COMPARISON OF SQUAT STRENGTH AND MUSCLE ACTIVITY BETWEEN FEMALE ATHLETES WITH VARUS VERSUS VALGUS KNEE ANGLES DURING JUMPING

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Abstract

COMPARISON OF SQUAT STRENGTH AND MUSCLE ACTIVITY BETWEEN FEMALE ATHLETES WITH VARUS VERSUS VALGUS KNEE ANGLES DURING JUMPING

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The exact physiological or biomechanical mechanisms responsible for varus versus valgus knee angles during jump landings are still unclear. This is of particular importance due to the previously reported association between valgus knee angles during jump landings and knee injury, particularly in female athletes. The purpose of this investigation was to examine squat strength and muscle activation during jump landings between a group of female athletes who performed jump landings with a varus knee position versus those who performed jump landings with a valgus knee position. Twenty-one female athletes (age: 19 ± 1.12 years; height: 177.8 ± 8.48 cm; weight: 72.7 ± 5.79 kg; squat 1 RM: 86.6 ± 11.7 kg) were recruited from the student population at Appalachian State University. Subjects had at least two years of resistance training experience, and played either basketball or volleyball at least 4 hours per week. All subjects performed a one repetition maximum (1RM) in the back squat and performed three of each of the following jumps: counter-movement jump (CMJ), 20 cm drop jump (DJ20), 40 cm drop jump (DJ40), and 60 cm drop jump (DJ60). Knee position (valgus/varus) was calculated using 3D videography at the moment of peak knee flexion.

EMG activity was collected on the Vastus Lateralis (VL), Vastus Medialis (VM), Biceps Femoris (BF), and Gluteus Maximus (GM) using wireless electrodes. Average muscle activity for 100 ms prior to peak knee flexion was averaged for the left and right leg. For the purpose of this study, EMG activity of the vastus lateralis and vastus medialis were averaged together to represent quadriceps activity. Activity for the quadriceps was not significantly different for the valgus versus varus knee angle groups, however a trend was observed between the two groups. Pre-activation of BF and GM were also not significantly different between the valgus versus varus knee angle groups. Differences between absolute 1RM (p=.98) and Relative 1RM's (p=.84) for the valgus and varus groups were not significant. Significant differences were observed in knee angles between the valgus and varus groups in all jump conditions ($p \leq 0.05$). In conclusion, females landing in a varus versus valgus position from jump landings do not demonstrate significant differences in squat 1RM capabilities or muscle EMG activity. It is possible that measuring squat strength is not an adequate field test to monitor athletes that may be at an increased risk for valgus knee position at landing.

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Introduction

The exact physiological or biomechanical mechanisms responsible for varus versus valgus knee angles during jump landings are still unclear (Schmitz et al., 2008; Shultz, 2008). This is of particular importance due to the previously reported association between valgus knee angles during jump landings and knee injury, particularly in female athletes (Ireland, 1999; Orishimo, Liederbach, Kremenic, Hagins, & Pappas, 2014). Several possible factors include lower body strength and muscle activation patterns during jumping (Brown, McLean, & Palmieri-Smith, 2013; Nagano, Ida, Akai, & Fukubayashi, 2011). A few investigations have indicated that generalized lower body strength might be a factor (Haines et al., 2011). Several other investigations have shown that the strength of individual muscles, such as adductors or abductors of the hip, could be responsible (Homan, Norcross, Goerger, Prentice, & Blackburn, 2013; Jacobs, Uhl, Mattacola, Shapiro, & Rayens, 2007). Muscle pre-activation occurs through reflex loops immediately prior to jump landings (Taube, Leukel, & Gollhofer, 2012) and some data indicate that this might predispose an individual to a certain pattern of subsequent knee position and also effect overall jumping performance (Bergmann, Kramer, & Gruber, 2013). The purpose of this investigation was to examine squat strength and muscle activation during jump landings between a group of female athletes who performed jump landings with a varus knee position versus those who performed jump landings with a valgus knee position.

A myriad of mechanisms have been proposed for differences in valgus versus varus knee positions at landing. These range from overall strength deficits (Shultz, Nguyen, Leonard, & Schmitz, 2009), to strength ratios (Malfait, Dingenen, Staes, Vanrenterghem, & Verschueren, 2014), and factors such as joint torque (Schmitz et al., 2008) and body composition (Nilstad, Andersen, Bahr, Holme, & Steffen, 2014). While examining joint torques, Schmitz et al. (2008) found that women exhibit less knee stiffness when low magnitude valgus/varus torques are applied to the knee joint. They also found that women demonstrate increasing knee joint stiffness in response to increasing torque application. This could have negative effects on knee joint biomechanics, particularly when transitioning from unloaded to loaded activities, such as jumping. In opposing results, Nilstad et al. (2014) found that knee joint laxity had no significant effect on lower extremity injury rates. Among several variables tested, results showed that only an increased BMI was related to developing lower body injuries.

Many aspects of lower body strength have been measured in regards to landing biomechanics. Some of this research has compared differences between sports (Herrington, 2011; Munro, Herrington, & Comfort, 2012), while others have compared absolute strength capabilities (Haines et al., 2011; Hollman, Hohl, Kraft, Strauss, & Traver, 2013; Howard, Fazio, Mattacola, Uhl, & Jacobs, 2011). Howard et al. (2011) found that participants with less hip-abduction-external rotation strength could be at a greater risk for medial collapse, particularly at the knee joint. Differently, Homan et al. (2013) found that differences in hip external rotation strength were unrelated to knee valgus at landing; however, they did find that those with lower strength capabilities demonstrated greater amounts of gluteus medius EMG activity, possibly pointing to a compensation strategy. Other studies have also reported that

increased hamstring and gluteus maximus EMG activity was seen in females landing with increased knee valgus (Croce, Russell, Swartz, & Decoster, 2004). Hollman et al. (2013) found a significant negative correlation between lower isometric hip-extension strength and knee valgus angles at landing. They were also able to show that lower overall gluteus maximus EMG activity was related to knee valgus in their subjects. While comparing squat strength and biomechanics, Wallace et al. (2008) found that squat strength did not affect knee varus landing, but hip abduction strength may be correlated with varus landing in women. Several training studies have also found that resistance training and increases in squat 1RM are related to improvements in knee position at landing (Arabatzi, Kellis, & Saez-Saez De Villarreal, 2010; Lamas et al., 2012; Lephart et al., 2005; Myer, Ford, Palumbo, & Hewett, 2005).

Lastly, researchers have also investigated the effects of muscle activation through the use of EMG during various activities (Homan et al., 2013; Struminger, Lewek, Goto, Hibberd, & Blackburn, 2013). It has been found that muscle activation strategies may differ depending on age or experience. Younger, less experienced individuals may use different activation strategies than older, more experienced athletes; more experienced athletes may pre-activate hamstrings before landing, while younger athletes may increase hamstring activation upon landing indicating a reflexive response to ground contact (Croce et al., 2004). More recent investigations have demonstrated that increased pre-activity in the Rectus Femoris is correlated to decreased knee flexion angles, and may also predispose an individual to increased ACL tear risks (Brown et al., 2013). An in vitro study also demonstrated that increasing hamstring force upon landing would lead to decreased strain on the ACL (Withrow, Huston, Wojtys, & Ashton-Miller, 2008); however, a study in healthy men found

that pre and post impact landing strategies according to EMG may be subject specific (Scholes, McDonald, & Parker, 2013). Five plyometric exercises were evaluated for the level of EMG activity produced in the gluteus maximus, gluteus medius and the lateral hamstrings (Struminger et al., 2013). They found that a double-leg, sagittal plane hurdle hop produced the greatest EMG activity in the medial and lateral hamstrings during the loading phase, and high gluteus maximus and medius activation levels during both preparatory and loading phases. Greater quadriceps activation in comparison to hamstring activation in both single and double leg landings has also been correlated with smaller knee-flexion angles (Walsh, Boling, McGrath, Blackburn, & Padua, 2012).

With so many variables known to be involved in landing biomechanics, and still so many uncertainties in what may predispose certain people to high ACL tear risks, it is important to continue researching possible factors. The purpose of this investigation was to combine multiple aspects of previous studies in order to gain a better understanding of what physical qualities are necessary for proper landing. Women's basketball and volleyball players were analyzed for differences in muscle activation, strength capabilities and landing biomechanics. To our knowledge, there is currently no research that ties together the EMG activity of the landing phase of drop-jumps with the lower body kinematics and maximum squat capabilities of athletes. It was hypothesized that team members with a varus knee angle at landing would possess greater relative squat capabilities. It was also hypothesized that subjects with varus knee angles at landing would demonstrate decreased hamstring and gluteus maximus and increased quadriceps EMG activity 100 ms prior to peak knee flexion.

Methods

Participants.

Subjects were recruited from the student populations at Appalachian State University. Subjects had at least two years of resistance training experience, and played their aforementioned sport at least 4 hours per week (*n*=21; *age*: 19 ± 1.12 years; *height*: 177.8 ± 8.48 cm; *weight*: 72.7 ± 5.79 kg; *squat 1 RM*: 86.6 ± 11.7 kg). All participants signed informed consent before entering the study. Medical history was collected for all subjects to ensure there were no contraindications to exercise that would eliminate them from the study. This study was approved by the institutional review board at Appalachian State University.

Study Design.

All subjects visited the Holmes Convocation Center's Neuromuscular and Biomechanics Laboratory for a single testing session. Upon arrival subjects height, weight, and age were recorded. A one repetition maximum in the back squat (1RM), as well as 12 jumps were performed. CMJ and DJ jumps were randomized for each subject prior to the testing session to ensure any level of fatigue was not a contributing factor. Jumps were performed on a force plate (AMTI, BP6001200, Watertown, Massachusetts, USA) time sequenced with both LabView and Vicon Software. Knee position and EMG activity were measured for all trials and averaged together for each subject.

1 RM Testing.

Subject's back squat 1RM was found utilizing procedures established in previous research. (Cormie, McBride, & McCaulley, 2007; Winchester, Erickson, Blaak, & McBride, 2005). This included a warm-up of 4-6 reps at 30% of estimated 1RM, 3-4 reps at 50% 1RM, 2-3 reps at 70% 1RM and 1 rep at 90% of 1RM. Subjects had up to 4 attempts to reach a true 1RM (Winchester et al., 2005). Rest periods of five minutes were given between all sets.

Jump Trials.

Jump trials were randomized by sets of countermovement jumps (CMJ), and depth jumps from 20 cm, 40cm, and 60 cm (DJ20, DJ40, DJ 60). Subjects performed three jumps under each condition. CMJ was instructed to be a maximal effort vertical jump as they would typically perform it. No set instructions for knee depth were utilized during any jump conditions. DJ's were instructed to step off of the platform, land on two feet within the area of the force plate, and immediately perform a maximal vertical jump. Familirization periods were given from all of the heights to ensure all subjects followed proper safety protocol, adjusted to box heights, and were landing within the designated force plate area.

Kinetic & Kinematic Data Collection and Analysis.

Knee valgus/varus angles were found using 3D Videography (Vicon Nexus, Centennial, CO, USA) consisting of seven MX03+ NIR cameras at a frequency of 240 Hz using infrared detection of optical markers. A global orthogonal coordinate system was used and calibrated using set spaced markers (0.2 m) connected to a rod provide by VICON Systems. Reflective markers were applied to the greater trochanter, lateral epicondyle and lateral mallelous of both legs, allowing researchers to track the location of lower body joints

during each jump. The mean residual for each camera was < 1.1 mm and static reproducibility was < 1%. Filtering was performed using Woltring predicted mean square error quintic spline (VICON Systems). Analog signals from the force plate were collected for every trial at 1000 Hz using a BNC-2010 interface box with an analog-to-digital card (National Instruments, NI PCI-6014, Austin, Texas, USA). Knee varus/valgus position was calculated at peak knee flexion. Neutral knee position was set at 0° and knee valgus was any position less than 3°, while knee varus were any values greater than 3°. Knee positions were averaged for the left and right leg to represent overall varus or valgus positions. Subjects were then seperated into valgus and varus groups based on the average knee position of each type of jump (Table 1).

Electromyography.

Muscle activity was measured by electromyography (Delsys Trigno Wireless System, Natlick, Massachusetts, USA) applied to the gluteus maximus (GM), vastus medialis (VM), biceps femoris (BF), and vastus lateralis (VL) of both legs. EMG electrodes (27x37x15 mm dimension with 4, 5x1mm contact points; gain=909, bandwidth frequency=20-450 Hz, common mode rejection ratio= 85 dB; sampling=2000/sec) were attached to the skin over the appropriate muscle belly parallel to the muscle fibers and distal to the motor point. All subjects had EMG placement locations abraided and cleansed with isoproyl alcohol, and if necessary, excess hair was shaved. Electrodes were affixed to the skin using Delsys Adhesive Sensor Interfaces (Delsys Inc., Natlick, Massachusetts, USA). All electrodes were applied by the primary researcher on all subjects. EMG activity was recorded and analyzed during all 12 jumps being performed with custom designed LabVIEW software and was averaged for each jump type. The signal was full wave rectified and filtered (six pole Butterworth, notch filter 60 Hz, band pass filter 10-200 Hz). Average EMG activity was calculated for the 100 ms

prior to peak knee flexion as calculated from time-sequenced force plate data with Vicon software. EMG activity for the right and left leg of each muscle group was averaged together to mimic knee angle calculations.

Statistical Analysis

The general linear model with repeated-measures analysis of variance and Bonferroni post hoc tests were used to determine changes in the jump performance variables from individual force- and power-time curves within and between groups. Intergroup differences for each data point within the average force- and power-time curves were assessed through a general linear model with repeated-measures analysis of variance. Bonferroni post hoc tests were used to determine the locations of any differences along the curves. The assumptions for linear statistics were met, and statistical significance for all analyses was defined by $p \leq 0.05$. All statistical analyses were performed using SPSS version 12.0 (SPSS Inc., Chicago, Ill)

Results

Differences between absolute 1RM (p=.98) and Relative 1RM's (p=.84) for the valgus and varus groups were not significant. Average Squat 1RM and Relative 1RM's are listed in Table 2. Significant differences were observed in knee angles between the valgus and varus groups in all jump conditions ($p \leq 0.05$). Average knee angles for each jumping condition are seen in Figures 1 and 2. For the purpose of this study, EMG activity of the vastus lateralis and vastus medialis were averaged together to represent quadriceps activity. Pre-activty for the quadriceps (Table 3) was not significantly different for the valgus versus varus knee angle groups, however a trend was observed between the two groups and can be seen in Figures 3 and 4 . Pre-activation of BF (Table 4) and GM (Table 5) were also not significantly different between the valgus versus varus knee angle groups. Group averages for BF and GM can be seen in Figures 5-8.

Discussion

Howard et al. (2011) found that among a multitude of variables, being female was a predictor of knee abduction excursion, however the results our the current investigation show that there was a significant difference within the subjects that landed in a more valgus or more varus position within an all female population. This poses the question of if gender alone is the primary factor mediating medial knee collapse's higher prevelance rate amoung female atheletes. While joint torques and strength ratios were not evaluated in the course of this study, absolute and relative strength, along with average muscle activiation were, and no signifcant relationships were found.

Previous research (Howard et al., 2011; Jacobs et al., 2007) has indicated that isometric hip abduction strength correlates well with knee position at landing, however this can be a difficult task to measure for strength and conditioning coaches who do not have access to force transducers and laboratory equipment to monitor their athletes. Exercises such as the dynamic back squat could offer more practical "field" measurements to identify athletes who may be at an increased risk for medial knee collapse. In a study by Stearns, Keim & Powers (2013), it was found that subjects with a higher ratio of knee-hip extensor isometric strength also demonstrated higher knee extensor moments. Previous research (Chrisman et al., 2012; Haines et al., 2011; Huston, Vibert, Ashton-Miller, & Wojtys, 2001) has also found that differences exist in both landing patterns and squat capabilities between genders, however this relationship was not observed when measuring within a gender. Females landing in a more varus position showed no significant difference in absolute or relative squat strength

compared to females landing in a more valgus position. Given the similarities in movement patterns, and the known relationship between squat strength and jumping (Barr & Nolte, 2014), it was hypothesized that squat strength and jump landings would display a strong correlation regardless of gender. Research has also found that in youth athletic populations, elite and recreational females show no significant differences in strength or landing biomechanics (Chrisman et al., 2012). Our investigation has shown that these same patterns are not observed in adult female athletes, pointing again to a factor outside of gender leading to differences in valgus versus varus jump landings. It is possible that the mostly concentric muscle requirements of a squat do not translate to the high eccentric component of jump landings (Aboodarda, Yusof, Abu Osman, Thompson, & Mokhtar, 2013; Luera, Stock, & Chappell, 2014). Future research could look to identify if there is any relationship between squat strength and muscle activity patterns during the eccentric and concentric portions of jump landings separately.

Brown et al. (2013) found that muscle pre-activity was not a predictor of knee abduction during single leg landings, and the current study helps to solidify this finding in double-leg landings as well. As seen in Figure 2, there is a noticable trend of increased VLVM EMG activity in subjects landing with an increased knee varus as DJ jump height increased. There is also a steady decline in VLVM EMG activity with increasing DJ height in the valgus knee position group. Homan et al. (2013) found that subjects who were weaker in hip abduction and external rotation strength exhibited increased gluteus maximus and gluteus medius activity, and proposed that increased neural drive was utilized to compensate for decreased force production. The current study observed increased gluteus maximus EMG in the valgus landing group, coinsiding with findings from Brown et al. (2013) that subjects

landing in a more valgus position had greater hamstring and gluteus EMG activity, possibly as a reactionary response to impact forces. This study evaluated EMG activity in the 100 ms prior to peak knee flexion to examine the relationship between muscle activity at the time of knee valgus or varus measurements. It is possible that true pre-activiation in these muscle groups may have differed between the females landing in a more valgus versus more varus position, such as what was seen by Malfait et al. (2014).

Our results did not coincide with the original hypothesis of the study, and significant differences were only noted between the valgus and varus knee landing position of the two groups. The findings from our study are in line with findings from Wallace et al. (2008) and demonstrate that dynamic squat strength alone is not a large enough contributor to the individualized manner of jumping biomechanics. However, the trend of decreasing EMG in the valgus group, and increasing EMG activity in the varus group with increasing DJ height shows that some factor is helping to mediate neural drive during eccentric loading. Further research should look at factors such as jumping experience, age, resistance training experience and impact forces as possible explanations for the significant differnces observed in knee position when landing from jumps.

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Withrow, T. J., Huston, L. J., Wojtys, E. M., & Ashton-Miller, J. A. (2008). Effect of varying hamstring tension on anterior cruciate ligament strain during in vitro impulsive knee flexion and compression loading. *J Bone Joint Surg Am, 90*(4), 815-823. doi: 10.2106/jbjs.f.01352

Variable	Valgus Group	Varus Group
Knee Angle (°) CMJ	-4.80 ± 5.54	9.86 ± 3.22*
Knee Angle (°) DJ20	-7.49 ± 5.11	11.06 ± 4.37*
Knee Angle (°) DJ40	-7.86 ± 3.43	11.41 ± 5.49*
Knee Angle (°) DJ60	-6.37 ± 4.99	13.26 ± 4.91*

Table 1: Average Knee Position. * Denotes significant differences ($p \leq 0.05$) between the Valgus and Varus Group in each jump condition

Variable	Valgus Group	Varus Group
Squat 1RM (kg)	86.6 ± 12.7	86.5 ± 10.9
Squat 1RM/BM	1.19 ± .20	1.21 ± .19

Table 2: Average Squat 1RM and Relative Squat 1RM

Variable	Valgus Group	Varus Group
Muscle Activity (mV) CMJ	0.164 ± .068	0.128 ± .056
Muscle Activity (mV) DJ20	0.151 ± .062	0.142 ± .048
Muscle Activity (mV) DJ40	0.146 ± .045	0.149 ± .075
Muscle Activity (mV) DJ60	0.143 ± .065	0.156 ± .046

Table 3: Average Quadriceps EMG activity. (VL+VM)

Variable	Valgus Group	Varus Group
Muscle Activity (mV) CMJ	0.055 ± .033	0.063 ± .069
Muscle Activity (mV) DJ20	0.052 ± .037	0.052 ± .027
Muscle Activity (mV) DJ40	0.055 ± .041	0.061 ± .060
Muscle Activity (mV) DJ60	0.047 ± .028	0.055 ± .032

Table 4: Average Biceps Femoris EMG Activity

Variable	Valgus Group	Varus Group
Muscle Activity (mV) CMJ	0.045 ± .029	0.041 ± .019
Muscle Activity (mV) DJ20	0.039 ± .014	0.044 ± .018
Muscle Activity (mV) DJ40	0.039 ± .019	0.037 ± .012
Muscle Activity (mV) DJ60	0.042 ±.024	0.034 ± .013

Table 5: Average Gluteus Maximus EMG Activity

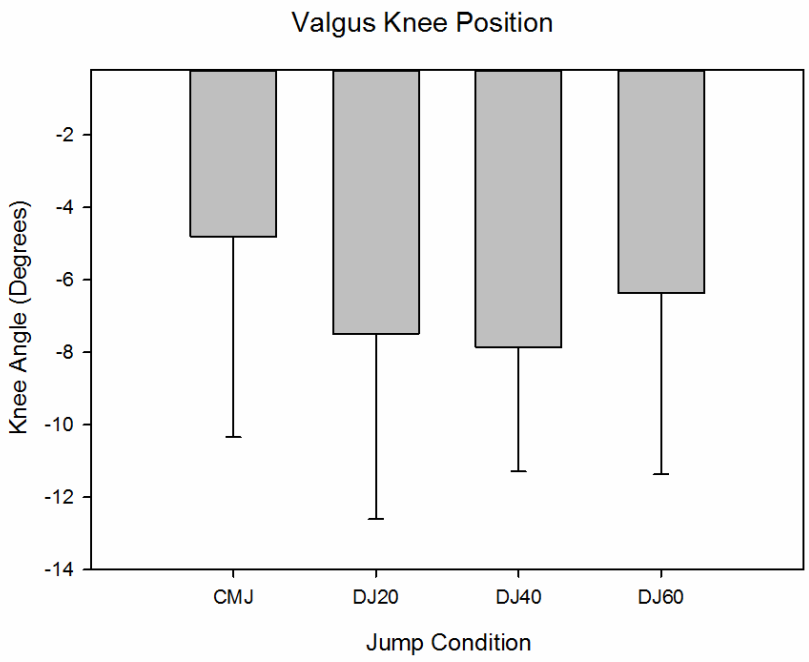

Figure 1: Valgus Group Average Knee Angles

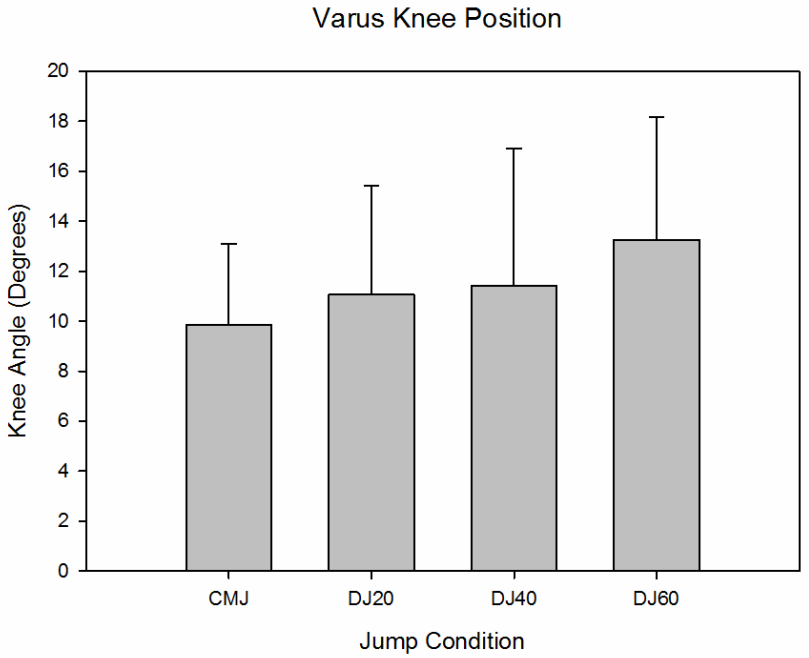

Figure 2: Varus Group Average Knee Angles

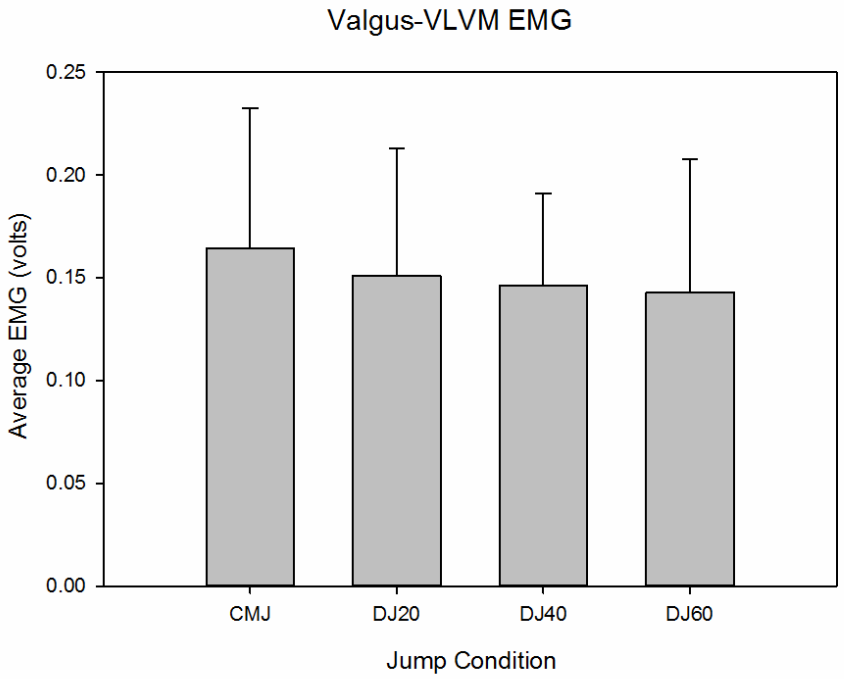

Figure 3: Average VLVM Activity in Valgus Group (Collectively as Quadriceps)

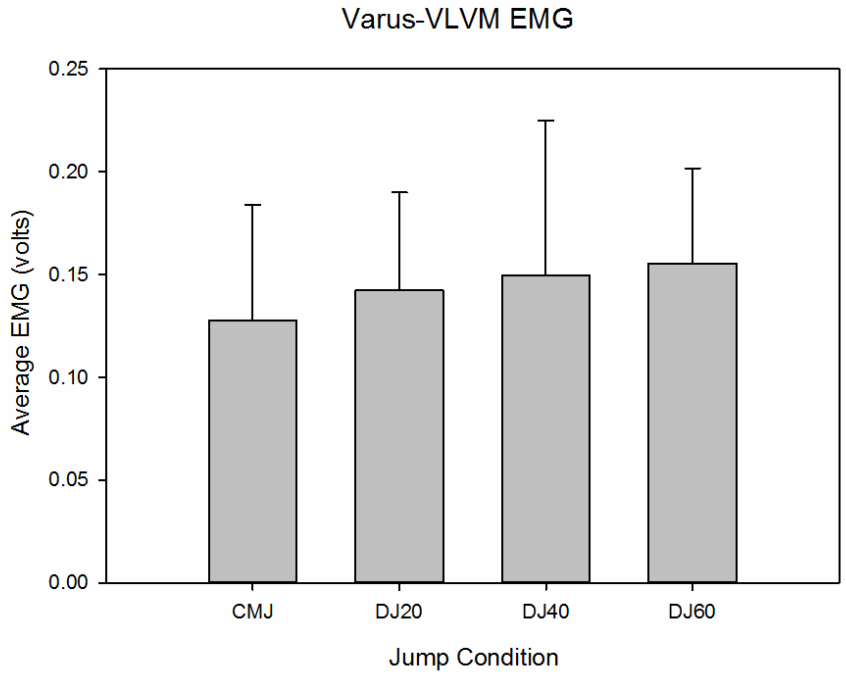

Figure 4: Average VLVM Activity in Varus Group (Collectively as Quadriceps)

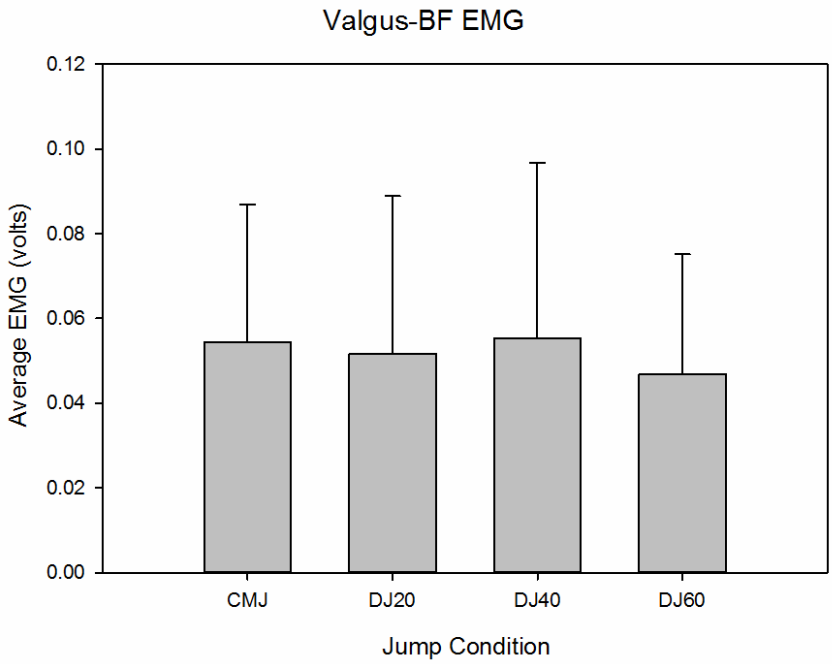

Figure 5: Average BF Activity in Valgus Group

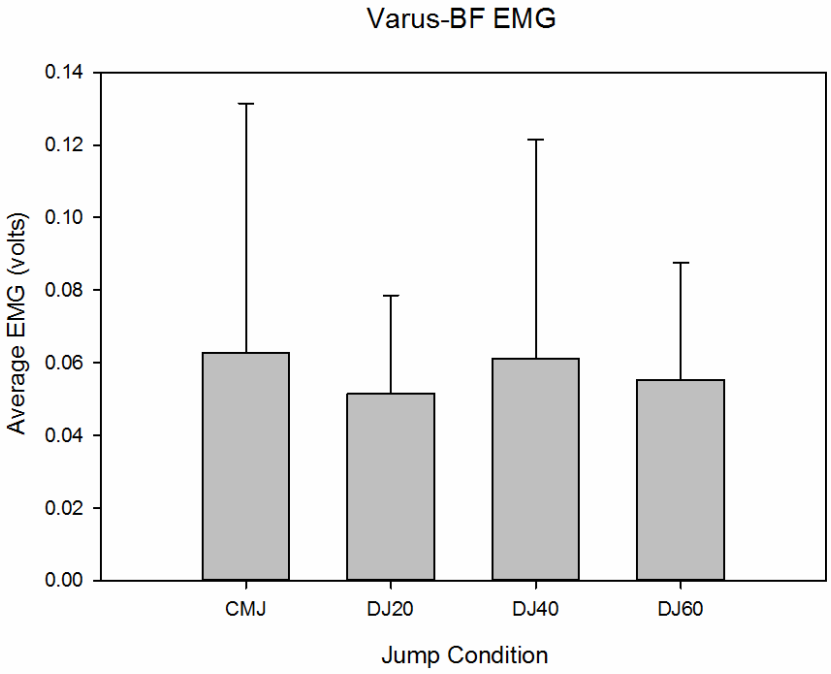

Figure 6: Average BF Activity in Varus Group

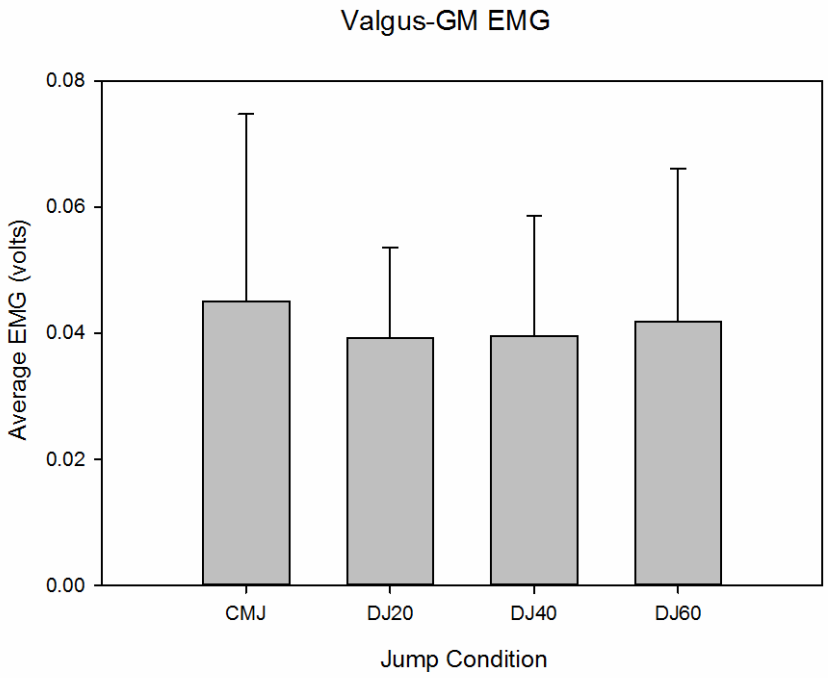

Figure 7: Average GM Activity in Valgus Group

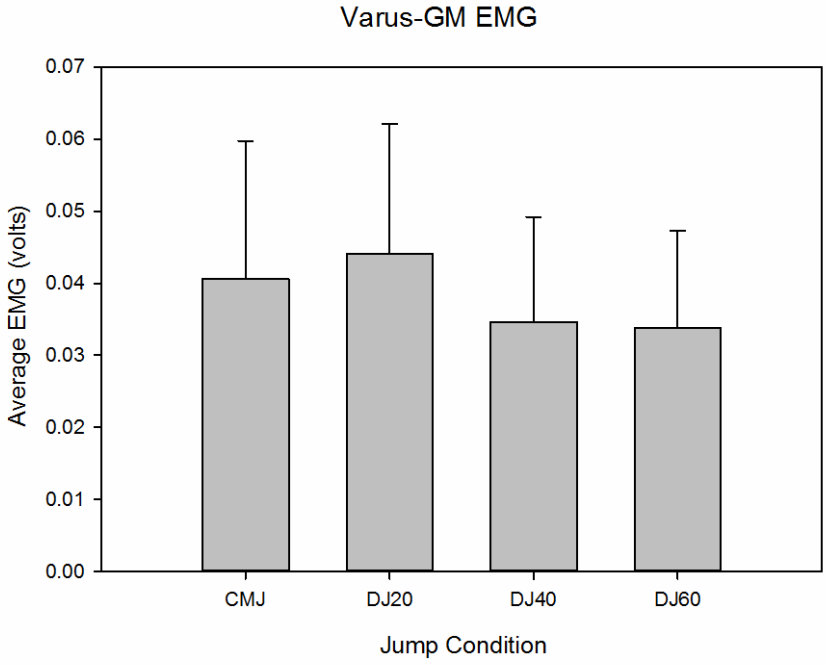

Figure 8: Average GM Activity in Varus Group

Appendix A-Institutional Review Board Documentation

Request for Review of Human Participant Research

Appalachian Human Research Protection Program

Instructions: ***Complete and send the request form electronically to irb@appstate.edu.***
Note: *checkboxes can be checked by putting an "x" in the box.*

Section I: Study Description

1. Study Title: The Effects of Muscle Activation and Strength on Landing Biomechanics

2. Study Description: Briefly describe any relevant background, the purpose of the research, any literature searches performed, the research question, and anticipated plans for disseminating results.
A limited number of studies have evaluated the effect of hip strength and muscle activation on landing biomechanics in jumping. This has important implications for determining appropriate strength & conditioning programing for improvements in jumping ability. Therefore, the aim of this study is to determine if there are any associations between maximal squat strength and jumping performance in terms of muscle activity patterns and knee position upon landing during various types of jumping activities.

3. Principal Investigator(s) (PI) and faculty advisor if student is the PI: Jeffrey M. McBride

Department(s): HLES

4. By submitting this request, the PI (and faculty advisor if PI is a student) accept responsibility for ensuring that all members of the research team: 1) complete the required CITI training and any other necessary training to fulfill their study responsibilities, 2) follow the study procedures as described in the IRB approved application and comply with *Appalachian's Guidelines for the Review of Research Involving Human Subjects* and all IRB communication and 3) uphold the rights and welfare of all study participants.

The parties (i.e., the IRB, the PI, and faculty advisor if any) agree to conduct this application process by electronic means, and this application is signed electronically by the PI and faculty advisor, if applicable.
My name and email address together constitute the symbol and/or process I have adopted with the intent to sign this application, and my name and email address, set out below, thus constitute my electronic signature to this application.

Jeffrey McBride	McBridejm@appstate.edu
PI Name	PI Email Address

I certify that I have read and endorse the materials submitted. Date: 9/23/13

Faculty Advisor name if PI is a student Faculty Advisor email if PI is a student

5. Type of Research, check all that apply:

[x] Faculty Research [ ] Dissertation/Thesis/Honor's Thesis

[ ] Product of Learning [ ] Class Project – Course Number:

[ ] Other: describe

6. Source of Funding

[x] Not Funded [ ] Funds Awarded [ ] Funds Pending

[ ] Federally Funded [ ] University Funded: describe

If external funds awarded/pending, provide the sponsor name and Sponsored Programs number: Attach a copy of the contract/grant/agreement.

7. Is another institution engaged in the research (i.e., an agent of another institution will obtain informed consent, interact with participants to obtain information, or access private identifiable information about participants)?

[x] No [ ] Yes If yes, list institution(s) and whether that IRB will review or rely on the ASU IRB.

8. What, if any, relationship exists between the researcher(s) and agencies (e.g., schools, hospitals, homes) involved in the research? *Attach statement of approval (e.g., letter of agreement) from any agencies that will need to approve the research.* N/A

Section II: Research Personnel

Enter each team member (including PI) in the table below. (*A member of the research team is defined as one who will: 1) access participants' private identifiable information, 2) obtain informed consent **or** 3) interact with participants.)*

Name	**Role** (e.g., PI, co-I, Research Assistant, Research Coord., Faculty Advisor, etc.)	**Responsibilities**: Select all that apply from the list of Responsibilities below (e.g., "a, b, c")	**Receive IRB Correspondence** (Y/N)? If yes, provide preferred email address.
Jeffrey McBride	PI	A, b, c, f, g, h, j, l, m	Mcbridejm@appstate.edu
Courtney Goodman	Co-PI	A, b, c, f, g, h, j, l, m	Goodmancl1@appstate.edu
Christopher Capps	Co-PI	A, b, c, f, g, h, j, l, m	Cappsc@appstate.edu

(Note: If you need additional room, you can add rows by a right click, insert, and then insert rows below. Changes in personnel must be sent to the IRB. Minor personnel changes can be sent via an email; non-minor personnel changes require a modification request.)

Responsibilities:

a. Screens potential participants	**h**. Conducts physical exams
b. Obtains Informed Consent	**i**. Collects biological specimens (e.g., blood samples)
c. Has access to identifiable data	**j**. Conducts study procedures
d. Administers survey	**k**. Dispenses medications
e. Conducts interviews	**l.** Supervises exercise
f. Enters subject data into research records	**m.** Educates participants, families, or staff
g. Analyzes data with identifiable information	**n.** Other: describe

Note: In some cases, expertise to perform study procedures (e.g., blood draws, interviewing participants about sensitive topics) must be documented to show that risks to participants is minimized. The Research Personnel Form and/or a CV may be attached to document expertise.

Section III: Conflict of Interest

1. Do any of the researchers responsible for the design, conduct, or reporting of this research have a known or potential conflict of interest related to this research?

Conflict of interest relates to situations in which financial or other personal considerations, circumstances, or relationships may compromise, involve the potential for compromising, or have the appearance of compromising a researcher's objectivity in fulfilling research responsibilities. University policy is available at: http://policy.appstate.edu/Conflicts_of_Interest_and_Commitment_Policies_and_Guidelines_for_Faculty/EPA_Administrative_Personnel

[x] No [ ] Yes If yes, explain who has the conflict, whether the conflict has been disclosed and/or managed and explain how participants will be protected from the influence of competing interests.

Section IV: Participant Population and Recruitment

1. Number of participants sought: 60

2. Targeted Participant Population (check all that apply):

[x]	Adults (>= 18 yrs old)	[x]	College Students (only 18 or older)
[ ]	Minors (< 18 yrs old) Age range:	[ ]	College Students (under 18 may participate)
[ ]	Minorities	[ ]	Prisoners
[ ]	Institutionalized Participants	[ ]	Cognitively or emotionally impaired
[ ]	Inpatient participants	[ ]	Non-English speaking
[ ]	Outpatient participants	[ ]	Pregnant Participants
[ ]	International research	[ ]	Employees of a profit or non-profit organization

3. Federal regulations require the equitable selection of participants. Is the targeted population an appropriate group to bear the burdens of this research?

[x] Yes [ ] No If no, please explain:

Are participants a subset of the population most likely to receive the benefits of this research?

[x] Yes [ ] No If no, please explain:

4. Explain any inclusion and exclusion criteria for the study: Subjects must have at least two years' experience with jumping activities (i.e. basketball, volleyball). All subjects must be between the ages of 18-25. Subjects who are at moderate or high risk of a cardiovascular event will be excluded. During orientation, participants will be asked to complete the AHA/ACSM screening tool to ensure physical preparedness required for this study. Subjects who are at moderate or high risk of cardiovascular event will be excluded. Subjects will not be excluded on the basis of race, color, or any other demographic characteristics other than age.

5. Describe how subjects will be recruited. Recruitment will occur through flyers and email.

6. Does the research include any compensation, or reimbursement for participation?
[x] No [ ] Yes If yes, explain payment schedule:

Section V: Informed Consent Process

1. Explain how informed consent will be obtained. Include information about the setting, any time provided to consider participating in the research, and opportunity to ask questions. One week prior to the day of data collection participants will be given an informed consent sheet upon entering the Neuromuscular and Biomechanics Laboratory. A verbal explanation of research procedures will be given, and subjects will also be instructed to read through the information and ask questions at any time. The primary investigator (McBride) or a co-investigator (Goodman, Capps) will be available as they read through the form to answer any questions.

2. If applicable, describe the safeguards in place to protect the rights and welfare of any vulnerable participants *(e.g., children, prisoners, pregnant persons, or any population that may be relatively or absolutely incapable of protecting their interests through the informed consent process).* N/A

3. Select factors that might interfere with informed consent:
- [x] None known
- [ ] Participants or their authorized representative (parent) may not speak and/or read English
- [ ] Research will involve current students in a course/program taught by member of research team
- [ ] Participants are employees whose supervisor is recruiting/requiring participation
- [ ] Participants have a close relationship to research team
- [ ] Other (please specify/indicate any relationship that exists between research team and participants):

For selected factors, describe any efforts to mitigate:

4. Will participants sign a consent form?
[x] Yes [ ] No

If no, participants must still be provided with a statement regarding the research and one of the following criteria must be met and selected and followed:
- [ ] The only record linking the participant and the research is the consent document and the principal risk is potential harm resulting from a breach of confidentiality, and the research is not FDA-regulated. Each participant will be asked whether he/she wants documentation linking the participant with the research and the participants wishes will govern; OR
- [ ] The research presents no more than minimal risk of harm and involves no procedures for which written consent is normally required outside of the research context.

5. Are you requesting a modification to the required elements for informed consent?
[x] No [ ] Yes If yes, explain:

Section VI: Study Procedures

1. Describe research procedures as they relate to human participants. Information must be sufficiently detailed to explain what participants will be asked to do, duration of procedures, and frequency of procedures. All subjects will be asked to visit the Holmes Convocation Center's Neuromuscular and Biomechanics Laboratory for a single testing session lasting approximately 2 hours. At the beginning of the testing session, participants will be asked to complete the AHA/ACSM screening tool to ensure physical preparedness required in this study. Subjects who are at moderate or high risk of a cardiovascular event will be excluded. All subjects will be asked to refrain from performing strenuous resistance training for 48 hours prior to the testing session. A one repetition maximum in the back squat (1RM), as well as landing biomechanics will be recorded following the procedures below. Subject's back squat 1RM will be found utilizing procedures established in previous research. This will include a warm-up of 4-6 reps at 30% of estimated 1RM, 3-4 reps at 50% 1RM, 2-3 reps at 70% 1RM and 1 rep at 90% of 1RM. Subjects will then have up to 4 attempts to reach a true 1RM. The load prescription will be subject to research assistant's discretion and recommendations. Subjects will begin the squat by standing with their feet shoulder width apart, barbell positioned on their upper back. They will squat down to 80 degrees as determined by researchers, and return to a standing position. Rest periods of 5 minutes will be given between all sets. Injury potential with the depth jump and back squat is no more that that of any other type of rseistance training exercise or other general types of exercise which includes muscle strains or pulls. All exercises will be performed with either body weight alone or a barbell and weight plates while standing on a SS Performance weightlifting platform. Knee valgus/varus angles will be found using 3D Videography (Vicon). Reflective markers will be applied to the greater trochanter, lateral epicondyle and lateral mallelous of both legs, allowing researchers to track the location of lower body joints during each jump. This will be done through the use of double sided tape attached to the bottom of all 6 markers. Each subject will perform 3 trials of a standard countermovement jump, along with 3 drop-jumps (DJ) from 20, 40 and 60 cm which will be randomized prior to completion. Familirization periods will be given from all of the heights to ensure all subjects are following proper safety protocol, adjusted to box heights, and are landing with the designated force plate area. Depth-jumps will be instructed as follows: drop off of the box then as you land, immediately jump straight up as high as you can. Muscle activity will be measured by electromyography (Delsys Trigno Wireless System) applied to the gluteus maximus, vastus lateralis, and the medial and lateral hamstrings of both legs. EMG will be recorded during all 9 jumps being performed during the videography analysis. EMG's will be attached by preparing the area with an alcohol swab (BD) and then an EMG abrasive pad (BioPak). You are asked not to apply any lotion or creams to the above listed areas 24 hours before your testing session. Shaving a small part of these areas may be needed to ensure adequate adhesion of the EMG electrode. Placing of electrodes will be done in a secure room with only the needed research technician to ensure the privacy of all subjects. If subjects are uncomfortable with technician placing electrodes, they will be walked through the appopriate location and steps for adhering the electrodes. Placement of electrodes for electromyography can cause temporary skin irritation, such as itching or inflammation of the skin.

2. Projected data collection dates: October 1, 2013 – November 30, 2014

3. Check all locations of study procedures that apply:

- [ ] N/A – online survey
- [x] Appalachian campus, indicate building: Holmes Convocation Center, Neuromuscular and Biomechanics Laboratory
- [ ] School system(s):
- [ ] Human Performance Lab, NCRC
- [ ] Off-campus location(s). List:

4. If your study does not involve biomedical procedures or accessing private health information, skip to question #5. Otherwise, select all data collection activities that apply:

- [ ] Blood samples by finger stick, heel stick, ear stick or standard venipuncture

  Indicate the type of participants and how much blood will be drawn:

  - [ ] from healthy, non pregnant adults who weigh at least 110 pounds
  - [ ] from other adults or children
  - [ ] How many times per week will blood be drawn?
  - [ ] How much blood will be drawn at one time?
  - [ ] How much blood will be drawn in an 8-week period?
  - [ ] How often will collection occur?
- [ ] Obtaining private health information (PHI) from a HIPAA covered entity
- [ ] Test articles regulated by the FDA
- [ ] Other: describe

5. Does the study involve deception of participants?

[x] No [ ] Yes If yes, please describe:

6. Does the data to be collected relate to any illegal activities (e.g., immigration status, drug use, abuse)?

[x] No [ ] Yes If yes, please describe:

7. Will human subject data/specimens be used for future research that is not described in the research procedures? (Future use of data/specimens should be disclosed to the participant in the informed consent.)

[x] No [ ] Yes If yes, please explain:

Section VII: Confidentiality and Safeguards

1. Explain provisions to protect the privacy of subjects (if applicable): Information will be collected so that participants can be identified, either directly or indirectly, by the research team but identifying information will not be disclosed publicly.

2. Participants' identification (check one):

- [ ] Anonymous: the identity of the subject cannot be matched to his/her responses at any time.
- [x] Confidential: participants can be identified but identifying information will be kept confidential.
- [ ] Identifiable: participants can be identified and identifying information will be disclosed publicly.

3. Explain how the confidentiality of the data will be maintained by explaining 1) where data will be stored,
2) any plans to de-identify or anonymize data, and 3) any plans to share identifiable data with personnel not listed on the application. **Note**: *The IRB expects researchers to access the minimal amount of data to conduct the study and comply with HIPAA and the Family Educational Rights and Privacy Act (FERPA):* Information on subjects will be kept in the Neuromuscular and Biomechanics Laboratory, which has limited public access. In addition, all

identifying information will be kept in a locked filing cabinet, and informed consent will be kept in a separate location from the data. All computers containing subject information are also password protected. No persons not associated with the study will have access to any subject information.

4. Data security for storage and transmission:

Electronic data:

- [ ] Data anonymized by research team so source of data cannot be determined
- [ ] Secure network
- [x] Password-protected access
- [ ] Encryption of all identifiable data transmitted (e.g., email)
- [ ] Encryption of all identifiable data stored electronically
- [x] Using subject codes on all collected data with the key linking subject codes to identifiable information stored in a separate location from data
- [ ] Portable storage (e.g., laptop, flash drive)—private identifiable information stored on portable devices will be encrypted
- [ ] Other, please describe:

Hard copy data and/or specimens:

- [ ] Data anonymized by research team so source of data cannot be determined
- [ ] Locked suite or office
- [x] Locked cabinet
- [ ] Using subject codes on all collected data and maintaining the key linking subject codes with identifiable information in a separate location from data
- [ ] Other, please describe:

5. Secure Disposal: *Note: consent forms should be stored for 3 years after study completion.*

5a. How long will the data be stored?

- [x] 3 years after study completion
- [ ] Data without identifiers stored indefinitely
- [ ] Indefinitely
- [ ] Other, please describe (e.g., sponsor requirements):

5b. How will data be destroyed?

- [x] Paper will be shredded by: Jeffrey McBride
- [ ] Biological samples will be destroyed by:
- [x] Destroy electronic files from computer/PDAs/removal media (CDs, diskettes) by: Jeffrey McBride
- [ ] Other, please describe:

Section VIII: Risk and Benefits of Study

The risks (the probability and magnitude of harm) to participants must be reasonable in relation to any anticipated benefits for participants and the importance of the knowledge you are expecting to gain. When applicable, the research plan must include provisions for monitoring collected data to ensure the safety of subjects.

1. Describe the potential risks (e.g., psychological, legal, physical, social harm, loss of confidentiality): Injury potential associated with the depth/drop jump and squat is no more than that of any other type of resistance training exercise or other general types of exercise which includes muscle strains or pull. Placement of electrodes for electromyography can cause temporary skin irritation, such as itching or inflammation of the skin.

2. Assessment of level of risk:

- [x] Risks (including physical, emotional, social, legal or financial) are the same as encountered in daily life or during the performance of routine physical or psychological examinations or tests (minimal risk).
- [ ] Risks are more than minimal in that either: a) the probability of harm or discomfort anticipated, or b) the magnitude of harm or discomfort anticipated is greater than that encountered in daily life.
- [ ] Information to be collected could cause participants to be at risk of criminal or civil liability if responses are disclosed outside of the research setting.
- [ ] Information to be collected could be damaging to participant's financial standing, employability, or reputation if disclosed outside of the research setting.

3. Describe procedures for protecting against, or minimizing, the potential risks; including (where applicable) how collected data will be monitored to protect the privacy and safety of subjects: Each subject will be given proper instruction and adequate monitoring during depth jumps and squat performance. During this time they will be given opportunities to ask questions. Subjects will be monitored by research team members with CPR and first aid certifications at all times.

4. Describe the potential benefits of the study:

- [x] Participants of the study may directly benefit (compensation is not considered a benefit): Participants of this study may directly benefit by an increase in knowledge of their own body. Subjects will be informed on any potential issues with lower body landing biomechanics, as well as knowing their 1RM maximum in the back squat, possibly leading to improvements in resistance training programs for

them.

[X] Society may benefit from the study: Society may benefit from this study by gaining a better understanding of relationships between squat capabilities, muscle utilization and landing biomechanics in high level, collegiate athletes of both sexes. This could lead to better training protocols for these athletes, and potentially less injuries.

Please **send an electronic Word attachment (not scanned) of this application and any accompanying materials (recruitment, consent form, data collection instruments such as surveys, or interview questions) as separate files to irb@appstate.edu**. Thank you for taking your time to promote ethical human participant research at Appalachian!

Consent to Participate in Research

Information to Consider About this Research

The Effects of Muscle Activation and Strength on Landing Biomechanics

Principal Investigator: Jeffrey M. McBride

Department: Health, Leisure & Exercise Science

Contact Information:
Jeff McBride, (828-262-6333), mcbridejm@appstate.edu
045 Convocation Center
Boone, NC 28607

What is the purpose of this research?

Strength and muscle activation patterns may be important factors affecting variables associated with landing. The aim of this study is to determine if there are any associations between maximal squat strength and jumping performance in terms of muscle activity patterns and knee position upon landing during various types of jumping activities.

Why am I being invited to take part in this research?

You are being invited to take part in this research because you are between the ages of 18-25 and you qualify for one of two groups: Group 1) Male with at least 2 years of strength and power
training or, Group 2) Female with at least 2 years of strength and power training

Are there reasons I should not take part in this research?

You are free to withdraw from the study at any time without penalty. You are free not to answer any questions or respond to experimental situations that you choose without penalty. There may be circumstances under which the investigator may determine that you should not continue to participate in the study. To participate in this study you should be physically fit. You will be asked to complete a health screening tool to ensure you're able to participate in this study.
If you volunteer to take part in this study, you will be one of approximately 60 people to do so.

What will I be asked to do?

As a participant in this investigation, you will be asked to visit the Holmes Convocation Center's Neuromuscular Laboratory (Room 086) for testing on one occasion lasting approximately two hours. Upon arrival you will be asked to read through and sign an informed consent form, and a research assistant (Courtney Goodman) will be present to answer any questions you may have. The testing session will require the completion of 12 total jumps and test your one repetition maximum (1RM)

back squat strength. The jumps will be separated by 2 minutes each, followed by a 10-minute rest prior to squat.

The 12 jumps will consist of 3 countermovement jumps and 9 drop-jumps from varying heights. A countermovement jump will consist of squatting down to a preferred depth and then reactively jumping straight up. A drop-jump is characterized by dropping from a specified height and, upon landing, reactively jumping as high as possible. A squat consists of standing with your feet shoulder width apart, barbell positioned on your upper back. You will then squat down to 80 degrees as determined by researchers, and return to a standing position. A warm-up of 4-6 reps at 30% of estimated 1RM, 3-4 reps at 50% 1RM, 2-3 reps at 70% 1RM and 1 rep at 90% of 1RM. You will then have up to 4 attempts to reach a true 1RM. The load prescription will be subject to research assistant's discretion and recommendations.

Knee angles will be found using 3D Videography (Vicon). Reflective markers will be applied to the greater trochanter, lateral epicondyle and lateral mallelous of both legs, allowing researchers to track the location of lower body joints during each jump. This will be done through the use of double sided tape attached to the bottom of all 6 markers. You will perform 3 trials of a standard countermovement jump, along with 3 drop-jumps (DJ) from 20, 40 and 60 cm which will be randomized prior to completion. Familirization periods will be given from all of the heights to ensure all subjects are following proper safety protocol, adjusted to box heights, and are landing with the designated force plate area. Depth-jumps will be instructed as follows: drop off of the box then as you land, immediately jump straight up as high as you can. Muscle activity will be measured by electromyography (Delsys Trigno Wireless System) applied to the gluteus maximus, vastus lateralis, and the medial and lateral hamstrings of both legs. EMG's will be attached by preparing the area with an alcohol swab (BD) and then an EMG abrasive pad (BioPak). You are asked not to apply any lotion or creams to the above listed areas 24 hours before your testing session. Shaving a small part of these areas may be needed to ensure adequate adhesion of the EMG electrode. Placing of electrodes will be done in a secure room with only the needed research technician to ensure the privacy of all subjects. If you are uncomfortable with technician placing electrodes, you will be walked through the appopriate location and steps for adhering the electrodes.

What are possible harms or discomforts that I might experience during the research?

Squat and jump performance will be monitored by an individual who is certified in first aid and CPR. Injury potential with the squat, drop jump, countermovement jump, and static jump is no more than that of any other type of resistance training exercise or other general types of exercise which includes muscle strains or pulls. Placement of electrodes for electromyography can cause temporary skin irritation, such as itching or inflammation of the skin.

What are possible benefits of this research?

This research should help us learn more about training to manipulate jump performance. This will provide scientists with more information to accurately develop training programs to meet an individual's needs. By participating in this study you will be given information concerning your jumping performance and squat capabilities. This information may help you to accurately design a training program to enhance your overall jump performance.

Will I be paid for taking part in the research?

There will be no financial compensation for participating in this study.

How will you keep my private information confidential?

Your information will be combined with information from other people taking part in the study. When we write up the study to share it with other researchers, we will write about the combined information. You will not be identified in any published or presented materials. Confidentiality of your records will be maintained at all times during and after your involvement in this study. Individual data collected will remain confidential and will not be disclosed in any published document or shared with anyone but the experimenters.

What if I get sick or hurt while participating in this research study?

If you need emergency care while you are at the research site, it will be provided to you. If you believe you have been hurt or if you get sick because of something that is done during the study, you should call your doctor or if it is an emergency call 911 for help. In this case, tell the doctors, the hospital or emergency room staff that you are taking part in a research study and the name of the Principal Investigator. If possible, take a copy of this consent form with you when you go. Call the principal investigator, Dr. Jeff McBride (828-262-6333) as soon as you can. He needs to know that you are hurt or ill. If you are injured during the study, there are procedures in place to help attend to your injuries or provide care for you. Costs associated with this care will be billed in the ordinary manner, to you or your insurance company. However, some insurance companies will not pay bills that are related to research costs. You should check with your insurance about this. Medical costs that result from research-related harm may also not qualify for payments through Medicare, or
Medicaid. You should talk to the Principal Investigator about this, if you have concerns.

Who can I contact if I have a question?

The people conducting this study will be available to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at 828-262-6333 (Jeff McBride). If you have questions about your rights as someone taking part in research, contact the Appalachian Institutional Review Board Administrator at 828-262-2130 (days), through email at irb@appstate.edu or at Appalachian State University, Office of Research and Sponsored Programs, IRB Administrator, Boone, NC 28608.

Do I have to participate? What else should I know?

Your participation in this research is completely voluntary. If you choose not to volunteer, there will be no penalty and you will not lose any benefits or rights you would normally have. If you decide to take part in the study you still have the right to decide at any time that you no longer want to continue. There will be no penalty and no loss of benefits or rights if you decide at any time to stop participating in the study. This research project has been approved by the Institutional Review Board (IRB) at Appalachian State University. This study was approved on 9/24/2013. This approval will expire on 9/23/2014 unless the IRB renews the approval of this research.

I have decided I want to take part in this research. What should I do now?

The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I understand that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

_____

Participant's Name (PRINT) Signature Date

Vita

Courtney Lea Goodman was born in Reading, Pennsylvania. After graduating from Muhlenberg High School, she attended Slippery Rock University and graduated with a Bachelor of Science in Exercise Science. After graduating, she went on to pursue her Master of Science Degree from Appalachian State University. Here, she took a graduate assistantship under Dr. Travis Triplett. Courtney was awarded the 2014 College of Health Sciences Graduate Student Award and graduated with a Masters of Science in May 2014. Courtney plans to pursue a PhD in Exercise Science and start a career as a college professor. Courtney's parents are Christopher and Patti McNeill who reside in Reading, Pennsylvania.