP) is a phenomenon whereby the peak force and rate of force development of a muscle contraction is acutely enhanced by its contractile history (Robbins, 2005). Some literature also suggests that PAP may increase neuromuscular efficiency (Gago, 2018). Electromyographic (EMG) activity can decrease following a PAP protocol while rate of torque development remains the same or even increases. Peak force production and rate of force/torque development are important qualities for athletes participating in power sports (i.e. American football, weightlifting, hockey, etc.). Because of this, the use of PAP has become popular in the strength and conditioning setting; coaches can use PAP to enhance performance during training and competition. PAP can be elicited and observed in different settings, using different methodology. Some studies involve electrically stimulating skeletal muscle fibers and measuring the fibers' contractile properties, while others have human subjects perform a conditioning contraction (CC) followed by a powerful activity, often referred to as the subsequent activity (SA) (i.e. jumps, maximal sprints, weightlifting movements) (Robbins, 2005). Although there is evidence that provides reason to use PAP for athletic populations, the optimal protocol for its application is not yet identified.

The volume, intensity, and type of CC can all affect the PAP response (Chaouachi et al., 2011). Some studies have analyzed the differences that isometric, eccentric only, concentric only, and dynamic (eccentric and concentric) contractions had on the PAP response (Esformes, Keenan, Moody, & Bampouras, 2011; Lim & Kong, 2013). Lim & Kong, (2013) found no difference between the contraction types, whereas Esformes et al., (2011) found increased peak power after only the isometric contraction. The exercise selected as the CC and the SA used to test for a PAP response can also influence the results. In order to obtain the best PAP response, the kinematics of the CC should be similar to the SA (Tillin & Bishop, 2009).

Despite the potential influences, few studies have specifically examined how the kinematics of the CC affect the muscular performance of the SA. One study had participants complete 6 weeks of training using isometric contractions at either a large or short knee joint angle, then tested maximal isometric force and rate of force development at various knee angles. The results showed great increases in max. isometric force and rate of force development at larger joint angles in the group that trained at larger joint angles, while the group that trained at a smaller joint angle displayed modest increases in max isometric force at all angles that were tested (Bogndanis et al., 2018). However, this study looked at the effects of a 6-week training program, not the acute effects of PAP. Thus, the purpose of this study was to investigate the acute effects that performing CC at different hip joint angles had on vertical ground reaction force (VGRF) and lower body muscle activation during power cleans. The authors hypothesized that (1) Average VGRF would increase following both PAP protocols, (2) VGRF patterns would be altered following the PAP protocols. Specifically, the Min condition would increase instantaneous VGRF in the earlier portion of the lift (first pull) and the Max condition would increase instantaneous VGRF in the later portion of the lift (second pull), (3) EMG activity would not change or slightly decrease.

METHODS

Experimental Approach to the Problem

We analyzed the acute effects that performing maximal isometric deadlifts at two different hip joint angles had on electing PAP prior to power clean trials. This study included a randomized repeated-measures design, whereby participants served as their own controls. Each participant completed 3 power cleans at 70% of his/her 1 repetition maximum (1RM) as a baseline measure (before), and an additional 3 power cleans at 70% 1RM after completing 4 maximal isometric deadlifts at two different hip joint angles (Min and Max).

Subjects

10 healthy, resistance trained subjects (8 males and 2 females) were recruited for participation in the study. In order to participate, subjects had to be between the ages of 18-30 years and have been participating in a resistance training regimen at least 2 times per week for the past 2 years and have at least 2 years of experience with the power clean exercise to ensure safety and quality for data collection. A description of the subjects can be seen in Table 1. All participants were informed of the research procedures, benefits, and risks before obtaining written informed consent.

Table 1. Summary of Demographics

Age	Height (cm)	Body Mass (kg)	BMI (kg/m^2)	Years of Experience
23.7±1.5	176.7±5.6	81.0±8.5	26.0±2.6	5.35±3.37

Procedures

Each participant met in the lab on two separate occasions to complete two different PAP protocols. Both conditions were completed during separate sessions, with at least 48 hours between each session. During the first session, height, body mass, and self-reported 1RM power clean were determined.

During the first session, subjects completed a brief dynamic warm-up consisting of 5-minutes of exercise on a cycle ergometer at a self-selected, light intensity 10 barbell front squats, 10 barbell Romanian deadlifts, and 10 barbell upright rows using a weighted barbell (20.4 kg).

Then, participants completed another 5 repetitions of front squats, Romanian deadlifts and upright rows with a load of 45% of the subject's 1RM power clean. After the warm-up, participants performed a power clean at a weight of 90% of their 1RM followed by 10 minutes of rest. After the rest period, 3 power cleans at 70% of their 1RM were completed and used for baseline data. Participants then rested for another 10 minutes. Next, participants completed either the Min or Max PAP Protocol using a back dynamometer. Finally, immediately following the PAP protocol, another 3 trials of power clean at 70% of their 1RM were completed. The second session was completed in the same sequence as the first, with the exception of the power clean performed at 90% 1RM and the PAP protocol that was not performed during session 1 was completed.

Two 1000-Hz force plates (Model Optima; Advanced Mechanical Technology, Inc., Watertown, MA, USA) were used to obtain kinetic data (VGRF). Myoelectric activity was recorded using Noraxon Desktop ETS Wireless EMG (Model) with electrodes placed on the Rectus Femoris (RF), Biceps Femoris (BF), and the Gluteus Maximus (GM). EMG data during the trials at 70% 1RM were normalized to the 90% 1RM clean by dividing the average values from the 70% 1RM cleans by the values from the 90% 1RM clean. Results are expressed as a percentage of the MVC.

Statistical Analysis

2-way repeated measures analysis of variance (ANOVA) was conducted to determine differences in average VGRF, with time (pre/post) and each condition (min/max) being the independent variables. Three separate 2 (time) x 2 (condition) repeated measures ANOVAs were used to determine the differences in mean muscle activation of the RF, BF and GM for each time point (pre/post) and for each condition (Min/Max). Statistical analyses were conducted using IBM SPSS Statistics version 25 (IBM, New York) with the α level set at .05.

RESULTS

Ground Reaction Force

There was no significant main effect for time ($F_{(1,9)}$ =.311, p=.591) or condition ($F_{(1,9)}$=.449, p=.520) and no significant interaction effect for time*condition ($F_{(1,9)}$=.603, p=.457) for VGRF.

Muscle Activation

For the RF, there was no significant main effect of time ($F_{(1, 8)}$=2.001, p=.195), no significant main effect of condition ($F_{(1,8)}$=.538, p=.484) and no significant interaction effect of time*condition ($F_{(1,8)}$=.007, p=.934). For the BF, there was no significant main effect of time ($F_{(1,9)}$=.025, p=.877), no significant main effect of condition ($F_{(1,9)}$=.001, p=.974), and no significant interaction effect of time*condition ($F_{(1,9)}$=2.146, p=.177). For the GM, there was no significant main effect of time ($F_{(1,8)}$=1.315, p=.285), no significant main effect of condition ($F_{(1,8)}$=.102, p=.757), and no significant interaction effect of time*condition ($F_{(1,8)}$=1.650, p=.235). Means and standard deviations are displayed in table 2.

Table 2. Summary of Results

		Min		Max	
		Pre	Post	Pre	Post
GRF (N/kg)		14.39±2.18	14.40±2.24	14.80±1.65	14.57±1.41
EMG (%MVC)	RF	85%±26%	78%±26%	91%±38%	85%±34%
	BF	70%±33%	74%±33%	73%±28%	70%±25%
	GM	68%±17%	74%±21%	73%±16%	72%±12%

DISCUSSION

This study investigated the effects of two different PAP protocols on subsequent power clean performance and lower body muscle activation. No differences in average VGRF were observed regardless of time (pre/post) or condition (Min/Max). There were also no differences in muscle activation for time and condition.

The lack of significant findings is in agreement with Lim and Kong (2013), who found isometric contractions performed for short durations did not elicit PAP responses. The authors also found that sprint times were not affected when performing isometric squats, isometric knee extensions, or dynamic squats when compared to control conditions. However, the participants in Lim and Kong's study completed 3 isometric contractions with 2-minutes between contractions and 4-minutes of recovery prior to sprinting, which may have allowed for the onset of fatigue, thus preventing a PAP response to be observed.

Other studies have shown clear PAP responses when isometric contractions are used as the CC (Higuchi, Nagami, Mizuguchi, & Anderson, 2013; Esformes et al. 2011; Miyamoto, Kanehsia, Fukunaga, & Kawakami, 2011). Higuchi et al. (2013) used a similar protocol as our study, where participants completed 4 repetitions of 5 second maximal isometric contractions, with 5 seconds between repetitions, then swung a bat at maximal effort 1 minute following the isometric contractions. This study showed increases in bat swinging velocity following the isometric contractions. However, this study only analyzed the bat velocity, not GRF or other kinetic variables. Esformes et al. (2011) also found significant improvements in peak power of a barbell bench press throw exercise following an isometric CC. In this study participants completed a 7 second isometric bench press, then completed a bench press throw exercise 12 minutes following the CC. One difference between these two studies and our study that may explain the discrepancies in results is the SA used to test for PAP. In each of the aforementioned studies, a maximal effort, ballistic type exercise served as the SA. However, in our study, a submaximal power clean served as the SA. Because the power clean was performed at 70% of the participants' 1RM, maximal effort and force production is not required to successfully complete the repetition.

The lack of an observable PAP response could also be due to the rest period following the CC. In our study, participants rested only 1 minute before beginning the subsequent power cleans, similar to Higuchi et al. (2013). This rest period may have been too short, as other studies have shown longer rest periods may be required to allow for neuromuscular fatigue to subside. Wyland, Dorin, and Reyes (2015) found that heavy back squats did not improve sprint times when the sprints were performed within 3 minutes of the completion of the back squats. However, sprint times improved after back squats with accommodating resistance when the sprints were performed 4 minutes after the back squats. Chaouachi et al. (2011) found that individuals responded differently to different volumes and intensities of the CC and after different rest periods following the CC. The authors state that most individuals showed a PAP response between 1 and 5 minutes, but some individuals didn't show a response until up to 15 minutes after the CC. The authors recommend that PAP protocols be tailored specifically to the individual performing the task in order to produce the best results. The protocol in our study may not have been designed for optimal results for the participants, which may explain the non-significant results.

VGRF patterns also did not seem to be influenced by either condition. It was hypothesized that the Min condition would increase instantaneous VGRF from baseline at the point where the barbell was in front of the knees (~90˚ hip flexion), and the Max condition would increase instantaneous VGRF from baseline at the point where the barbell was near the top of the thigh (~50˚ hip flexion). Since training with isometric contractions can cause angle-specific adaptations (Bogdanis et al., 2018), it was hypothesized that isometric contractions could cause acute, angle-specific changes in the form of PAP. Figure 1 shows the ensemble averages of each trial.

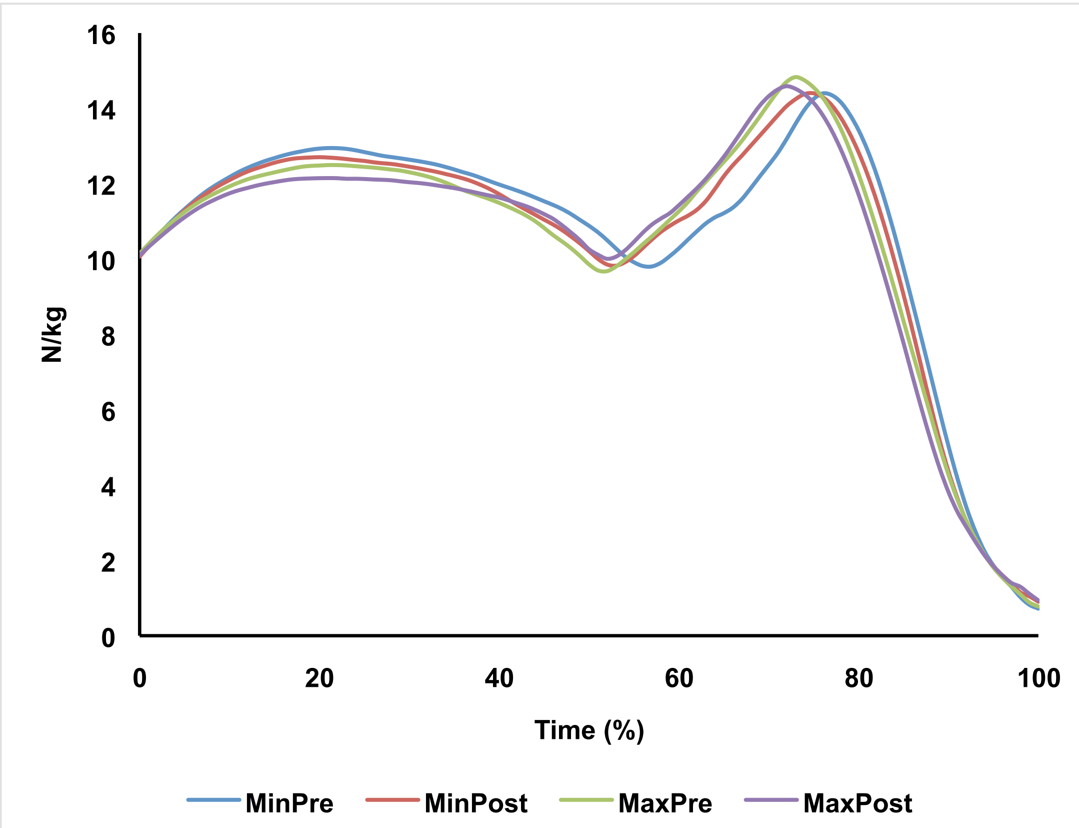

Figure 1: GRF Patterns

Muscle activity of the RF, BF, and GM was recorded to observe if an isometric contraction PAP protocol would influence muscle activation during a power clean, however, no significant differences or changes in activation were observed in the experiment. These results suggest that short duration, maximal effort isometric contractions do not fatigue the muscles to a degree that requires greater recruitment to perform power cleans. This is supported by a review article (Tillin & Bishop, 2009) that explains that the onset of PAP happens more rapidly than the onset of fatigue.

Figure 2 displays the muscle activation of each muscle, normalized to the 90% 1RM clean. In each trial, the RF activation appears to be slightly greater than both the BF and GM. The greater knee extensor activation, although not statistically significant, is in agreement with a previous study in our lab (Lee, DeRosia, Lamie, & Levine, 2017) who found that knee extensor torque was correlated with whole body power during the power clean exercise. Greater knee extensor activation increases knee extensor torque, which is essential for successful power cleans.

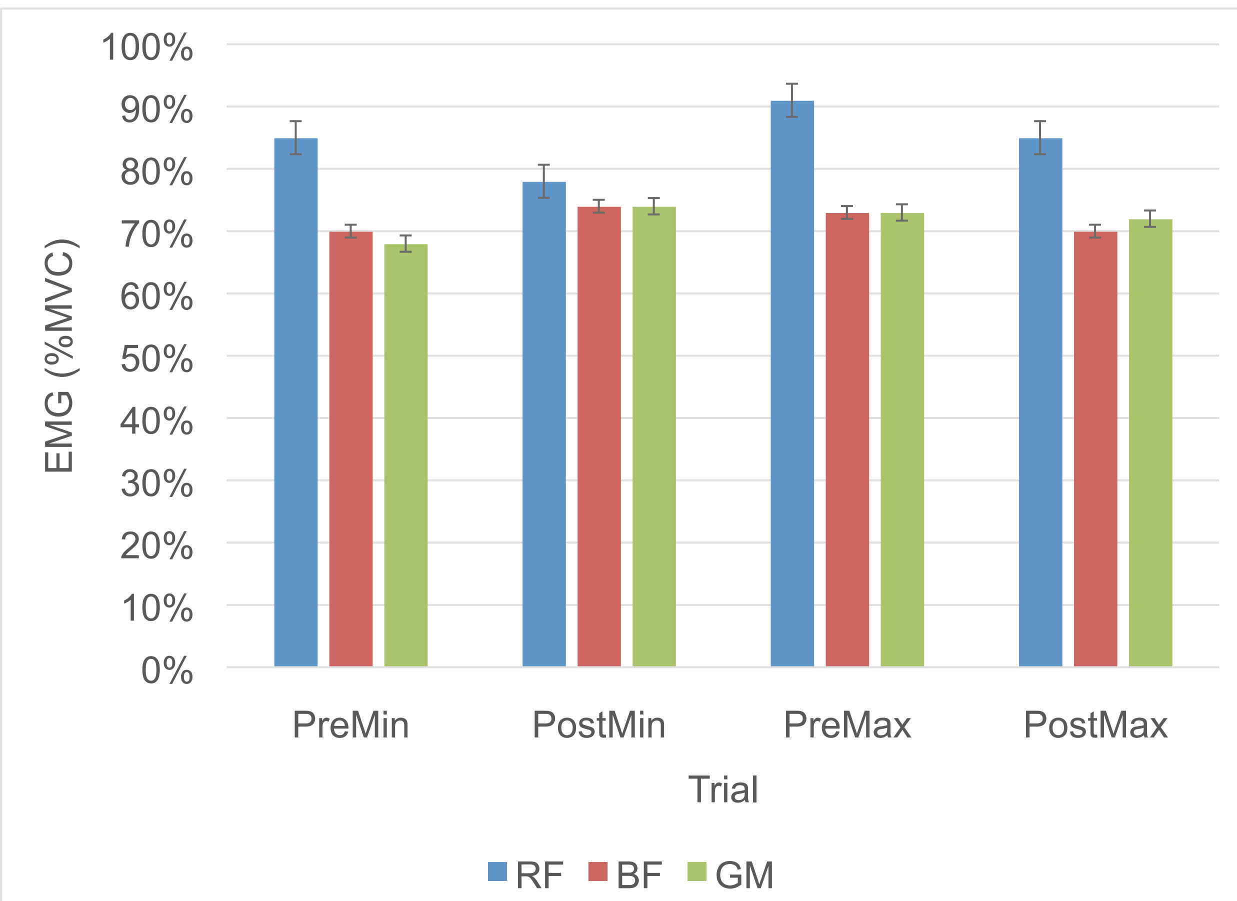

Figure 2: EMG Graph

In conclusion, low volume, maximal isometric deadlifts may not induce PAP during submaximal power cleans regardless of the hip joint angle they were performed at. This may be due to the submaximal effort required for successful completion of the exercise. Future research is needed to determine if maximal isometric deadlifts can induce PAP for maximal effort exercises such as sprinting or jumping.

PRACTICAL APPLICATIONS

Results from the current study suggest that implementing an isometric PAP protocol prior to submaximal power cleans may not be beneficial for performance. Strength and conditioning coaches do not need to include PAP protocols in warm-ups for lower intensity or submaximal lifts. However, the use of PAP protocols may be beneficial for maximal effort exercises such as sprinting or jumping. Coaches should take the time to individualize the protocol for optimal results.

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Appendix A: Informed Consent Document

Western Michigan University
Human Performance and Health Education

Principal Investigator: Dr. Sangwoo Lee

Student Investigator: Kyle DeRosia

Title of Study: Postactivation potentiation Effects from Maximal Isometric Contractions Performed at Different Knee Joint Angles

You have been invited to participate in a research project titled " Postactivation potentiation Effects from Maximal Isometric Contractions Performed at Different Knee Joint Angles." This project will serve as Kyle DeRosia's thesis for the requirements of the Master of Science in Exercise and Sports Medicine: Exercise Physiology Concentration. This consent document will explain the purpose of this research project and will go over all of 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?

The purpose of this study is to investigate how maximal isometric deadlifts performed at different knee joint angles influences power production and muscle activity during a power clean exercise.

Who can participate in this study?

In order to participate in this study, you must be between the ages of 18-30 and healthy with a body mass index (BMI) under 30. You must have no musculoskeletal injuries within the past 6 months by self-report. You must also be trained in power clean technique with at least 2 years of experience with the exercise.

Where will this study take place?

This study will take place on the first floor of the Student Recreation Center (SRC) in the biomechanics lab.

What is the time commitment for participating in this study?

The total estimated time commitment for this study is 2.5 hours. 30 minutes will be used to cover informed consent and measure BMI. There will be 2 data collection sessions that are estimated to take 1 hour each, for a total of 2 hours.

What will you be asked to do if you choose to participate in this study?

You will first be informed of how the study will be conducted. The purpose and possible risks and benefits will be explained during a meeting in which you, if you choose to participate, will sign the informed consent form and will be asked to have your BMI measurement taken. Next, you will be familiarized with the equipment. During the data collection sessions, you will be asked to change into specific clothing used for motion capture (dark, tight-fitting spandex). A separate room will be provided for changing. Next, you will complete an active warm-up to reduce risk of injury. After the warm-up, 59 reflective markers will be placed over the whole body on anatomical landmarks. 3 surface electrodes will be placed on the skin to collect myoelectric activity of the biceps femoris, rectus femoris, and gluteus maximus. Once you are set up with the proper equipment, then you will complete 1 power clean at 90% 1 repetition maximum followed by a long rest. Next, you will perform 3 power cleans at 70% 1 repetition maximum used for baseline data. After another rest, you will complete 5 sets of 5 second maximal isometric deadlifts at a predetermined knee joint angle. One minute after the isometric deadlifts, you will perform 3 repetitions of power clean at 70% of his/her 1 repetition maximum. The second experimental session will follow the same procedures, except the isometric deadlifts will be performed at a different knee joint angle.

What information is being measured during the study?

Measurements taken in this study include: height, weight, a total of 13 power cleans, ground reaction force, motion capture, and EMG.

What are the risks of participating in this study and how will these risks be minimized?

By participating in this study, you are at risk for musculoskeletal injury and muscle soreness. Risks will be minimized by completing a dynamic warm-up before beginning trials. Also, to limit the risk of injury due to fatigue, repetitions will be completed one at a time with ample rest in between. Experience with the power clean exercise will also reduce the risk of injury caused from improper form. All investigators will be present to provide care in the event of an accident. All of the investigators are CPR and first aid certified. If you wish to stop participation at any point during the study, you are free to do so.

As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken; however, no compensation or additional treatment will be made available to you except as otherwise stated in this consent form.

What are the benefits of participating in this study?

Benefits of this research may be seen primarily in strength and conditioning. This research could serve as a way to optimize the application of postactivation potentiation. You may not see any direct benefits from the exercises.

Are there any costs associated with participating in this study?

You are responsible to pay for parking at the Student Recreation Center if needed.

Is there any compensation for participating in this study?

There will be no compensation for participating in this study.

Who will have access to the information collected during this study?

Confidentiality of all subjects and data collected will be maintained throughout the research process. The data collected will be stored in the principal investigator's office for at least 3 years after the close of the study. You will be assigned a number to be used for data analysis. The de-identified data will be stored separately from the signed consent forms. Only the investigators will have access to the data.

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, Kyle DeRosia at 586-610-3881 or kyle.d.derosia@wmich.edu or Dr. Sangwoo Lee at 269-3872546 or sangwoo.lee@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

____________________________________ ______________________________

Participant's signature Date

Appendix B: Recruitment Flyer

WESTERN MICHIGAN UNIVERSITY

Human Performance and Health Education

Attention Weightlifters!

Research study looking for participants

- Be involved in research investigating how isometric deadlifts incorporated into your warm-up affects your power clean performance.

- To be eligible, you must be between the ages of 18-30 with a BMI under 30, be injury free, and have at least 2 years of experience performing power cleans.

- Participation involves 2 visits to the lab. Both visits include 3 power cleans, 4 isometric deadlifts, and another 3 power cleans

- Total time commitment will be between 2-2.5 hours.

For more information, contact Kyle DeRosia:
kyle.d.derosia@wmich.edu or 586-610-3881

Appendix C: Email Recruitment

Subject: Postactivation Potentiation Study

You are invited to participate in a research project titled "Postactivation Potentiation Effects from Maximal Isometric Contractions Performed at Different Knee Joint Angles". The purpose of this study is to investigate the differences in kinetic and kinematic variables after performing maximal isometric contractions at different knee joint angles. This study will consist of one 30-minute meeting and two, 1-hour sessions performing a total of 9 power cleans and 8 maximal isometric deadlifts. Informed consent and baseline measurement of Body Mass Index (BMI) will last approximately 30 minutes and the two experimental sessions will last approximately 1 hour each.

To participate in this study subjects must be:

- 18 - 30 years of age
- Experienced in the power clean for at least 2 years
- Below a BMI of 30

All the sessions of this study will be held in the Student Recreation Center on Western Michigan's Main Campus.

If you are interested in learning more about participating in this study, please email or call to set up a time to go over the procedure with you in more detail.

Thank you,
Kyle DeRosia
586-610-3881
kyle.d.derosia@wmich.edu

WESTERN MICHIGAN UNIVERSITY

Institutional Review Board
FWA00007042
IRB00000254

Appendix D: HSIRB Approval Letter

Date: November 5, 2018

To: Sangwoo Lee, Principal Investigator
Kyle DeRosia, Student Investigator for thesis

From: Amy Naugle, Ph.D., Chair

Re: IRB Project Number 18-10-26

This letter will serve as confirmation that your research project titled "Postactivation Potentiation Effects from Maximal Isometric Contractions Performed at Different Knee Joint Angles" has been **approved** under the **expedited** category of review by the Western Michigan University Institutional Review Board (IRB). 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 to 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 IRB 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: **November 4, 2019**

Office of the Vice President for Research
Research Compliance Office
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