Effects of Pre-Determined Barbell Hip Thrusting Surface Height on Motor Unit Recruitment and Activation Patterns

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Abstract

Several variations of the barbell hip thrust that manipulate stance width and resistance type rather than surface height to better isolate muscle groups that act as prime movers for the exercise have been previously researched. The purpose of this study was to identify the effects of hip thrusting surface heights on neuromuscular activity in the gluteus maximus (GM), vastus lateralis (VL), and biceps femoris (BF). Twelve averagely fit, resistance trained individuals were recruited for this study. Participants completed a dynamic warm-up followed by 10 repetition max (RM) testing of the barbell hip thrust. Prior to trials, root mean square (RMS) values collected by surface electromyography(sEMG) during maximal voluntary isometric contractions of the (GM), (VL), and (BF) to enable data normalization. Three 10RM sets of the barbell hip thrust were performed on surface heights of 16.00 inches, 17.25 inches, and 18.50 inches. RMS values from each set were averaged across all 10 repetitions and statistical analysis was performed using a Friedman test with Wilcoxon post-hoc for significant differences. Kendall’s W was used to determine effect size. Results demonstrated no significant change in GM activity among all surface heights ($\chi^2(2)=1.167$, $W=0.049$, $p=0.558$). A significant increase in activity of the VL was found with the Friedman test ($\chi^2(2)=8.000,W=0.333$, $p=0.018$). With post-hoc analysis, the significant change only occurred from 16 inches to 18 inches ($Z=-2.040$, $p=0.041$). A significant decrease activity in the BF was also found with the Friedman test ($\chi^2(2)=10.5000$, $W=0.438$; $p=0.005$), but the significant decrease was only found from 16 inches to 17 inches ($Z=-2.353$, $p=0.019$). Overall, no significant differences were found among bench heights for GM activation. However, as VL activation was found to increase as surface height increased, a higher bench height may be used to more efficiently recruit the VL during hip thrust. Conversely, as surface height decreased, the involvement of the BF increased. Study outcomes suggest that lower bench heights may be more efficient at recruiting the BF during the barbell hip thrust.
Keywords: variation, neuromuscular activity, surface electromyography
Introduction

The hip thrust exercise is a multipurpose hip extension exercise that has been correlated to increases in gluteal muscle strength for end range hip extension, improvements in horizontal force production through post-activation potentiation during running and sprinting, and hamstring coactivation for injury prevention (3,12,14,15,18). The relatively low load requirements for maximally engaging the gluteus medius and gluteus maximus activity with the hip thrust and the numerous options for isolating a specific muscle with hip thrust variations suggests that the barbell hip thrust exercise is an ideal exercise for a busy weight room or a rehabilitative setting. Investigations using surface electromyography (sEMG) have found that the muscular activation induced by the hip thrust is highest in the gluteus maximus (GM), then successively followed by the gluteus medius, biceps femoris (BF), semitendinosus, vastus lateralis (VL), vastus medialis, and rectus femoris (3,8). By manipulating body position within the exercise, it is possible to create a higher level of activation within the accessory hip musculature to the GM during the barbell hip thrust to change their coactivating patterns. Collazo et al. found that widening the foot placement in the hip thrust produces a higher level of activity in the hamstrings in conjunction with maximal gluteal activity while decreasing the level of activity in the quadriceps (8). This study was conducted at 40% of the participant’s 1 repetition maximum supporting the practice of using low loads to induce high levels of gluteal and surrounding muscle activity (8). Contreras et al. found that using anterior pelvic tilt during the barbell hip thrust elicited greater levels of activity in the vastus lateralis compared to a neutral pelvic alignment with either the original barbell hip thrust or the banded hip thrust (5).

As the exercise becomes more muscle specific, coaches and clinicians can prescribe the best variation of the hip thrust to achieve the desired result. With respect to injury prevention and
management, gluteal loading is a common strategy in treating knee and hip pain pathologies (20). Current studies that analyzed activation patterns during the barbell hip thrust have identified greater activation of the hip extensor muscles compared to conventional exercises that involve simultaneous extension in the surrounding musculature such as the barbell squat (16, 17). Training this simultaneous extension can improve poor lumbopelvic mechanics which is, in addition to a history of injury to the posterior hip musculature, a predictor of injury or reinjury of the site (13). The training variations described above can be implemented into a training program to increase neuromuscular muscular activity in the target site to improve strength and coordination (Appendix A).

While research has been performed on the effects of foot placement and resistance type variations, no current studies have investigated the effects of hip thrusting surface heights. The purpose of this study is to identify the neuromuscular excitement during the hip thrust at 16 inches, 17.25 inches, and 18.50 inches from the ground through sEMG activity in the GM, VL, and BF. Prior to study completion it was hypothesized that an increase in VL activity and a decrease in GM and BF activity will occur as bench height increases during the hip thrust.,

**Methods**

**Subjects**

This study took place in the Biomechanics & Motion Analysis Laboratory on the residential campus of Liberty University. Participants (n=12; 7 males, 5 females) were 24.0 ± 3.9 years old, 171.9 ± 7.0 cm tall, 71.9 ± 10.1kg, and had 16.8 ± 6.4% body fat. To ensure adequate experience with strength training techniques and safety measures, all participants were Exercise Science students at a sophomore level and had completed a weight training course. Inclusion
criteria also included meeting American College of Sports Medicine’s (ACSM) guidelines for physical activity level (31), as well as cleared for physical activity based on Physical Activity Readiness Questionnaire (PAR-Q) 2020 screening form (Appendix A). Exclusion criteria consisted of musculoskeletal injury within 6 months prior to the study. All participants completed an informed consent (appendix B) prior to the study.

Procedures

Participants’ body composition and weight were measured with the InBody 770 (Cerritos, CA). Height was measured with a Seca adjustable height scale (Chino, CA). After measuring anthropometrics, participants completed a dynamic warm up that was in agreement with the National Strength and Conditioning Association’s (NSCA) RAMP protocol (25), ACSM general warm-up guidelines (31), and based on prior studies (4,5,8). Five to ten minutes of cardiorespiratory and muscular endurance activities were performed consisting of 5 minutes of low intensity treadmill walking at a self-selected pace, glute bridges, bird-dogs, and light-weighted kneeling squats. Participants completed 2 sets of 6 reps of each exercise with 1-minute rests between sets. Following the warm-up, participants were instructed in a 10-repetition maximum (10RM) test in the hip thrust exercise according to the NSCA. This test required individuals to perform 3 progressively heavier sets with 3 minutes of rest between sets until reaching a moderately heavy load. Using that load, they completed as many repetitions as they could safely perform. The participant's load for a 10RM in the hip thrust was calculated using an estimate table from the NSCA for use during the testing session (32).

Proper lifting technique was taught to participants prior to data collection. Instructions included placing the shoulder blades across a bench or box slightly below the position of a low-bar squat bar, sliding the bar over the legs to inguinal crease height, using a thick pad across the
bar to improve the comfort of the lift, placing the feet shoulder-width apart toward the buttocks such that the knees are at a 90-degree angle at the end range of motion, placing the hands evenly on the bar to reduce unwanted movement, followed by leaning back into the bench to extend the hips (3). The concentric portion was held for a 1-count at end range and then released back to the starting position with the bar lightly touching the ground for 1-count (3).

Each participant rested 10 minutes after 10RM testing. During this rest period, sEMG sensors (Trigno Avanti Wireless EMG by Delsys, Natick, MA) were placed over the subject’s GM, VL, and BF using SENIAM recommendations for electrode locations (30). After the rest period, maximal voluntary isometric contractions (MVICs) were recorded during 3-second isometrics in a standing GM contraction, body weight hip thrust, prone hamstring curl, and seated leg extension. After MVIC data capture, participants received a 10-minute rest period prior to hip thrust trials. During the trials, participants performed 1 set of 10 repetitions of the hip thrust using the calculated 10RM at three different counterbalanced hip thrusting surface heights for a total of 3 sets (5). Five minutes of rest was provided between each set. EMG activity was assessed by taking the average RMS of all 10 repetitions in each set.

Statistical Analysis

MVC RMS values were normalized in EMGworks Analysis software (Delsys, Boston, MA). Data was found to be non-parametric after analysis with Shapiro-Wilks and Kolmogorov-Smirnov tests of normality. A Friedman Test was utilized to determine the relationship between different hip thrusting surface heights and electrical activity of the GM, VL, and BF muscles. Wilcoxon post-hoc analyses were performed on the VL and BF at bench height sets that met significance. Kendall’s W was used to determine effect size of the statistically significant sets. Significance was set at p < .05.
Results

No significant differences were found within subjects during sEMG of the GM at all three bench heights ($x^2(2)=1.167$, $W=0.049$, $p=0.558$). Initial comparisons of VL activity showed significant differences among bench heights ($x^2(2)=8.000$, $W=0.333$, $p=0.018$). Post-hoc analysis revealed VL activity increased within subjects as bench height increased between 16 inches and 18.50 inches ($Z=-2.040$, $p=0.041$), but no significant change between 16 inches and 17.25 inches ($Z=-1.961$, $p=0.05$) or between 17.25 inches and 18.50 inches ($Z=-0.628$, $p=0.530$) difference in comparisons of BF activity also showed a significant difference among bench heights ($x^2(2)=10.500$, $W=0.438$, $p=0.005$). Post-hoc analysis identified a decrease in BF activity occurred when bench height increased from 16 inches to 17.25 inches ($Z=-2.353$, $p=0.019$). No significant differences were found between 17.25 inches and 18.50 inches ($Z=-1.098$, $p=0.019$) or between 16 inches and 18.50 inches ($Z=-1.490$, $p=0.136$). Similar to the VL, no differences were observed in the BF between other bench heights.

Discussion

Based on data analysis, the hypothesis that muscle activity would decrease in the GM as bench height increased was rejected and the alternative hypothesis was accepted. Muscle activity did not decrease as bench height was raised. This implies that the range of bench heights tested does not impact the recruitment of the GM during hip thrust variation when the distance of the feet from the hips, stance, and barbell resistance is maintained. This is consistent with the nature of the hip thrust as described by previous research (1, 2,3,4,5,9). Full hip extension provided by the GM is required at the end range of motion. As the musculature of the lower body contracts, it also maintains greater tension of the hip extensor muscles when horizontal force is applied.
throughout the range of motion (3). Continual tension of the gluteal region may explain the constant GM values.

The hypothesis that the VL would increase as bench height increased was accepted only between the comparison of 16 to 18.5 inch heights. No differences were observed when hip thrust surface height increased from 16 to 17.25 inches or from 17.25 to 18.50 inches. Mean VL, GM, and BF activity during the 17- and 18- inch conditions increased, however they were not significantly different. Further research is recommended to investigate the effects of moderate vs. greater increases in bench height. Increases in muscle activity of the VL may be the result of the changed torso angle which changed the force vectors through the feet when the torso was angled more perpendicular to the ground. Greater heights may require the resistance to be stabilized further anteriorly placing more force through the anterior chain, however additional research is recommended to investigate this theory.

The hypothesis that the BF would decrease in muscle activation as bench height increased was partially accepted, as mean EMG activity did reduce between a surface height of 16 inches. This affect was not observed between the 17.25- and 18.50-inch heights. In contrast to the possible anterior chain involvement during an increased bench height, the less perpendicular position of the torso may have produced greater horizontal force, which could have resulted in the greater involvement of the biceps femoris at a lower bench height (2,10).

The limitations of this study involve a small sample size and a varied population. After analysis, the study did not meet statistical power and due to statistical skewness and kurtosis of the data, the use of non-parametric statistics was required. This is consistent with other biomechanical studies performed on the hip thrust that have had small sample sizes (4,5,8,9). Sex differences may have contributed to outliers in EMG readings due to the differences in body
composition. Higher body fat deposition in the area of an electrode can change the strength of an EMG signal due to spatial filtering within the device (33). Muscle fatigability and contractility vary between males and females due the concentrations of Type IIA fiber types, thyroid hormone, estrogen, and testosterone (26, 27).

This study’s research design was modeled after a study by Contreras et al. (2016) that examined the differences in the barbell hip thrust, American hip thrust, and banded hip thrust since no other study had previously evaluated varying bench height as a hip thrusting surface (5). Statistical analysis in this study also mirrored others that utilized non-parametric statistics. The body positioning for MVICs was modified from the example study to produce the strongest possible contractions that the literature suggests (28, 29). However, it is possible that the body positioning for the seated leg curl and seated leg extension produced slightly different baselines than contractions in a body weight hip thrust as performed for the glutes. Future studies may include a body position as close as possible to the hip thrust position for stronger sEMG to reflect the baseline contraction.

**Practical Applications**

In conclusion, the results of this study could provide a basis for coaches and therapists to fine tune training programs according to targeted muscle groups. The emphasis of the gluteals may not significantly change bench height during the hip thrust, but the involvement of the quadriceps and hamstrings muscle groups may. Individuals may have a difficult time maintaining form under load during vertical movements such as the squat and deadlift, but the hip thrust has demonstrated considerable cross-over to vertical movements (4, 19, 23). Based on the outcomes of this study, a higher bench height with a barbell hip thrust may serve as a more targeted substitute for the squat and a lower bench height under load based on neuromuscular
recruitment patterns. Further research on bench height variation may involve a larger, more homogenous population and different MVIC testing positions for stronger statistical power.
Appendix A

Review of Literature

The barbell hip thrust is effect at engaging the primary agonist for hip extension, the gluteal muscle group. The nature of this exercise implies benefit for sprinting and jumping sport performance because of this muscle group’s heavy involvement in deceleration from explosive movements (12). The differences in muscle activation sequencing between the barbell hip thrust and the more tradition weight room exercises like the barbell back squat and the conventional deadlift demonstrate the potential for greater neuromuscular adaptions in the gluteal muscles. Furthermore, variations of the barbell hip thrust show promising neuromuscular activation strategies for isolating different muscles of the hamstring muscle complex (16). However, the current literature does not address muscular activation patterns based on hip thrusting surface height. This may impact an individual’s ability to fully adapt to the exercise.

Muscle Activation

The most widely used way to quantify the amount of nervous electrical activity is through surface electromyography. Through it, we can measure muscle recruitment timing and relative muscle excitement, both of which help identify muscle recruitment patterns and lend themselves to the term ‘muscle activation’ (21). The barbell hip thrust has been shown to increase gluteal muscle activation due to the presence of active insufficiency such that the hamstring muscle complex (biceps femoris, semitendinosus, and semimembranosus) is already at a reduced level of activation with knee flexion. This maximizes the role of the gluteal muscles in the end range of hip extension during the exercise (3). In comparison with the barbell back squat, Contraras et al. found that the barbell hip thrust elicited greater peak and mean muscle activation in the upper
gluteals, lower gluteals, and biceps femoris. Interestingly, there was no significant difference between the exercises when evaluating peak and mean activation of the vastus lateralis. These findings were under the conditions of a submaximal load, similar to the conditions of a sports or rehabilitation workout program (4). Findings that compare activation at submaximal and maximal loads in hip extension exercises support that there are significant differences between glute activation during the hip thrust and the back squat in submaximal loads. However, maximal voluntary contractions with a 1 repetition maximum load show higher activation in the back squat than the hip thrust. This research has also found comparable gluteals and biceps femoris activation between the Romanian deadlift and hip thrust exercises at both maximal and submaximal loads (9). Unilateral research that involved comparison of the back squat, hip thrust, and split squat support these findings and reveal a greater gluteal stimulus using the barbell hip thrust versus the split squat (23). Among the barbell hip thrust variations, the barbell hip thrust has been found to elicit higher EMG amplitudes in the upper and lower glutes at less than 60% of a 1 repetition max (RM) (10RM load) than the banded hip thrust or the American hip. These differences in amplitude results could be attributed to the fact that the bands do not require the same amount of resistance throughout the entire range of motion and the American hip thrust has a shorter lever arm to the barbell (5). Collazo et al. found that wide stance variations of foot placement during the barbell hip thrust at 40% of a 1RM load also highly recruited the gluteus maximus. Additionally, a wider stance recruits greater levels of activity in the hamstring muscles, improving posterior chain development. Overall, lighter loads (36-40% of 1RM) in the hip thrust seem to elicit greater gluteal activation that maximal loads (full 1RM) than other hip extension exercises (2017).

**Exercise Translation and Sport Performance**
In study comparing the effects of fronts squats and barbell hip thrusts on sprint performance, barbell hip thrust training has been shown to have significant transferability to strength in the front squat exercise and to horizontal force production while sprinting. However, no clear significance could be stated on the effects of front squat training. The previously described gluteal activation patterns and the anteroposterior force production during the hip thrust seem to be the attributable factors for these results (6). Other factors such as post activation potentiation (PAP) prior to sprinting and change of direction drills using the barbell hip thrust have shown promise using both heavy and moderate loads depending on the recovery protocol between lifting and sprinting (10,11,14,18). Hip thrusting may also influence the maximum acceleration phase of sprinting if the exercise is included in an athlete’s training program (15). Only one study found in this review of literature stated that hip thrust training has no impact on sport performance (2).

**Injury Prevention and Management**

Hamstring injuries tend to be prevalent among athletes who perform successive explosive hip extension movements during competition. One significant predictor of injury risk for the hamstrings is a previous injury to the region, implying that the rehabilitation program is crucial for reduce the prevalence of reinjury to the area. Another significant indicator of injury risk is poor lumbo-pelvic coordination which leads to insufficient hip extension range of motion and altered hamstring mechanics (13). However, hip extension focused programming has been shown to improve motor recruitment patterns during jump landing mechanics that reduces valgus with knee flexion and increases hip joint muscle involvement in their range of motion (20).
Appendix B

Consent

Title of the Project: Comparison of Neuromuscular Activity Among Three Predetermined Bench Heights During the Hip Thrust Exercise
Principal Investigator: Abigail McCarty, EP-C, CSCS, FMS-1, Liberty University
David Titcomb, PT, DPT, EP-C, CES, Liberty University

<table>
<thead>
<tr>
<th>Invitation to be Part of a Research Study</th>
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<tr>
<td>You are invited to participate in a research study. In order to participate, you must be 18 years of age or older and a student of Exercise Science or Human Performance in the Allied Health Department with at least sophomore standing. You must have a history of being physically active for a minimum of 30 minutes, 3 days a week for at least 3 months. You must also be free of any lower body musculoskeletal injuries for the last 6 months. Taking part in this research project is voluntary.</td>
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Please take time to read this entire form and ask questions before deciding whether to take part in this research project.

<table>
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<tr>
<th>What is the study about and why is it being done?</th>
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<td>The purpose of the study is to determine appropriate height for a weight room bench while performing the hip thrusting exercise based on the limb length and optimal muscular engagement of an individual. This research is intended to improve results in muscular strength and coordination from performing the hip thrust exercise in both a weight room and a rehabilitation setting.</td>
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<th>What will happen if you take part in this study?</th>
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<tr>
<td>If you agree to be in this study, I would ask you to do the following things:</td>
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1. You will be asked to come to the Human Movement Analysis Lab and complete a physical activity questionnaire (PAR-Q) form. The research team will then assess your body composition including height, weight, body fat percentage, lean muscle mass, lower limb length, and torso length.

2. The research team will instruct you in a 10-minute dynamic warm-up consisting of body weight movements that promote mobility and muscular recruitment for the purpose of the hip thrust.

3. Following the warm-up, you will be instructed in a test of your 10-repetition maximum (10RM) in the hip thrust exercise. Before attempting this test, you will be informed of proper technique by the researcher. You will be asked to perform 3 progressively heavier sets until you reach a moderately heavy load, and then you will complete as many repetitions with that load as you can safely perform. Your 10RM in the hip thrust will...
then be calculated for use during the testing session and you will receive 10 minutes of rest.

4. During the 10-minute rest period, a member of the research team will place small electromyographic (EMG) sensors on your skin to measure the electrical activity within your muscles. Placement areas will include your upper glutes, lower glutes, front of the thigh, and back of the thigh.

5. After 10 minutes of rest, you will be asked to perform maximal voluntary isometric contractions (MVICs) on the muscles of your lower body. You will be instructed in and assisted with performing a standing glute contraction, body weight hip thrust, a resistied lying hamstring curl, and a resisted seated leg extension, all of which you will hold for 3 seconds.

6. Following MVIC testing, you be provided with another 10 minutes of rest.

7. After the 10-minute rest period, you will be asked to perform 1 set of 10 repetitions of the hip thrust using your calculated 10RM at three different bench heights for a total of 3 sets. During these sets, you will be recorded via cellular phone to the analyze joint angles of your torso and knees.

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**How could you or others benefit from this study?**

The direct benefits participants should expect to receive from taking part in this study are receiving proper instruction in performing the hip thrust exercise that is increasing in popularity among strength and conditioning/injury rehabilitation settings. This will be useful information for individuals pursuing one of these fields with an exercise science degree.

Benefits to society include a more individualized approach for implementing the hip thrust into exercise and injury rehabilitation programs that improve the muscle strength and coordination patterns more that previous methods.

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**What risks might you experience from being in this study?**

The risks involved in this study are minimal, which means they are equal to the risks you would encounter in everyday life.

Liberty University will not provide medical treatment or financial compensation if you are injured as a result of participating in this research project. This does not waive any of your legal rights nor release any claim you might have based on negligence.

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**How will personal information be protected?**

The records of this study will be kept private. Published reports will not include any information that will make it possible to identify a subject. Research records will be stored securely, and only the researcher[s] will have access to the records. Data collected from you may be shared for use in future research studies or with other researchers. If data collected from you is shared, any information that could identify you, if applicable, will be removed before the data is shared.
• Participant testing data will be kept confidential through the use of codes. Once data has been collected, any identifying information will be stripped from the data and replaced with an assigned code. The codes will be written in a participant key that is stored in a separate place from the data.
• Data will be stored on a password-locked computer and may be used in future presentations. After three years, all electronic records will be deleted.
• Video recording of participants performing the hip thrust will be taken with a cellular phone. Recordings will be transferred to a computer and used to measure knee angles throughout the exercise. Videos may be used for educational and professional presentations. Recordings will be stored on a password locked computer for three years and then erased. Only the researcher[s] will have access to these recordings.
• All the data that is collected will remain confidential. Any data that is publish as part of a research report will not include any identifying information. Any videos that are used for educational purposes will not reveal the participant’s identity.

Does the researcher have any conflicts of interest?
The researcher serves as a graduate student assistant at Liberty University. To limit potential or perceived conflicts, the researcher will not offer participation as academic credit. This disclosure is made so that you can decide if this relationship will affect your willingness to participate in this study. No action will be taken against an individual based on his or her decision to participate in this study.

Is study participation voluntary?
Participation in this study is voluntary. Your decision whether to participate will not affect your current or future relations with Liberty University. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

What should you do if you decide to withdraw from the study?
If you choose to withdraw from the study, please contact the researcher at the email address/phone number included in the next paragraph. Should you choose to withdraw, data collected from you will be destroyed immediately and will not be included in this study.

Whom do you contact if you have questions or concerns about the study?
The researcher conducting this study is Abigail McCarty. You may ask any questions you have now. If you have questions later, you are encouraged to contact her at [email protected] or [contact information]. You may also contact the researcher’s faculty sponsor, David Titcomb, at [email protected].
Whom do you contact if you have questions about your rights as a research participant?

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Institutional Review Board, 1971 University Blvd., Green Hall Ste. 2845, Lynchburg, VA 24515 or email at irb@liberty.edu

Your Consent

By signing this document, you are agreeing to be in this study. Make sure you understand what the study is about before you sign. You will be given a copy of this document for your records. The researcher will keep a copy with the study records. If you have any questions about the study after you sign this document, you can contact the study team using the information provided above.

*I have read and understood the above information. I have asked questions and have received answers. I consent to participate in the study.*

☐ The researcher has my permission to video-record me as part of my participation in this study.

______________________________
Printed Subject Name

______________________________
Signature & Date
References


