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# Relationship between One Repetition Maximum Parallel Squat and Jump Squat Peak Power

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# RELATIONSHIP BETWEEN ONE REPETITION MAXIMUM PARALLEL SQUAT AND JUMP SQUAT PEAK POWER

by

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Thesis Committee:

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Corey Klitzke

RELATIONSHIP BETWEEN ONE REPETITION MAXIMUM PARALLEL SQUAT AND JUMP SQUAT PEAK POWER

Corey Klitzke, M.S.

Western Michigan University, 2019

Jump squats are a simple exercise that can be used to train lower body power. Unlike many other methods of power training, jump squats do not require any specialized equipment (platforms, bumper plates, etc.). Jump squats can be used when other forms of power training are not available or are not allowed. In order to most efficiently train power, the intensity must balance force and velocity. The purpose of this study was to find the intensity that yields the peak power output of a jump squat. 12 participants (9 males, 3 female) participated in the study. Each participant completed a parallel back squat one repetition maximum (1RM) test. The results of the test were used to assign the loads for the jump squats. On a separate day, each participant completed a series of jump squat trials starting at 0% of the back squat 1RM and working up to 50% in 10% increments. A one-way repeated measures ANOVA showed that power output was significantly higher at the 30% and 40% intensities than the 0%, 10%, and 20% intensities ($p<0.05$). Power output was significantly higher at the 50% intensity than the 0% and 10% intensities ($p<0.05$). It was concluded that power output is maximized with jump squats when an intensity of 30%-40% of parallel back squat 1RM is used.

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# INTRODUCTION

Power, the ability to move a given load quickly, is essential in most athletic contests (Bevan et al., 2010). In general, the more powerful an individual is, the faster they can run, the farther they can throw, and the higher they can jump. These movements are improved primarily through an improvement in muscular power rather than muscular strength (Mcbride, Triplett-Mcbride, Davie, & Newton, 1999).

Power can be trained in many ways. Olympic weight lifting (snatch and clean and jerk) is one of the most common ways used to train for power (Loturco et al., 2015). However, Olympic weight lifting is not necessarily the best way to train for power. In a study by Loturco et al. (2015), jump squats were found to have a stronger correlation to jumping and sprinting than Olympic push presses. In addition to this, there are facilities in which Olympic weight lifting is not available. In these situations, jump squats may be one of the few resistance-based power exercises that are available.

Jump squats do not require any specialized equipment to utilize. Jump squats can be performed in any facility with a squat rack. Olympic weight lifting typically requires more specialized equipment. Due to the nature of Olympic weight lifting ending in an overhead position, it is inevitable that the barbell will be dropped for safety reasons. With traditional barbell plates, the impact from the drop can damage the plates, the floor, or both. For this reason, specialized rubber bumper plates are used with Olympic weight lifting. Unless the facility has these plates available to those who wish to use them, Olympic weight lifting is not advised. Considering that Olympic weight lifting will not be available in some facilities, jump squats are an exercise that should be considered.

While jump squats are a viable option for training for power, there seems to be some disagreement on the best methods of using them. Many studies involving jump squats are performed with a Smith machine (Mcbride, Triplett-Mcbride, Davie, & Newton, 2002; Sleivert & Taingahue, 2004); Thomas et al., 2007); however, in a study by Sheppard and Taylor (2008), free weight jump squats were found to yield higher power outputs than jump squats using a Smith machine. In addition to this, Smith machines do not allow the same natural movements that free weights allow. Barbells can only move vertically on a Smith machine, thus it reduces the amount of stabilizing muscles that would be recruited using a free barbell. Considering these stabilizing muscles are necessary during most activities and competition, it is essential to ensure that they are utilized during training. The validity of Smith machines seems questionable as well. While Smith machines may be able to increase strength and have high internal validity, the external validity is not as good. Very rarely does a situation arise outside of a weight room in which a person needs to move a mass in a perfectly straight vertical or slightly angled line. Using free weights allows the weight to move with the individual, which is a more similar to what would happen during competition.

There is also conflicting information regarding the optimal load to use to achieve peak power outputs in the jump squat. In general, most recommendations are based on either a percentage of body mass or a percentage of a one repetition maximum (1RM) back squat (Li, Olson, & Winchester, 2008; Loturco et al., 2015; Loturco et al., 2016; Sheppard and Taylor, 2008). Due to strength and power differences between individuals, it appears using a percentage of body mass is less reliable. Two athletes that have the same mass may have different body compositions. In this situation, using body mass as a method of assigning training loads would be ineffective. An athlete that has a low percentage of body fat may find the load to be too light. An athlete that has a higher percentage of body fat may find the load to be too heavy. Different levels of training experience may also create inconsistencies between athletes. For these reasons, using a percentage of an already established baseline, such as a training percentage of a different exercise, reduces variability between individuals. The current research shows a wide range of loading recommendations based upon a percentage of 1RM back squat. The recommendations range from as low as no loading at all (0% 1RM back squat) up to approximately 90% 1RM back squat, although most results suggest that the correct load is somewhere between 0-20% 1RM (Dayne et al., 2011).

Whether the correct loading is a low percentage or a high percentage of 1RM back squat, it is generally recommended to train at the loading that will yield peak power output (Bevan et al., 2010). In terms of training outside of this parameter, research shows that it is either equally as beneficial or less effective to train at loads above a load that yields peak power output (Harris, Cronin, Hopkins, & Hansen, 2008; Mcbride et al., 2002). In a study by Mcbride et al., (2002), training with jump squats for 8 weeks at 30% of 1RM yielded significantly greater improvements to sprint times than training at 80% 1RM. Considering most of the research suggests that the proper loading to achieve peak power in a jump squat is <50% 1RM back squat, more improvements at a lower resistance supports these claims. It is also inefficient to train too far below the load that yields peak power output. If the load is too heavy, force output will be higher, but the velocity will decrease too much to increase power output. If the load is too light, velocity will be higher, but the force output will not be high enough to create as much power. For attaining peak power output, a proper balance must be achieved between force production and velocity.

While most of the research seems to support that peak power in a jump squat is achieved at a low percentage of back squat 1RM, the methodology for these studies could be improved. In some of the prominent studies on jump squat loading, large percentages of 1RM back squat were added to the barbell (12-20%) (Cormie, Mcbride, & Mccaulley, 2007; Dayne et al., 2011). The possibility exists that the correct loading for jump squats lies somewhere between the last load that power increases and the first load where power decreases. For this reason, it seems valuable to try to determine peak power loading for jump squats with smaller increases in loading. Using smaller increases in loading can help prevent underestimating or overestimating the correct load in which power output is the highest. Considering the proper load seems likely to be a low percentage of 1RM back squat, smaller increases are going to be necessary. Therefore, the purpose of this study was to determine the optimal load for a jump squat based on a percentage of a back squat 1RM.

## METHODS

### Participants

12 participants (9 males, 3 females) were recruited for the study (Table 1). The inclusion criteria required participants to be 18+ years old and had at least two years of high intensity resistance training experience. To ensure that the participants had adequate training experience, males were required to be able to back squat 125% of their body mass and females were required to be able to back squat 100% of their body mass. Participants were excluded if they reported any musculoskeletal injuries in the past 6 months. All participants read and signed an informed

consent form that was approved by the Human Subjects Institutional Review Board at Western Michigan University.

Table 1. Descriptive Statistics of the Participants

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Age (years) | 12 | 19 | 27 | 21.58 | 2.64 |
| Total Body Mass (kg) | 12 | 62.14 | 90.49 | 77.27 | 9.58 |
| Lean Body Mass Percentage | 12 | 78.36 | 95.34 | 83.53 | 4.72 |
| Fat Body Mass Percentage | 12 | 4.65 | 21.63 | 16.45 | 4.71 |

**Experimental Protocol**

Each participant reported for 2 days of testing that were separated by a minimum of 48 hours. There was no deadline for the completion of data collection, though participants were encouraged to finish the study at their earliest convenience. After consenting to the study, each day of testing began with a body composition analysis via a BIA scale (InBody, California, USA). The participants were informed before arriving what the requirements were for the body composition assessment to produce the most accurate results possible. Body composition was analyzed on each day for consistency. If the body composition was similar on both of the days, the analysis on the second day was used for data collection. If the fat body mass percentage for a participant differed by ≥5%, they were excluded from data analysis.

On the first testing day, the participants completed a parallel back squat 1RM test. Parallel back squats were defined as a squat where the top of the thigh becomes parallel with the floor. The participants were given a verbal cue to rise when their squat reached the correct depth, and were given the opportunity to perform their own warm-up prior to starting the 1RM test. When the participants were ready, the test began with a three set build-up. The build-up consisted of 5 reps at 50% of their self-reported back squat 1RM, 3 reps at 70% of their self-reported back squat 1RM, and 1 rep at 90% of their self-reported back squat 1RM. After the build-up, a series of 1RM attempts were completed with the intensity increasing with each successful attempt. The load for the test increased by 3% of the self-reported back squat 1RM for each successful attempt. The participants were allowed to change how much the load increased by if they felt that they either over- or underestimated their back squat 1RM. The test continued until failure or voluntary termination of the test. 2-4 minutes of rest were given between each of the build-up sets and the 1RM attempts. If the participants were able to meet the back squat requirements (125% body mass for males; 100% body mass for females), they were scheduled for a second testing day. If they were not able to meet the back squat requirements, they were dismissed from the study and their data was discarded.

On the second testing day, the participants performed a peak power jump squat assessment. Jump squats were defined as squatting to parallel and then jump straight up as high as possible. The participants were told that the movement was not intended to be a countermovement jump, nor was there intended to be a pause in the movement. They were given a verbal cue to jump when their squat reached the correct depth. The assessment began with a 5 minute warm-up on a cycle ergometer. They were told the intensity should be light-to-moderate but were given no further instruction on how to gauge intensity. The peak power jump squat assessment consisted of progressively increasing intensities based on the results of the parallel back squat 1RM test. The intensity started at a negligible weight (0.6 kg pipe in the back rack position) that was labeled as 0% of the back squat 1RM test. The pipe was used in place of no loading at all to keep the biomechanics of the jump as similar between the different intensities as possible. The intensity increased by 10% for each increase to a max of 50% of the participant's back squat 1RM. Each intensity consisted of 2 trials, resulting in a total of 12 jumps. Each jump was separated by 2-4 minutes of rest, and was completed on a force plate (Advanced Mechanical Technology Inc., MA, USA). The force plate was used to measure total time in the air for each jump, which was then used to calculate power. Additionally, filming was set to 200 frames per second using the Kwon3D Motion Analysis Suite (Visol Inc., Seoul, Korea) to accurately measure time in the air. The total time in the air was divided in half to only include the time moving away from the floor. The time was then multiplied by the acceleration of gravity ($9.81 m/s^2$) to obtain the velocity. The velocity was then multiplied by the force of the system (total amount of mass (body mass+barbell mass) and the acceleration of gravity) to obtain the power. The complete equation is as follows:

$$v = 0.5t * 9.81m/s^2$$
$$P = F * v$$
$$P = ((body\ mass + barbell\ mass) * 9.81m/s^2) * v$$

**Statistical Analysis**

A one-way repeated measures ANOVA was used to determine whole-body power between the different intensities ($p \leq 0.05$). LSD pairwise comparisons were used to test significance of difference between each of the intensities. Statistical significance for all analyses was defined as $p \leq 0.05$. Data analysis was performed using SPSS v26 (IBM, New York, USA).

## RESULTS

The average power output for each intensity is listed in Table 2 and Figure 1. The 30% jump squat resulted in significantly higher power than the 0%, 10%, and 20% jump squats ($p < .05$). The 40% jump squat resulted in significantly higher power than the 0%, 10%, and 20%

jump squats ($p<0.05$). The 50% jump squat resulted in significantly higher power than the 0% and 10% jump squats ($p<0.05$).

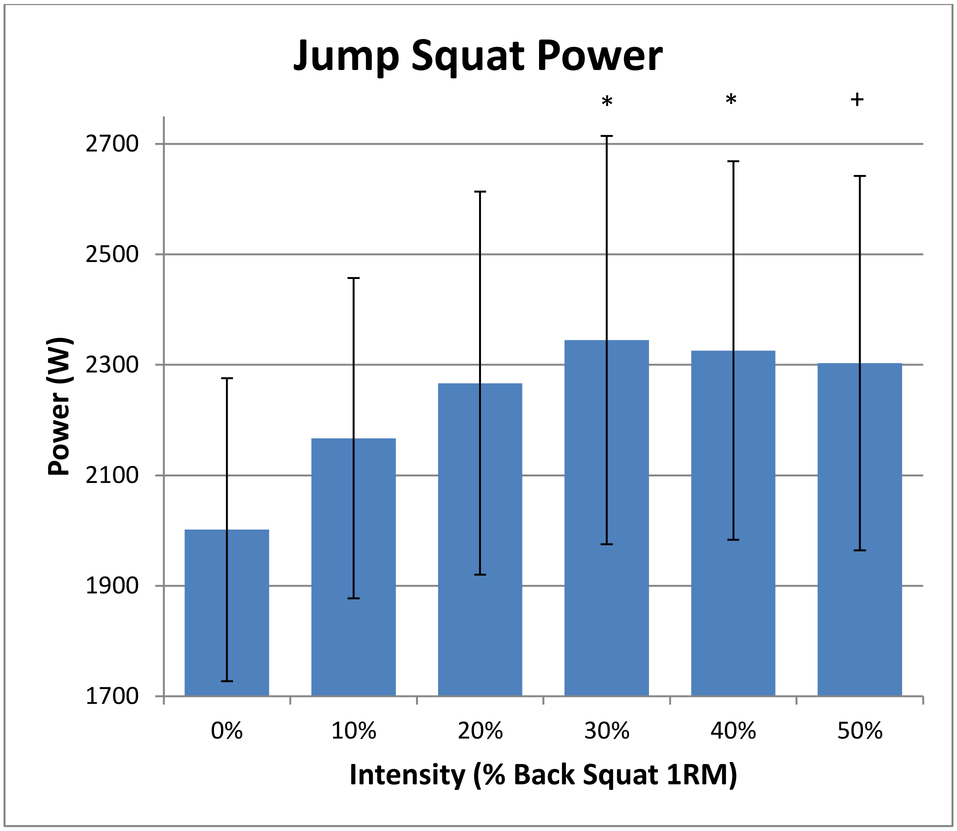

Figure 1. Power output at each of the jump squat intensities.
*: significantly greater than 0%, 10%, and 20%.
+: significantly greater than 0% and 10%.

## DISCUSSION

The results of this study show that the optimal load for training with jump squats is between 30%-40% of the back squat 1RM. While there was a not a significant difference between the three highest percentages, 50% was the only intensity of the three that was not significantly different than the 20% intensity.

One study that had similar findings was a study by Thomas et al., (2007, where sex-related differences for various power exercises were examined. The results showed that peak power output in the jump squat was found at 30%-40% of back squat 1RM for males and 40% for females. The present study did not examine the differences in sex due to a small amount of female participants. Considering both groups showed that 40% of back squat 1RM yielded one of the highest power outputs, it seems that there were not great differences between the groups. The present study also showed 30%- 40% of back squat 1RM to yield maximum power.

The results of this study were different than most other studies investigating jump squat peak power output. Some studies found that peak power output occurred with no loading at all (Cormie et al., 2007; Dayne et al., 2011). In these studies, linear position transducers were used to collect velocity data. This allows velocity data to be collected throughout the entire exercise. Considering the majority of the methodology was similar to that in the present study, it seems that potentially the difference comes from the method of data collection. Cormie et al., (2007) stated that peak power is often attained before the athletes actually leave the floor. The present study collected power data based on flight time, and thus did not measure power at various points in the exercise. This difference may be why peak power output was found at different percentages from the present study.

In other studies, peak power output was found to be higher than what was found in the present study. Sleivert and Taingahue (2004) found that peak power in a traditional squat jump was at 50%-70% of back squat 1RM. The protocol for the jump squats was considerably different from the present study. In their study, the jump squats were with a harness strapped to the participants to reduce barbell movement during the jumps. The starting position for the squats and squat jumps was also different from the present study. In both the back squat 1RM testing and the jump squat trials, the participants started from a stopped position with their knees at 90 degrees. This means that the eccentric portion of the exercise was eliminated. The study also used accelerometers in order to measure power at various portions of the exercise. In the present study, the participants performed a full parallel squat, including both the eccentric and concentric portions of the exercise. It is possible that this difference in methodology is why different percentages for peak power output were discovered.

One limitation of the present study is the potential inconsistency between participants. While each participant completed the same build-up prior to 1RM attempts, an individual warm-up was allowed prior to the build-up. Some people opted to do nothing and proceed with the build-up, while other people performed some mobility work and a general warm-up. While this may have created some differences between participants, it is unlikely that it would have significantly affected their performance during the 1RM test. Each participant was made to feel as comfortable and prepared as possible before beginning the 1RM protocol. Another factor of variability was the squat depth for the 1RM testing and the jump squat trials. Each participant squatted to a depth where the top of their thigh was parallel to the floor. Because of the varying speeds of descent between the participants, it is likely that some people were given the cue to rise slightly early or slightly late. It is also possible that some participants may have started rising before a cue was given or started rising a few moments after the cue. An effort was made to make the criteria the same for every participant, but with any protocol that involves a visual gauge and verbal cues, some human error may exist.

## CONCLUSION

In closing, jump squats are an exercise that can be used to train power using equipment available at most facilities. No specialized plates are needed, and thus there is little danger in dropping the barbell or requiring additional space that may not be available. When using jump squats to train power, an intensity of 30%-40% of parallel back squat 1RM should be used, assuming the same depth is used with the jump squats. This provides an easy and quick way to add power training into a program that is already focused on using percentages for training squats.

Appendix A

HSIRB Approval Letter

WESTERN MICHIGAN UNIVERSITY

Institutional Review Board
FWA00007042
IRB00000254

Date: October 29, 2018

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

From: Amy Naugle, Ph.D., Chair Amy Naugle

Re: IRB Project Number 18-10-21

This letter will serve as confirmation that your research project titled "Relationship between 1 Repetition Maximum Parallel Squat and Jump Squat Peak Power" 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:** **October 28, 2019**

Office of the Vice President for Research
Research Compliance Office
1903 W. Michigan Ave., Kalamazoo, MI 49008-5456
PHONE: (269) 387-8293 FAX: (269) 387-8276
WEBSITE: wmich.edu/research/compliance/hsirb

CAMPUS SITE: Room 251 W. Walwood Hall

Appendix B

Informed Consent Form

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

OCT 29 2018

x [signature]
HSIRB Office

**Western Michigan University**
**HPHE**

| | |
|---|---|
| **Principal Investigator:** | Dr. Sangwoo Lee |
| **Co-Investigators:** | Nicholas Hanson & Timothy Michael |
| **Student Investigator:** | Corey Klitzke |
| **Title of Study:** | Relationship between 1 Repetition Maximum Parallel Squat and Jump Squat Peak Power |

You have been invited to participate in a research project titled *"Relationship between 1 Repetition Maximum Parallel Squat and Jump Squat Peak Power"*. 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 try to determine the load on a jump squat that yields the highest power output. If this load can be determined based on a percentage of back squat 1RM, it would provide an alternative method of training power that does not require Olympic weight lifting equipment.

**Who can participate in this study?**
You must be at least 18 years old. You must have at least 2 years of experience with high intensity resistance training. You must be able to back squat at least 125% of your body mass if you are a man or back squat 100% of your body mass if you are a woman. You must be able to perform maximal effort back squats and jump squats. You will be excluded if you have had any musculoskeletal injuries in the last 6 months.

**Where will this study take place?**
This study will be conducted at the Western Michigan University Student Recreation Center building (SRC) in the Human Performance Research Lab.

**What is the time commitment for participating in this study?**
The total estimated time requirement for this study is approximately 2 hours (two visits to the lab; ~one hour for each visit).

**What will you be asked to do if you choose to participate in this study?**
There are two visits required for this study. In the first session you will have your body parameters (height and body composition) measured and perform a parallel back squat 1RM (one repetition maximum) test. You will perform a series of warm up sets before the 1RM assessment begins.

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

OCT 29 2018

x

HSIRB Office

The assessment will proceed as follows:

**1RM half back squat assessment**

- Squat to parallel and rise after a verbal cue
- Loads selected based on a self-selected estimated 1RM
- Warm up consisting of 5 reps at 50%, 3 reps at 70%, 1 rep at 90%
- Increase load by 3% 1RM each successful attempt until failure
- 2-4 minutes of rest between warm up sets and 1RM attempts

If you were not able to meet the inclusion back squat requirements, you will not be scheduled for the second day of testing and your data will not be included in the study. In the second session, your body parameters will once again be measured for consistency and you will complete a peak power jump squat assessment. A 5-minute warm up on a cycle ergometer at a self-selected intensity will precede the assessment. The assessment will proceed as follows:

Peak power jump squat assessment

- Squat to parallel and jump as high as possible after a verbal cue
- Load the bar progressively with 0%, 10%, 20%, 30%, 40%, and 50% 1RM back squat
- 2 attempts per load (record attempt with highest power)
- 2-4 minutes of rest between jumps

**What information is being measured during the study?**

We will be measuring height, body composition, parallel back squat 1RM, and indirectly measuring peak power output during the jump squat trials, which will be directly measured with ground reaction force and barbell velocity.

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

You may be at risk for musculoskeletal injury as well as some muscle soreness. These risks will be diminished by performing a warm up before performing the actual trials. Ample rest periods are provided to help diminish the risk of an injury due to fatigue. Spotters will be used for every parallel back squat warm up repetition and the 1RM trials. Before the start of this study you will be reminded that you have the right to stop participation at any point during the study.

As in all research, there may be unforeseen risks to you as 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 as otherwise stated in this consent form.

**What are the benefits of participating in this study?**

The potential benefits of this study will primarily be related to strength and conditioning. This study could help to assign loads for jump squat to individuals who have a goal to improve their power output. This study may help to give an equation that can be used with other measurable variables to estimate the correct load. You could potentially directly benefit from this study if you use or plan to use jump squats in your personal training programs.

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

**Is there any compensation for participating in this study?**
Unfortunately, no compensation will be provided for participating in this study.

**Who will have access to the information collected during this study?**
Confidentiality will be maintained at all times throughout the research process. This will be explained to you during the orientation session. All data will be kept confidential. The data will be stored in the principal investigators office in the department of HPHE for at least three years after the study. Only the research team will have access to the information for the research.

**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. In this situation, it was determined that participation should be terminated for safety concerns.

Should you have any questions prior to or during the study, you can contact the student investigator, Corey Klitzke at corey.e.klitzke@wmich.edu or 920-527-0075 or the principal investigator, Dr. Sangwoo Lee at sangwoo.lee@wmich.edu or 269-387-2546. 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

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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

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