THE EFFECT OF TRAINING STATUS ON MUSCLE LENGTH CHANGE DURING JUMPING

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by
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Abstract

THE EFFECT OF TRAINING STATUS ON MUSCLE LENGTH CHANGE DURING JUMPING

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The purpose of this investigation was to utilize a novel technique involving the insertion of a Fiber Bragg Grading sensor through the patellar tendon to determine changes in tendon length in a single trained and untrained jumper. Muscle-tendon unit (MTU) force output and length change during stretch-shortening cycle activities has been investigated but the exact mechanism for optimal function is still unclear. It has been speculated that MTU function differs between trained and untrained individuals, thus effecting concentric performance. Fatigue has also been speculated to decrease concentric performance due to an alteration in MTU function. The purpose of this investigation was to determine the effect of training status on muscle, tendon, and muscle tendon unit length change during jumping. One trained jumper (height = 71 in, weight = 82.5 kg, age = 22 yrs) and one untrained individual (height = 71.2 in, weight 74.8 kg, age 19 yrs) were recruited. They both reported to the laboratory one time for three hours. An optic fiber was inserted through the patellar tendon and used to determine tendon length change. An ultrasound probe was attached to the vastus lateralis and used determine muscle length. Each subject was asked to perform a total of 6

individual counter movement jumps (CMJ), 6 individual static jumps (SJ), and 20 sequential CMJ. Individual CMJ were performed before and after the sequential jumps to determine changes in MTU function due to fatigue. The trained subject had a 11.2% increase in peak force, a 2.3% increase in jump height, a 25% decrease in tendon length change, and a 50% increase in muscle length change after 20 countermovement jumps. The ratio of tendon to muscle length change decreased from .86 to .43. The untrained subject had a 3.4% decrease in peak force, a 7.5% decrease in jump height, a 94% decrease in tendon length change, and a 50% decrease in muscle length change after 20 countermovement jumps. The ratio of tendon to muscle length change decreased from .64 to .08. This indicates that a trained individual is better able to maintain muscle length during jumping. Fatigue impacts MTU function by decreasing the muscle's ability to maintain length. Increasing change in muscle length and decreasing change in tendon length decreases concentric performance. Jump training may influence performance by varying the function of the MTU; thus future research should focus on longitudinal study of these variables.

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Introduction

Muscle-tendon unit (MTU) force output and length change during stretch-shortening cycle activities has been investigated but the exact mechanism for optimal function is still unclear (Finni, Ikegawa, Lepola, & Komi, 2003; Finni, Komi, & Lepola, 2000; Hay, Thorson, & Kippenhan, 1999; Komi, 2000; Taube, Leukel, & Gollhofer, 2012). The SSC is made up of three phases; the eccentric phase, the amatorization phase, and the concentric phase (Komi, 2000). During the eccentric phase the MTU lengthens, and during the concentric phase the MTU shortens (Kawakami, Muraoka, Ito, Kanehisa, & Fukunaga, 2002). The amortization phase is the period of transition between the eccentric and concentric phase. The SSC leads to an increase in concentric performance through three main mechanisms; stored elastic energy (Mantovani, Heglund, & Cavagna, 2001), cross bridge potentiation (Brown & Loeb, 1999), and the stretch-reflex (Taube et al., 2012). Initially it was believed that during the eccentric portion of the SSC the muscle and the tendon lengthened (Hay et al., 1999). However, recent literature suggests the muscle may behave differently, and in actuality may be simultaneously shortening, as the MTU as a whole is lengthening (Alexander, 2002; Ichinose, Kawakami, Ito, & Fukunaga, 1997; Ishikawa, Finni, & Komi, 2003; Kawakami et al., 2002; Kubo, Kawakami, & Fukunaga, 1999).

Concentric work production has been shown to be greater when preceded by an eccentric contraction than when performed alone (Cavagna & Citterio, 1974; Cronin,

McNair, & Marshall, 2002; Finni et al., 2000; McCaulley et al., 2007). This increase in work is not accounted for by increases in muscular activity alone, indicating the contribution of energy stored in the MTU. As the MTU lengthens during the eccentric phase, it stores elastic energy. When the eccentric action is coupled with a rapid concentric action, some of the stored elastic energy is transferred to the concentric action, increasing work production. The potential to return stored elastic energy has been quantified as approximately 78% for the tendon (Kubo, Kawakami, Kanehisa, & Fukunaga, 2002) and 56% for the muscle (Linari, Woledge, & Curtin, 2003).

The storage of elastic energy in the tendon has been documented in a number of animal and human investigations (Alexander, 2002; Gosline et al., 2002; Griffiths, 1991; McGowan, Skinner, & Biewener, 2008; Pollock & Shadwick, 1994; Prilutsky, Herzog, Leonard, & Allinger, 1996; Roberts & Azizi, 2011). The elasticity of the tendon is dependent on a number of factors such as tendon cross sectional area and the amount of collagen versus the amount of elastin in the tendon (Gosline et al., 2002). If there is too much elasticity, the tendon loses some potential to return energy; however, if the tendon is too stiff there will be no deformation. Deformation is necessary for the storage of elastic energy (Roberts & Azizi, 2011). In order for optimal deformation to occur in the tendon while the MTU is lengthening, the muscle must produce a force equal to the force exerted on the tendon (McGowan et al., 2008; Pollock & Shadwick, 1994). If the force exerted on the MTU is greater than maximal force the muscle is capable of producing the muscle will lengthen. This is evident in an investigation by Ishikawa and colleagues where individuals performed drop jumps from varying heights (Ishikawa, Niemela, & Komi, 2005). When dropping from optimal heights

the medial gastrocnemius maintained its length while the MTU lengthened. When dropping from a height greater than optimal, medial gastrocnemius lengthened due to the increase in force required to decelerate the body. It is more desirable for the tendon to lengthen rather than the muscle due to the increased capability of the tendon to store elastic energy (Alexander & Bennet-Clark, 1977; Kubo, Kawakami, et al., 2002; Linari et al., 2004); however, the muscle is still capable of storing elastic energy due to the protein composition and elastic components of the muscle.

When the muscle is lengthened it absorbs a portion of the mechanical work required to lengthen it. This active muscle lengthening is known as an eccentric contraction. Numerous investigations have demonstrated greater force generation by the muscle during an eccentric contraction compared to an isometric contraction (Alexander, 2002; Linari et al., 2004). When an eccentric contraction is followed by a concentric contraction the muscle has the potential to return 56% of the elastic potential energy stored during the eccentric contraction to the concentric contraction (Linari et al., 2003). This ability to return energy is due to the storage of elastic energy in the elastic components of the muscle. Both the protein composition and the elastic components of the muscle contribute to the storage of elastic energy (Linari et al., 2004; Lindstedt, Reich, Keim, & LaStayo, 2002). Titin may play a key role in the elasticity of the muscle, as it spans the entire half sarcomere and develops tension as the muscle lengthens (Lindstedt et al., 2002). Based on a model of a half sarcomere created by Williams et. al. (2012), elastic energy storage is greater at the cross-bridges than in either thick or thin filaments (Williams, Regnier, & Daniel, 2012). They found that each cross-bridge can store 20% of the force it is capable of producing in a power stroke.

However, in order to store energy the cross-bridge needs to be tightly bound. Muscle cross-bridging plays in important role in the ability of the muscle to store elastic energy.

Muscle cross-bridging has a positive influence on potential of the MTU to return stored elastic energy in two ways. First, an increase in cross bridging leads to a stiffening of the muscle, and a stiffer muscle may lead to increased potential of the muscle to return stored elastic energy (Lehmann & Dickinson, 1997; Williams, Regnier, & Daniel, 2010; Williams et al., 2012). A stiffer muscle decreases the ratio of muscle fiber length change to MTU length change, optimizing the ability of the MTU to transfer stored elastic energy. Pre-activity in the muscle may lead to an increase in concentric performance through the above mentioned mechanisms (Viitasalo, Salo, & Lahtinen, 1998). The second mechanism through which cross-bridging influences concentric performance is potentiation, or pre-activation. The amount of cross-bridging in the muscle, and the force capabilities of each cross bridge vary depending on the contraction state of the muscle: isometric, eccentric, or concentric. An eccentric contraction, or active lengthening of the muscle pre-activates the muscle, and leads to an increase in the angle of attachment of the muscle cross bridges (Brown & Loeb, 1999). As the angle of attachment increases, the ability of the muscle fiber to produce a force also increases (Brown & Loeb, 1999). While the effect of an eccentric contraction on the binding of myosin and actin during a concentric contraction isn't thoroughly understood, it is theorized that an eccentric contraction may impact regulatory light chain phosphorylation and myosin light chain kinase, leading to a stronger concentric contraction (MacIntosh, 2010).

The presence of a mechanism known as the stretch-reflex or short-latency response (SLR) is evident during the SSC (Taube et al., 2012), and is the third mechanism through which the SSC improves concentric contraction. After a stimulus (stretch) there is an immediate neuromuscular response, followed by a second response (Gollhofer & Rapp, 1993). Both the amplitude and velocity of the initial stimulus effect the strength of the response (Halaki, O'Dwyer, Cathers, & Heritier, 2012). The rate of change in muscle length is detected by the muscle spindles and motor unit firing frequencies are altered proportionately (Gollhofer & Rapp, 1993). When the muscle is quickly lengthened the stretch-reflex is activated and it contributes to an increased force production in the concentric phase (Avela & Komi, 1998).

As stated previously, the amount of length change in the tendon opposed to the muscle effects the amount of energy transferred from the eccentric to the concentric phase. Muscle fiber length changes are not indicative of total MTU changes (Finni et al., 2000). At a given MTU length change, the amount of change due to muscle fiber length change varies. In an action with a countermovement there is less muscle lengthening than in an action without a countermovement through the same range of motion (Kawakami et al., 2002), and some evidence indicates the muscle may actually be maintaining length as the MTU lengthens (Finni et al., 2003). Smaller changes in muscle fiber length at a given MTU length change mean a greater change in length of the tendon (Ishikawa et al., 2003). Since the tendon has a greater potential to store elastic energy than the muscle (Kubo, Kawakami, et al., 2002; Linari et al., 2004), minimizing muscle fiber length may lead to more efficient movement.

It has been well established that training improves performance; however, the mechanisms through which performance is enhanced are unclear. It is possible that adaptations to the muscle-tendon unit influence SSC activity, leading to improvements in performance. Numerous investigations demonstrate that the stiffness of the muscle and tendon can be influenced by training (Duclay, Martin, Duclay, Cometti, & Pousson, 2009; Kubo, Kanehisa, & Fukunaga, 2002; Kubo et al., 2007). Eccentric training has been shown to increase tendon stiffness, which may lead to an increase in the ability of the tendon to store energy improving efficiency (Duclay et al., 2009). Eccentric training also increases the angle of attachment of the muscle (Duclay et al., 2009), and it has been established that an increased angle of attachment increases the force capabilities of the muscle (Brown & Loeb, 1999). Physiological variables may also be the reason for improved performance after training. Changes in muscular activation may be partial responsible for performance improvements (Arabatzi, Kellis, & Saez-Saez De Villarreal, 2010). The type of training used to elicit changes in the tendon and muscle is unclear. Kubo et al. (2007) found that weight training improved tendon stiffness as opposed to plyometric training, while plyometric training improved joint stiffness when weight training didn't. Plyometric training appears to improve performance in activities using the SSC, while weight training does not (Kubo et al., 2007). Isotonic resistance training has also been shown to increase tendon stiffness(Kubo Kanehisa, et al., 2002).

The effect of fatigue on SSC activities has also been investigated (Morio et al., 2011; Wadden, Button, Kibele, & Behm, 2012). A fatigued state is associated with increases in blood lactate and decreases in maximum voluntary contraction (Wadden et al., 2012). Both neural and muscular fatigue leads to decreases in performance. Fatigue leads to a decrease in

the response to eccentric stretching (Komi, 2000). As stated previously, the eccentric movement is essential to the resulting improvements in concentric performance. Muscular damage associated with fatigue may lead to a reduced stretch-reflex sensitivity and may also decrease muscular stiffness (Komi, 2000). Fatigue in the muscle may lead to increased muscle lengthening as opposed to tendon lengthening.

Understanding the muscle-tendon unit and its function is essential to further advancing training techniques. Previous research has established the importance of muscle-tendon unit function to performance and the importance of training to muscle tendon unit function, however the mechanism through which training improves SSC performance is unclear. The purpose of this investigation is to determine if the difference in muscle and tendon function between trained and untrained individuals.

Methods

Subjects

One trained jumper (height = 180 cm, weight = 82.5 kg, vertical jump 29.5 in, age = 22 yrs) and one untrained individual (height = 181 cm, weight 74.8 kg, vertical jump 25.5 in, age 19 yrs) were recruited for this study. The trained subject had at least two years of weight training experience. The untrained subjects were perform less than two hours of stretch-shortening cycle activities (jumping, running, hopping) per week for the previous two years. Subjects refrained from any strenuous training for 24 hours prior to testing. Subjects were asked to volunteer and provide their written informed consent to participate in the study (Appendix II), and filled out a health history questionnaire. They were also compensated $200 upon completion of their participation. Approval was obtained from the Appalachian State University Institutional Review Board prior to data collection (Appendix I).

Study Design

Subjects reported to the neuromuscular laboratory once. Subjects performed three countermovement jumps and three static jumps with a one minute rest between each jump, in a randomized fashion. Following a five min rest they then performed 20 repetitions of a countermovement jump. These countermovement jumps occurred once 10 seconds and the time to complete 20 jumps was approximately 3.3 minutes. Immediately after the 20 jumps

were complete, an additional two static and two countermovement jump were performed. Subjects then rested for 10 min or until their metabolic values were back to resting levels. No formal instruction concerning jumping was provided to the subjects, however, subjects were asked jump as high as possible. During trial jumps the depth of each subjects countermovement jump was measured and marked with a rope. Subjects were instructed to use the rope as an indicator of the bottom of their countermovement. During the two jump conditions jump height (VanBruggen, Hackney, McMurray, & Ondrak, 2011), negative work (J), positive work (J), landing work (J), total work (J), and energy expenditure (J) were assessed for all 20 repetitions. Mechanical efficiency (ME) will be calculated as the ratio between the total work performed and energy expenditure for each jump condition. Muscle-tendon length changes will be monitored during all jumps use a Fiber Brag Grating (FBG) sensor inserted in the patellar tendon and by using visual ultrasound to monitor the vastus lateralis.

Work Performed

Work performed during the eccentric phase, concentric phase and landing were calculated during each jump using a force plate (AMTI, BP6001200, Watertown, MA, USA) and an unweighted bar attached to two linear position transducers (LPTs) (Celesco Transducer Products, PT5A-150, Chatsworth, CA, USA) by integrating the area under the force-displacement curve (Liu et al., 2006). Total work performed was the summation of both the negative work, positive work and landing work (Bosco et al., 1987). Data collected from the right side of the bar was used during analysis. Analog signals from the force plate and two LPTs (right side of the bar) was collected during each jump at 1,000 Hz using a BNC-2010

interface box with an analog-to-digital card (National Instruments, NI PCI-6014, Austin, TX, USA). Data was recorded and analyzed using a custom designed LabVIEW Program (National Instruments, Version 7.1). Signals from the two LPTs and the force plate as well as data derived using double differentiation underwent rectangular smoothing with a moving average half-width of 12. Force plate and LPT voltage output was converted into vertical ground reaction force and displacement from laboratory calibrations. The LPT was mounted above the subject to the anterior (LPT A) and posterior (LPT B), forming a triangle when attached to the barbell (Cormie et al., 2008). Vertical displacement was calculated by combining known displacements with measurements from LPT A and B. The method displays an intraclass correlation coefficient (ICC = 0.95) above the minimum acceptable criterion of 0.70 and is significant at an alpha level of 0.05. Peak displacement (jump height) was obtained from each subject during each jump. Peak force during each jump was also obtained from each subject.

Energy Expenditure and Mechanical Efficiency

Respiratory gases were measured using a Parvo Medics Metabolic cart. Breath-by-breath analysis of percent expired carbon dioxide (CO2), percent expired oxygen (O2), and total volume of expired air was collected and analyzed. Prior to each testing session the unit was calibrated to room air and a known gas (16% O2 and 4% CO2). The subjects' metabolic values were determined during the three minutes prior to beginning the set of jumps to establish baseline O2 consumption. The Haldane Transformation was used to determine absolute oxygen consumption (VO2). Energy expenditure (J) was calculated from total O2 consumption (L) during each set of jumps through the following conversion (20,202 J/L of

O2 (L)) (Kyrolainen et al., 2003). Mechanical efficiency (ME) was then calculated as the ratio between total work performed (J) and total energy expenditure (J).

Fiber Brag Grating (FBG) Sensors

This testing procedure involved the insertion of an FBG sensor through the patellar tendon of the knee (Finni et al., 2000). The amount of light passing through the sensor allowed for a calculation of patellar tendon force through a calibration procedure involving isometric knee extensions at four different intensities: easy, easy-medium, medium-hard, hard . A transceiver unit containing a PIN photodiode receiver and light emitting diode was attached to a plastic optic fiber cable (diameter 0.5 mm, length 1.0 m) and FBG sensor at a wavelength of 820 nm. Light intensity modulation as a result of pressure placed on the FBG sensor inserted in the patellar tendon caused variation in the voltage output from the transceiver. Force output during the knee extension was recording using a force transducer (Lafayette Instrument Company, SL1000lb, Lafayette, IN) attached to the lower leg. The voltage output from the transceiver and force transducer were recorded using a shielded BNC adapter chassis (National Instruments, BNC-2090, Austin, TX) and an A/D card (National Instruments, NI PCI-6014, Austin, TX) at a sampling frequency of 1000 Hz. LabVIEW (National Instruments, Version 7.1, Austin, TX) was used for recording and analyzing the data. Radiographs allowed for determination of moment arm length of the patellar tendon for calculation of knee torque. The force in the tendon was calculated using knee torque and plotted with wavelength change at each intensity to calculate a linear regression equation. Tendon length change was then calculated using a number of steps. First change in the wavelength of light was calculated the nominal wavelength value from the collected

wavelength. When the tendon exerts a force it can bend the fiber in multiple directions resulting in either a positive or negative change in wavelength. Because of this the absolute value of the data set was then taken. The regression equation was then used to convert wavelength to force. The force curve was smoothed using a customized Labview program. According to Couppe et al. (2012), the patellar tendon in a young (24 years) males has a stiffness of 3622 N/mm. The force time curve was divided by this constant to determine tendon length change in mm.

Visual Ultrasound

An ultrasound probe (50 mm, 7.5 MHz, B-mode, HITACHI EUB-420 with scanning frequency of 30 Hz) will be firmly attached to the mid-thigh immediately above the vastus laterlis (VL). The real-time images was captured on videotape at 30 Hz and analysed with kinovea software (Joan Charmant & Contrib). The superior and inferior aponeurosis and a fascicle will be identified and digitized from each image. For each subject, the entire length of the VL fascicle (LVL) was estimated using trigonometry (Finni et al., 2001; Finni et al., 2003) to make calculation possible. This estimation was necessary because LVL cannot be visualized throughout the contact phase of the jumps. The error for estimating LVL with this method has been reported to be 2–7% (Finni et al., 2001; Finni et al., 2003). Previous comparison has revealed that errors of the estimated length and pennation angle are less than 5.9 and 4.5%, respectively. Consequently, the linear extrapolation method can be applied reliably for the contact phase. The instantaneous lengths of fascicle and tendinous structures were determined on the basis of a geometric MTU model proposed by Allinger et al. (1996). The length of tendinous tissues was defined as the sum of the proximal and distal tendinous

structures, and aponeuroses (Kurokawa et al., 2001, Muraoka et al., 2001). Length changes in the tendinous tissue (tendon and aponeurosis; LT) were calculated as previously reported (Fukunaga et al., 2001; Kurokawa et al., 2001). The muscle length curve was smoothed using a customized Labview program. The nominal muscle length (length while standing) was subtracted from the smoothed data set so that muscle length change is reported.

Results

The trained subject had a 11.2% increase in peak force, a 2.3% increase in jump height, a 25% decrease in tendon length change, and a 50% increase in muscle length change after 20 countermovement jumps. These changes are reported as fatigued and non-fatigued values in Table 1. The ratio of tendon to muscle length change decreased from .86 to .43. The untrained subject had a 3.4% decrease in peak force, a 7.5% decrease in jump height, a 94% decrease in tendon length change, and a 50% decrease in muscle length change after 20 countermovement jumps. These changes are reported as fatigued and non-fatigued values in Table 2. The ratio of tendon to muscle length change decreased from .64 to .08.

When not fatigued, the trained subject jumped with 19.1% more force than the untrained subject. The trained subject also jumped 9% higher, and his tendon to muscle length change ratio was 25% greater than the untrained subject.

Discussion

This investigation supports the theory that fatigue influences concentric performance by increasing muscle length change during the eccentric phase of a counter movement jump. It also supports theories regarding the effect of strength training on muscle stiffness.

Assuming the theory that everyone will use the mechanics that allow them optimal movement during a countermovement jump, it is not logical to compare tendon or muscle length changes between subjects. Both depend on the depth of the countermovement. Therefore, the ratio between tendon length change and muscle length change was calculated. A higher ratio of tendon to muscle change means the tendon is lengthening more than the muscle. Since the tendon has a greater potential to store elastic energy than the muscle, a larger ratio of tendon to muscle length change is preferred. (Kubo et al., 2002; Linari et al., 2003).

In this investigation the muscle lengthened during all trials, different from conclusions drawn by Ishikawa et al. (2005). The reason for this difference is likely the muscle tendon complex analyzed. Ishikawa examined the function of the achilles tendon and gastrocnemius muscle as opposed to this investigation which examined the patellar tendon and vastus lateralis (Ishikawa et al., 2005). This investigation supports results found by Finni and colleagues, who examined the patellar tendon and vastus lateralis. They found that

during the countermovement jump there was some lengthening, and suggested that minimal lengthening was optimal (Finni et al., 2003).

The difference between the trained and untrained individual, and between fatigued and not fatigued state, indicate that when an individual is untrained or fatigued, the ability of the muscle to produce force decreases. This is evident when we consider the difference in force production between individuals and the decrease in force when the untrained individual became fatigued, combined with the changing tendon/muscle ratio. The increase in force production by the trained individual indicates that 20 jumps was not enough to cause fatigue. However, the trained individual did see a decrease in the ratio of tendon to muscle length. This change in MTU function without performance may indicate that the individual is using some unknown compensatory mechanism to maintain force output. This compensatory mechanism is necessary because the decrease in the tendon-muscle ratio indicates muscular lengthening, which is evident in Figure 1. If the force exerted on a muscle is greater than the force it is capable of producing it will lengthen (McGowan et al., 2008; Pollock & Shadwick, 1994). This lengthening of the muscle means less total MTU length change will occur in the tendon, decreasing the ability of the MTU to store elastic energy, and it may decrease concentric performance. This decrease in concentric performance was evident in the untrained subject, who had a decrease in jump height. The untrained subject had a dramatic change in MTU function, as evident in Figure 2. The large decrease in tendon decrease, accompanied by the large decrease in tendon-muscle ratio could indicate changing mechanics due to fatigue.

The exact mechanism through which the muscle's force production capabilities are decreased is not entirely understood, but likely involves both a decrease in the strength of

cross-bridge attachments and decreased stretch-reflex sensitivity (Debold, 2012; Komi, 2000). This investigation provides evidence that training may decrease the effects of neuromuscular fatigue after 20 consecutive jumps, leading to an increase in performance due to the continued functionality of the SSC. The results of this study demonstrate the plausibility of using the FBG sensor to measure tendon tension. Further investigations are required to determine if the results of this investigation are universal.

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Table 1. Trained Subject Results

	Force (N)	Jump Height (m)	Δ Tendon Length (mm)	Δ Muscle Length (cm)	Ratio
Non-Fatigued	1881	.44	9.6	11.1	.86
Fatigued	2091	.45	7.2	16.66	.43

Table 2. Untrained Subject Results

	Force (N)	Jump Height (m)	Δ Tendon Length (mm)	Δ Muscle Length (cm)	Ratio
Non-Fatigued	1521	.40	4.94	7.7	.64
Fatigued	1470	.37	.29	3.8	.08

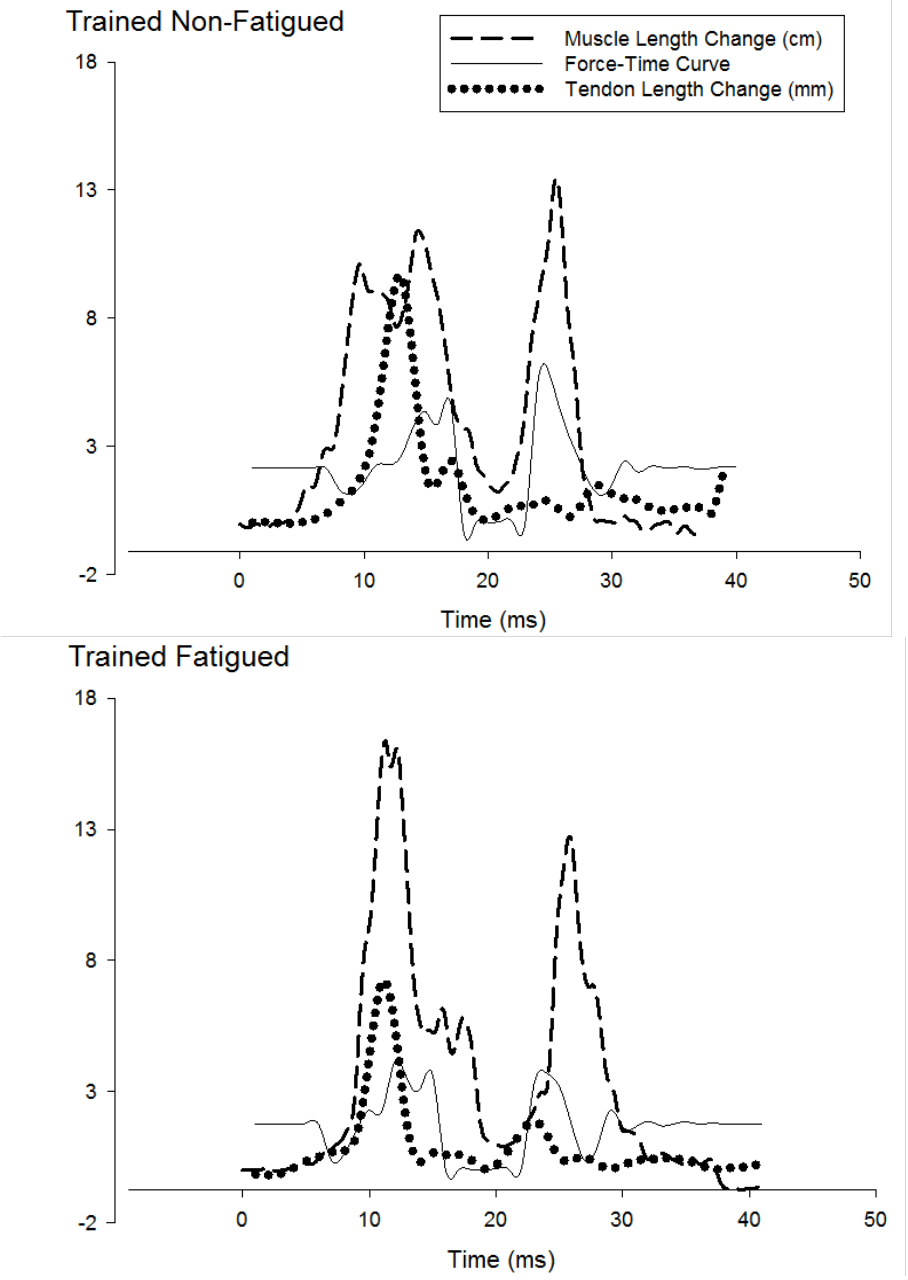

Figure 1. Trained non-fatigued and fatigued jump

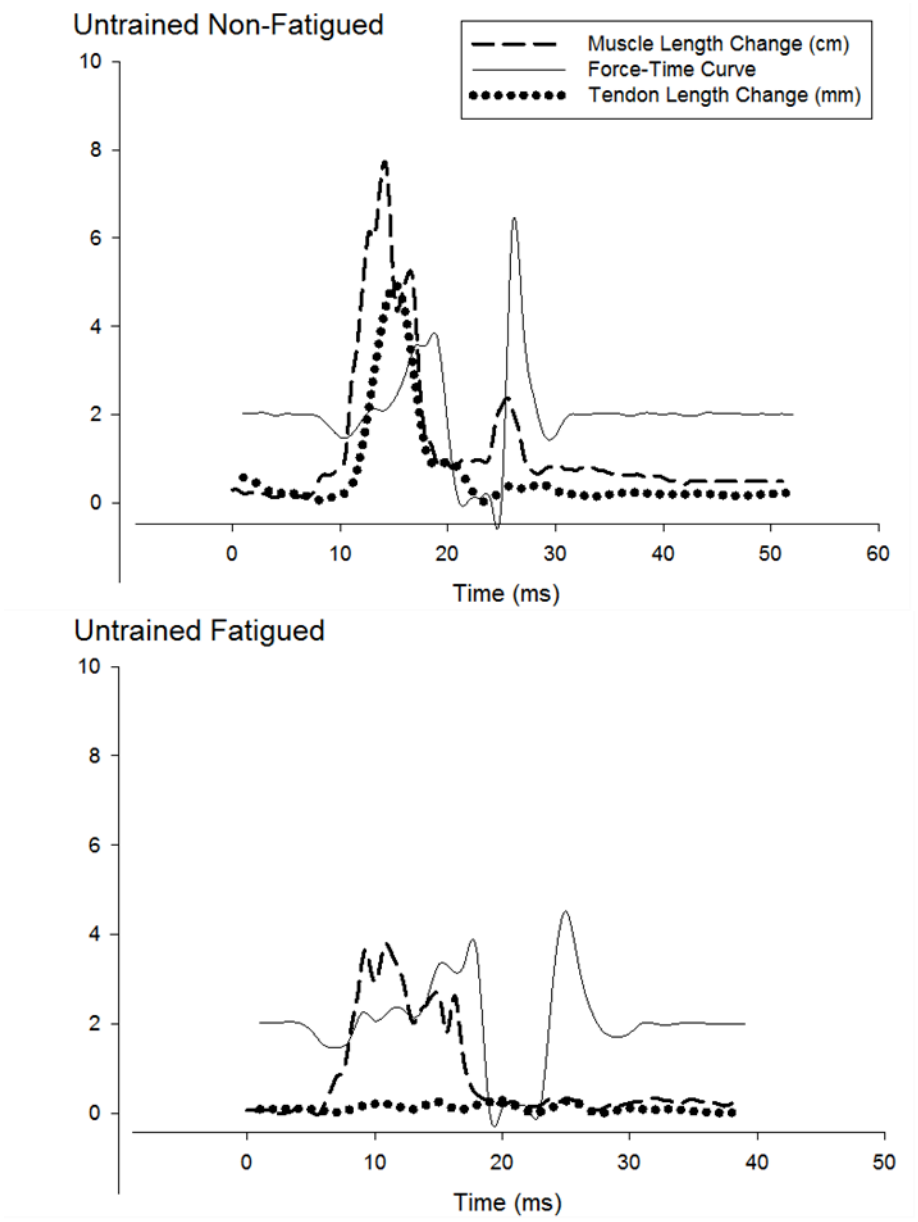

Figure 2. Untrained non-fatigued and fatigued jump

Appendix I

Request for Review of Human Participant Research

Appalachian Human Research Protection Program

IRB # *(To be filled out by IRB Administration)*

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: Effect of Training Status on Muscle-Tendon Length Change During Jumping

Study Description: *Please describe briefly the objectives of the study with the purpose, research question and any relevant background information.* The proposed investigation is to assess variation in both force and length change of a muscle-tendon unit during various types of single and repetitive jumps. While extensive data has been published on external force production (force plate measurements) during strength and power activities very limited data is available concerning direct measurement of in vivo force production and length change characteristics of the muscles and tendons during the stretch-shortening cycle. These measurements would provide valuable information concerning the actual biomechanical mechanisms that determine an individual's jumping ability.

2. Principal Investigator(s) and responsible faculty member if student is the PI: Dr. Jeffrey M. McBride
Department(s): HLES

3. By submitting this request, the Principal Investigator (and responsible faculty member if PI is a student) accepts 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 and the Principal Investigator and responsible faculty member if PI is a student) have agreed to conduct this application process by electronic means, and this application is signed electronically by the Principal Investigator and by the responsible faculty member if a student is the PI.

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 M. McBride	mcbridejm@appstate.edu
PI Name	PI Email address
Responsible Faculty Name if PI is a student	Responsible Faculty Email address if PI is a student

4. Do you plan to publish or present off-campus? [ ] No [X] Yes

5. Does this research involve any out-of-country travel? [X] No [ ] Yes

7. Type of Research, check all that apply:

- [X] Faculty Research
- [ ] Dissertation/Thesis/Honor's Thesis
- [ ] Product of Learning
- [ ] Class Project – Course Number:
- [ ] Educational Research Involving Normal Education Practices
- [ ] Other: describe

8. Source of Funding

- [ ] Not Funded
- [X] Funds Awarded
- [ ] Funds Pending
- [ ] Federally Funded
- [ ] University Funded: describe

If funds awarded/pending, provide sponsor name, Sponsored Programs number:
National Strength & Conditioning Association

Attach a copy of the contract/grant/agreement.

9. 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

10. 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 be involved with the research.*
N/A (no agencies involved).

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@appstat edu
Judith Paul	Co-I	a,b,c,f,g,h,j,l,m	paulja@appstate.edu
Travis Triplett	Co-I	a,b,c,f,g,h,i,j,l,m	triplttnt@appstate.ed u

(Note: If you need additional room, you can add rows by going to right click, insert, and then insert rows below. Personnel changes made after IRB approval can be submitted via email with the above information.)

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) should be documented by the IRB to show that risks to participants is minimized. The IRB uses the Research Personnel Form to document investigator expertise.

Section III: Conflict of Interest

1. Are there any known or potential conflicts of interest related to this research?

Conflict of interest relates to situations in which financial or other personal considerations may compromise or involve the potential/have the appearance for compromising an employee's objectivity in meeting University responsibilities including research activities.

Examples of conflicts of interest include but are not limited to: an investigator has equity in a business that conducts research in a related area; an investigator will receive an incentive/bonus based on the number or speed of enrollment or outcome of a study; or an investigator or family member is a consultant, holds an executive position or serves as a board member of the research sponsor or its holdings.

[X] No [ ] Yes If yes, describe and explain how participants will be protected from the influence of competing interests.

Section IV: Participant Population and Recruitment

1. Number of participants sought: 15

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 have established guidelines for the equitable selection of participants. Are participants 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 be male and between the ages of 18 and 25 who have at least 2 years of jumping experience (i.e. recreational involvement in basketball, volleyball, etc.). 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. Additional exclusion criteria will be subjects who have take Cipro (or any other antibiotic in the fluoroquinolone drug class) in the past month.

5. Recruitment Procedures (how will you find participants?)

- ☐ Student Subject Pool; indicate pool:
- x Email/Mailing/Handout
- ☐ Website ad/Newspaper ads/Flyers/Postings
- ☐ School children with request sent to parents
- ☐ Participants will be approached by staff members
- ☐ Other (explained below)

A copy of any recruitment materials must be submitted with this application.

6. Explain details of recruitment (e.g., obtain list of student emails from Registrar's office and send them recruitment email): Subjects will be males between the age of 18 and 25 will be recruited from the general population. Subjects will not be excluded solely on

the basis of race, color, or any other demographic characteristic other than age and gender. Participants from this study WILL NOT be recruitted from Dr. Jeffrey McBride's classes.

7. Does the research include any compensation, monetary inducements, or reimbursement for participation in this research study?

[ ] No [X] Yes If yes, explain payment schedule: Subjects will receive a payment of $200 upon completion of their data collection.

Section V: Informed Consent Process

1. Explain how informed consent will be obtained. *If applicable, include information about: the setting, whether participants will have an opportunity to ask questions, and the roles of any non-research personnel involved. If potential participants or their legally authorized representatives (e.g., parents) are non-English speaking, please explain how the investigator will identify these participants and ensure their ability to understand information about the study to provide consent.* Several days prior to the day of data collection participants will be given an informed consent sheet upon entering the Neuromuscular & 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. A Research Assistant (Judith Paul) and a faculty member (Dr. Travis Triplett) familiar with the optic fiber insertion procedure 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
- [ ] 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 for participants or legally authorized representatives?

☒ No ☐ Yes If yes, address criteria to waive elements of consent:

Section VI: Study Procedures

1. Projected data collection dates: August 10, 2012 to August 10, 2013.

2. Describe research procedures as they relate to the use of human participants. *Information should include what participants will be asked to do, duration of procedures, and frequency of procedures*.

Subjects will complete one session, lasting approximately 2 hours, involving DEXA for body composition and 20 repetitions of a static jump and 20 repetitions of a countermovement jump. Static jumps and countermovement jumps will occur every 10 seconds and the time to complete 20 jumps will be approximately 7 minutes. A static jump involves lowering the body to a knee angle of 90 degrees. The subject will hold this position for 5 seconds before jumping upwards as high as possible. The countermovement jump will involve rapidly moving downwards to a knee angle of 90 degrees and then immediately moving upwards and jumping as high as possible. The subjects will perform the jumps while standing on a force plate and with a plastic bar on their shoulders. Lactate will be measured at rest by a finger prick before the beginning of the test, and immediately upon completion of the test. The subject will be pricked a total of 2 times with a total of 200 μL of blood taken. Respiratory gases will be measured using a telemetered VO2 system which involves placing a mask over the subject's mouth. This is the same device as used for a VO2 max treadmill test but used instead to measure gas exchange during jumping. For measurement of tendon length change a chemically sterilized optic fiber (diameter 0.5 mm) will be inserted through the patella tendon using a 20 gauge needle (diameter of 0.9 mm). The area in which the optic fiber will be inserted will be anesthetized using a strong topical anesthetic cream one hour prior to the actual procedure to ensure the area is without sensation. The area for optic fiber insertion will then be shaved, cleaned and disinfected (iodine preparation) and then draped for the surgical procedure. The ends of the optic fiber will then be fitted with an optic fiber light source (transmitter) and a light source receiver for quantification of patellar

tendon loading during testing. Following the testing, the optic fiber will be removed from the patella tendon and post-operative care will be administered to minimize the possibility of infection. The process of optic fiber insertion has been previously approved by Dr. Jay Cranston, who observed Dr. Travis Triplett performing this technique and by the IRB. The approval process for optic fiber insertion has also been outlined by the IRB subcommittee for biomedical procedures (Tendon Fiber Optics: An individual performing tendon fiber optics should meet one of the following two criteria to be approved by the IRB for use of the technique: Documented experience (10 successful attempts); Competency assessment by another individual who meets criteria. It is also acceptable that an approved individual can train and assess competency of another individual who wishes to become proficient in the technique. Until competency is attained, any investigator who does not meet the above criteria will have to specify an approved individual as the primary individual who will perform the technique and any techniques performed by the not-yet approved investigator must be under the direct supervision of an approved individual). The level of risk and discomfort for optic fiber insertion would be equivalent to or less than that of a muscle biopsy. For measurement of muscle length change an ultrasound probe (60 mm, 7.5 MHz, B-mode, scanning frequency of 42 Hz) will be firmly attached to the mid-thigh (vastus laterlis muscle) using an Ace bandage and athletic tape. This is a non-invasive procedure as the probe is attached to the surface of the skin. Blood samples will be analyzed using a lactate plus analyzer (nova biomedical).

3. Participants' identification (check one):

- [ ] Information is collected so that participants CANNOT be identified directly (by names, images or other identifiers) or indirectly (by linking responses to participants).
- [X] Information is collected so that participants CAN be identified, either directly or indirectly, by the research team but identifying information will not be disclosed publicly.
- [ ] Information is collected so that participants CAN be identified, either directly or indirectly, by the research team and identifying information will be disclosed publicly.

4. Check all locations of study procedures that apply:

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

5. Data collection

5a. Please check all data collection activities involved in this study:

- [ ] Paper Surveys / Questionnaires

- [ ] Online Surveys / Questionnaires Name of Survey Provider:
- [ ] Telephone Surveys / Questionnaires Name of Survey Provider:
- [ ] Standardized Written / Oral / Visual Tests
- [ ] Interviews
- [ ] Focus Groups
- [ ] Tasks
- [ ] Public Observation
- [ ] Classroom Observation/Work Site Observation
- [ ] Voice, video, digital or image recordings made for research purposes
- [ ] Materials (i.e., data, documents, records/specimens) that have been collected or will be collected for **non research** purposes
- [ ] Collection or study of materials (i.e., data, documents, records/specimens) that are publicly available or if the information is recorded so that participants cannot be identified, directly or indirectly through identifiers
- [ ] Materials (i.e., data, documents, records/specimens) that have been collected for another research project
- [X] Moderate exercise and muscular strength testing
- [ ] Other:

5b. If your study <u>does not involve biomedical procedures skip to question #6</u>.
Otherwise, select all data collection activities that apply:

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

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

- [X] 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? 2
- [ ] How much blood will be drawn at one time? 100 μL
- [ ] How much blood will be drawn in an 8-week period? 200 μL
- [ ] How often will collection occur? Blood collection will occur 2 times (before and after jumping protocol)

- [ ] Noninvasive procedures to collect biological specimens for research purposes
- [x] Sterile Surgical/Invasive procedures
- [ ] Banking of biological materials
- [ ] Noninvasive procedures to collect data such as use of physical sensors applied to surface of body and electrocardiography

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- [x] Procedures involving x-rays (e.g., DEXA scan for body composition)
- [ ] Ingestion of wholesome foods without additives
- [ ] Ingestion/application of substances other than wholesome foods without additives
- [ ] Clinical study of a drug/medical device
- [ ] Obtaining medical data from a health care provider, health plan or health care clearinghouse
- [ ] Genetic Testing
- [ ] Other: describe

5c. Is this research FDA-regulated (i.e., It is an experiment that involves one or more of the following test articles: foods/dietary supplements that bear a nutrient content/health claim, infant formulas, food/color additives, drugs/medical devices/biological products for human use)? N/A

☐ No ☐ Yes

6. Is deception involved?

☒ No ☐ Yes If yes, please describe:

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

☒ No ☐ Yes If yes, please describe:

Section VII: Confidentiality and Safeguards

1. In most cases, the research plan should include adequate provisions to protect the privacy of subjects. How will the confidentiality of participants be maintained (e.g., how will access to participants be controlled)?

Subjects will be referred to only by subject code and all data and results will be kept in a locked file cabinet in the Neuromuscular & Biomechanics Laboratory. The key to the subject code will be destroyed within two years of collecting data. Individual data will not be reported in results of final publication.

2. Will collected data be monitored to ensure the safety of subjects (e.g., survey includes a question about suicidality so the investigator will…)?

☒ No ☐ Yes If yes, please explain procedures to ensure safety of participants:

3. Describe what will be done with the data and resulting analysis:

The data will be analyzed and statistical significance testing will be performed for interpretation of the results. A manuscript will be submitted for publication and the study will be presented at a national conference.

4. Describe measures you are taking to safeguard study data (check all that apply):

- ☐ Data is not linked to identifying information
- ☒ **X** Maintain consent forms in a separate location from data
- ☒ X Using subject codes on <u>all</u> collected data and maintaining the key linking subject codes with identifiable information in a separate location from data
- ☒ X Locking cabinets/doors. List location: Neuromuscular & Biomechanics Laboratory
- ☒ X Data kept in area with limited public access. List location: Neuromuscular & Biomechanics Laboratory
- ☒ X Password protected computers

- [ ] Encryption
- [ ] PDAs and removable media (e.g., CDs, etc.) will be kept in a secure location. List location:
- [ ] Other, please describe:

5. Data Sharing

5a. What type of data will be shared? (*Note: Sharing includes releasing, transmitting and providing access to <u>outside</u> of the research team.)* Check all that apply:

- [ ] Data collected anonymously
- [ ] Anonymized or De-linked data. Identity was once associated with data/specimen but identifying information destroyed
- [X] Coded and linked data (Data is coded. With the code, the data may be linked back to identifiers, but the link back to identifiers will not be shared.)
- [ ] Identifiable Data (e.g., names, email addresses, date of birth, IP addresses) Indicate which secure method(s) of transmission will be used:

5b. If identifiable data will be shared <u>within or outside of the research team</u>, please explain how it will be shared (check all that apply):

- [ ] Secured Website. Please provide name of website:
- [ ] Encrypted email
- [ ] U.S. Postal Service or other trackable courier services
- [ ] Fax in a secured area
- [ ] Shared drive with password protection
- [ ] Personal delivery by member of research team
- [ ] Private telephone conversation to member of research team
- [ ] Other, please describe:

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

6a. How long will the data be stored?

- [ ] 1 year after study conclusion
- [X] 5 years after study conclusion
- [ ] Indefinitely
- [ ] Data without identifiers stored indefinitely
- [ ] Other, please describe (e.g., sponsor requirements):

6b. How will data be destroyed?

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

Section VIII: Risk and Benefits of Study

1. The risks to participants must be reasonable in relation to anticipated benefits, if any, to participants and the importance of the knowledge that may be reasonably be expected to result. Select all applicable:

[X] Participants of the study may directly benefit by (describe)*:* Subjects will receive their individual results from the study and provided with comparative norms to provide them with knowledge of their current performance capabilities in jumping. [*Note that compensation is not considered a benefit.]*

[X] Society may benefit from the study by (describe): Subjects will be informed of their valued participation in expanding the body of knowledge in the area of exercise science.

2. Describe the potential risks (e.g., psychological, legal, physical, social harm, loss of confidentiality) to any individual participating in this project: Injury potential with jumping 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. With the optic fiber insertion there is the possibility of post-sampling infection resulting from the optic fiber and post-operative care. There are no known risks associated with the use of visual ultrasound. The risks of collecting a blood sample from the subject include the possibility of local discomfort (pinch when the needle enters your skin), minor bruising or bleeding at the site (10%), possible temporary lightheadedness, infection (<0.01%), or development of a blood clot (<0.01%). The amount of blood being withdrawn 200 µL (two finger pricks) and will not influence the ability of the subject to participate in normal daily activities.

3. Assessment of level of risk:

[ ] 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).

[x] 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.

4. Describe procedures for protecting against, or minimizing, the potential risks: This risk with optic fiber insertion will be minimized by taking samples in a hygienic setting with sterilized instruments and optic fiber. The subject will be instructed not to shower during the first day after the procedure, however, when doing so later the incision should be protected against direct water contact. To help minimize the mild discomfort that is experienced by subjects after the procedure the wound will be firmly bandaged and treated with an ice pack to aid in the healing process. The process of optic fiber insertion has been previously approved by Dr. Jay Cranston, who observed Dr. Travis Triplett performing this technique and by the IRB. The approval process for optic fiber insertion has also been outlined by the IRB subcommittee for biomedical procedures (Tendon Fiber Optics: An

individual performing tendon fiber optics should meet one of the following two criteria to be approved by the IRB for use of the technique: Documented experience (10 successful attempts); Competency assessment by another individual who meets criteria. It is also acceptable that an approved individual can train and assess competency of another individual who wishes to become proficient in the technique. Until competency is attained, any investigator who does not meet the above criteria will have to specify an approved individual as the primary individual who will perform the technique and any techniques performed by the not-yet approved investigator must be under the direct supervision of an approved individual). The optic fiber insertion procedure, such as that used in this current investigation, has not been shown to cause any acute or chronic harm to the body. This procedure has been reported in 50 previous research publications. Laboratories using this technique include the Division of Orthopedic Surgery at the Karolinska Institute in Sweden, and the Department of Biomedical Engineering at the Cleveland Clinic Foundation. This procedure has been previously performed by the investigators at the University of Jyvaskyla, Finland and Appalachian State University with no report of adverse effects. The level of risk and discomfort would be equivalent to or less than that of a muscle biopsy. Jumping performance will be monitored by an individual who is a Certified Strength & Conditioning Coach (CSCS) as regulated by the National Strength & Conditioning Association as well as first aid and CPR certification. The risk of infection associated with the finger prick method of collecting blood lactate is minimal, and will be protected against by cleaning the finger with an alcohol swab before blood collection. A trained and experienced individual will perform the technique and blood will be collected in a hygienic setting with sterile materials and biohazard protection measures to minimize these risks. In the rare case of research personnel exposure to blood or tissue, we will analyze blood for HIV and hepatitis (a positive HIV or hepatitis test will be reported to them).

5. If human subject data/specimens will be used for future research that is not described above, please explain. (Future use of data/specimens should be disclosed to the participant in the informed consent.) Data from this study may be used in a future study comparing different subject populations with different training statuses. N/A

Please check any materials below that will be submitted with your application. Note: please submit as separate files.

- [ ] Recruitment wording
- [X] Consent form(s)
- [ ] Letter(s) of Agreement
- [ ] Research Personnel Form(s)
- [ ] Instruments (Survey questions, interview questions, etc.)
- [ ] Copy of grant/contract/agreement
- [ ] Other (please describe):

Please **send an electronic Word attachment (not scanned) of this application and any accompanying materials to irb@appstate.edu**. Thank you for taking your time to promote ethical human participant research at Appalachian!

Appendix II

Appalachian
STATE UNIVERSITY

Consent to Participate in Research
Information to Consider About this Research

Effect of Training Status on Muscle-Tendon Length Change During Jumping

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?

Maximizing jumping performance has to do with the proper use of your muscle and tendons. This research will examine the force output and length of your muscle and tendons to see how they function during jumping. This will help in our understanding of how to train to help improve jumping ability.

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

You are being invited to take part in this research because of your general experience in jumping (recreational involvement in basketball, volleyball, etc.).

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 be involved with experimental situations you don't want to 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 about 20 people to do so. You will not be allowed to participate in this research if you have taken Cipro (or

any other antibiotic in the fluoroquinolone drug class) in the past month.

What will I be asked to do?

You will be asked to come to the Neuromuscular & Biomechanics Laboratory several days prior to the day of data collection and will be given an informed consent sheet upon entering the Laboratory. A verbal explanation of research procedures will be given, and you will also be asked to read through the information and ask questions at any time. A Research Assistant (Judith Paul) will be available as you read through the form to answer any questions. You will be asked to complete one testing session, lasting approximately 2 hours, involving an x-ray for body composition and 20 repetitions of a static jump and 20 repetitions of a countermovement jump. Static jumps and countermovement jumps will occur every 10 seconds and the time to complete 20 jumps will be approximately 7 minutes. A static jump involves lowering the body to a knee angle of 90 degrees. You will hold this position for 5 seconds before jumping upwards as high as possible. The countermovement jump will involve rapidly moving downwards to a knee angle of 90 degrees and then immediately moving upwards and jumping as high as possible. You will perform the jumps while standing on a force plate and with a plastic bar on their shoulders. Your lactate level, at rest, will be will be measured by a finger prick before you begin the jumping protocol, and immediately after completion of the protocol (each finger prick will involve 1-2 drops of blood). The amount of oxygen you use during jumping will be measured by placing a mask over your mouth. For measurement of tendon length change an optic fiber of a very small diameter (sewing thread) will be inserted through the tendon on the front of your knee using a needle like that used for a blood draw. The area around the knee and portions of the upper thigh and lower leg will be shaved for the optic fiber insertion procedure. For measurement of muscle length change an ultrasound probe will be attached to your thigh using an Ace bandage and athletic tape.

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

Jumping performance will be monitored by an individual who is a Certified Strength & Conditioning Coach (CSCS) as regulated by the National Strength & Conditioning Association as well as being certified in first aid and CPR. Injury potential with jumping 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. While optic fiber insertion in the tendon on the front of your knee can be uncomfortable there is no danger to the tendon. A topical analgesic will be used on the front of your knee to minimize any discomfort that might be associated with the optic fiber insertion. With the optic fiber insertion there is the possibility of infection resulting from the optic fiber and subsequent care. This risk with optic fiber insertion will be minimized by performing the procedure in a hygienic setting with sterilized instruments and optic fiber. You will be instructed not to shower during the first day after the procedure, however, when doing so later the site were the optic fiber was inserted should be protected against direct water contact for 48 hours. To help minimize the mild discomfort that may be experienced after the procedure the wound will be firmly

bandaged and treated with an ice pack to aid in the healing process. In the case of accidental exposure of a researcher to your blood the researcher will seek a blood sample to test for HIV/Hepatitis. In the rare case of exposure of your blood or tissue to research personnel, we will request a sample of your blood to test for HIV and hepatitis (a positive HIV or hepatitis test will be reported to you). There are no known risks associated with the use of visual ultrasound. The risks associated with a DEXA scan include exposure to small amounts of radiation. DEXA scanning utilizes radiation to obtain an image of your body. Everyone receives a small amount of unavoidable radiation from the environment each year. Some of this radiation comes from space and some from naturally-occurring forms of radioactive water and minerals. The DEXA scan technique gives your body the equivalent of about 4 extra days' worth of this natural radiation. The radiation dose we have discussed is what you will receive from this study only and does not include any exposure you may have received or will receive from other tests. If you are pregnant or trying to get pregnant, you should not participate in a DEXA scan.

What are possible benefits of this research?

We do not know if you will receive any benefits by taking part in this study. This research should help us learn more about muscles and tendons function during jumping. By participating in this study you will be given information concerning your jumping performance. This information may help you to accurately design a training program to enhance your jumping ability.

Will I be paid for taking part in the research?

You will be given $200 for completion of all the data collection. Current University policy requires the collection of Social Security numbers (or Appalachian Banner ID numbers) if study compensation is more than $100 for a single study or $599 for participation in multiple studies in a calendar year. Since the compensation for this study is more than $100, you will need to provide your address and Social Security number (or Appalachian Banner ID number) when you complete the form for payment.

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. Jeffrey M. 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 (Dr. Jeffrey M. 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 _____. This approval will expire on _____ 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

Judith Ann Paul was born in Escanaba, Michigan, in 1988. After graduating from Negaunee High School, she attended Bethel University where she graduated with a Bachelor of Science in Exercise Science. She then accepted a graduate assistantship at Appalachian State University in August 2011. Judith was awarded her Master of Science from Appalachian State in August 2013. Judith's plans include teaching at the collegiate level. Judith's parents are Katherine and David Paul who reside in the Upper Peninsula of Michigan.