6-1995

A Comparative Analysis of the Vertical and Plyometric Style Depth Jump Using Electromyography (EMG)

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A COMPARATIVE ANALYSIS OF THE VERTICAL AND PLYOMETRIC STYLE DEPTH JUMP USING ELECTROMYOGRAPHY (EMG)

by

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A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Health, Physical Education
and Recreation

Western Michigan University
Kalamazoo, Michigan
June 1995

ACKNOWLEDGMENTS

I would like to take this opportunity to thank the eight athletes who participated in this study for allowing me to utilize their talents and time to make this a quality study for the training of future athletes.

At this time I want to express my sincere gratitude to the members of my committee for whom I am grateful. To Dr. Roger Zabik and Dr. Mary Dawson for their teamwork and enduring tenacity; without them this project would have never seen the light of day. To Dr. Frye for her knowledge of writing; she was critical to this study.

I would also like to express my extreme thanks to my wife Christine for always being there for me when I needed her the most, and hanging in through the tough times. Her patience is a godsend during critical times like this.

Lastly, to the people who have always been there for me, my parents, Bob and Pat, for always being behind me 100% no matter what. They instilled the thought that I could achieve whatever I wanted. I am forever grateful for your determination and understanding.

I dedicate this thesis to Chrissy and my parents.

Robert M. Conatser

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Western Michigan University, 1995

The purpose of this investigation was to compare temporal data during the phases of jumping. Eight NCAA, Division I football players completed four jumps: three depth jumps from heights of 0.15 m, 0.30 m, and 0.46 m, and a standing vertical jump. Subjects were grouped according to height jumped. The dependent variables were phase time, amortization time, and time to peak EMG. Surface EMG synchronized with high speed video was used to analyze the response of six muscles used in the jumping movement. Findings indicated that subjects who consistently jumped higher spent more time in each phase of the jumping movement. Jumpers spent the most time in the eccentric phase and the least time in the amortization phase. The high jump group had a longer amortization time than subjects in the low jump group. Time to peak EMG indicated a distinct proximal to distal recruitment pattern.

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CHAPTER I

INTRODUCTION

Elastic energy is utilized in all sporting activities. The greater the efficiency an athlete has with respect to its use, the greater potential the athlete has to utilize stored muscle energy. Elastic energy occurs throughout the body within the muscles, tendons, and bones during the stretch-shortening cycle (Gambetta, 1993). During the eccentric phase of muscle contraction (stretching or lengthening), elastic energy is stored in the muscles and tendons. This elastic energy is then reused in the ensuing concentric contraction phase (shortening and contracting). There is also a third phase, which is the refraction period between the eccentric and concentric contractions, called amortization.

The storage of elastic energy within muscle is dependent upon the level of muscular activity present during the eccentric phase. The greater the tension in the muscle being stretched, the greater the potential to store elastic energy. Therefore, to maximize the storage of elastic energy, the stretching phase should be resisted by muscular effort. This is a process that occurs naturally as the body tries to overcome the forces of ground contact during depth jumps. In a stretching phase of short duration, such as the foot contact phase in sprint running, the energy can be stored during the entire stretching motion. The ability to recover the elastic energy is much greater than in comparison to a motion that occurs over a long duration. In an activity like the tennis serve, the elastic energy is best stored just prior to the shortening phase (Wilson, Elliott, & Wood, 1990).

Plyometric training is specific work for the advancement of explosive power. In most athletic events, the explosive/ballistic movements that athletes perform take less than 0.5 to 0.7 s, a speed often associated with an athlete's maximum strength output (Gambetta, 1993; Yessis, 1986). There is a premium that results from generating the highest possible force in the shortest period of time and reducing or stopping this force at the end of the action.

Plyometric training is used to develop efficiency in the stretch-shortening cycle (SSC) of muscle action. The key factor is to shorten the coupling time. Coupling time is the time it takes for the muscle to switch from the lengthening/yielding phase to the shortening/overcoming work phase. This leads us to a fundamental principle of plyometric training. It is the rate, not the magnitude, of the stretch that determines the utilization of elastic energy and the transfer of chemical energy into mechanical work (Stone, 1993).

Statement of the Problem

The problem of this study was to investigate selected temporal and EMG parameters for the lower body musculature during two different jump training techniques. Specifically the research investigated phases of motion and the resultant EMG responses in six lower body muscles during the performance of the vertical jump and three depth jumps of varying heights.

Delimitations

This study was delimited to the following characteristics:

1. The study was comprised of 8 male, varsity athletes.

2. The subjects were Western Michigan University football players.

3. All athletes were between the ages of 18 and 22 years.

4. The athletes played either the defensive back or receiver position.

5. All athletes performed two different jumping techniques: (1) the vertical jump (squat jump) and (2) the plyometric jump (depth jump).

6. All athletes performed depth jumps from only three heights: (1) 0.15 m, (2) 0.30 m, and (3) 0.46 m.

7. The athletes had no history of injuries to the lower extremity in the last 6 months.

8. Only six muscles of the lower extremity were analyzed by surface electrode EMG: (1) biceps femoris (BF), (2) medial head of the gastrocnemius (MG), (3) rectus femoris (RF), (4) peroneal group (PG), (5) vastus medialis (VM), and (6) semimembranosus\semitendinosus group (SS).

Limitations

The research was limited by the following:

1. The athletes had varying experience with the squat jump technique.

2. Athletes may have been apprehensive because they were attached to the EMG by surface electrodes.

3. All testing was performed in the Physical Education Laboratory, in a nonathletic environment.

4. The subjects were opportunistically selected.

Assumptions

The basic assumptions of the research were as follows:

1. The subjects were properly warmed up at the time that the trials were performed.

2. The subjects performed to the best of their capabilities on all trials.

3. The subjects obtained an acceptable level of strength during preseason conditioning conducive to performing plyometrics.

4. The electromyograph, camera, computer, and software were all operating properly.

Hypotheses

This study was conducted to test the following hypotheses:

1. The amortization time decreases as the depth jump starting height increases.

2. The amortization time for the vertical jump is greater than the amortization time for the depth jumps.

3. As amortization time decreases, jump height increases.

4. The time to peak recruitment after foot contact decreases as depth jump starting height increases.

5. As the time to peak recruitment after foot contact decreases, the jump height increases for the depth jumps.

Definition of Terms

The following terms and definitions are applicable and important to the understanding of this study:

1. Eccentric contraction: A type of muscle loading that involves an external force application with resultant tension increase during physical lengthening of the musculotendinous unit (Albert, 1991).

2. Concentric contraction: The internal force generated by the muscles that overcomes the force of the external resistance (Gray, 1991).

3. Negative work: A decrease in the potential energy of the system that occurs with the displacement of an object in an opposite direction to the force exerted by the muscles (Gray, 1991).

4. Stretch reflex: An involuntary action that occurs when the muscle is stretched rapidly and with large amounts of force. The muscle spindle reacts to the sudden stretch by sending signals to the spinal cord (Gray, 1991).

5. Eccentric phase: The period of time that begins when the athlete contacts the ground and ends when downward motion ceases.

6. Amortization phase: The period of time from the end of downward motion to the beginning of upward motion.

7. Concentric phase: The period of time from the beginning of upward motion until takeoff.

8. Stretch-shortening cycle: The eccentric-concentric coupling that occurs in all normal muscular activity.

9. Functional activity: Performances a researcher is able to measure that also mimic sport-specific activities.

10. Plyometrics: An eccentric contraction followed immediately by a forceful concentric contraction, using as many motor units (muscle fibers) as possible.

11. Power: A performance indicator calculated as Force (F) times Distance (D) divided by Time (T).

12. Amortization: The electromechanical delay between eccentric and concentric contraction during which time the muscle must switch from overcoming work to acceleration in the opposite direction (Tippet & Voight, 1995).

CHAPTER II

REVIEW OF LITERATURE

History of Plyometrics

Plyometrics was first introduced into the United States at the time of the 1972 Olympics. It was obvious at this time that the Eastern block countries, specifically the Soviets, had incorporated new training techniques into their typical routine. Plyometrics was a technique used by the Soviet track coach Yuri Verhoshanski in the late 1960s in an effort to heighten the explosive strength necessary for competition. Verhoshanski experimented with certain techniques like the depth jump to increase the athlete's reactive ability and train the whole neuromuscular system in a sport-specific manner (McCollum, 1994).

This method, "Plyometrics" was brought to the American scene mainly through the efforts of track coach Fred Wilt. The term is derived from the Greek words "plythein" and "metric," which translate to "more" and "measure," respectively. The practical definition of plyometrics is a quick powerful movement that involves a prestretching or countermovement that activates the stretch-shortening cycle (Voight & Draovitch, 1991; Wilk & Arrigo, 1993). The purpose of plyometric training is to heighten the excitability of the nervous system for improved reactive ability of the neuromuscular system. Because all types of movements, nonathletic and competitive, are ballistic in nature, they utilize the natural elastic components of muscle and the myotatic reflex to produce a more powerful muscular response.

Muscle Physiology

The skeletal muscles throughout the human body are activated by the nervous impulses from two primary sources: (1) voluntary contractions and (2) involuntary contractions or reflexes. Voluntary contractions are those that involve muscle shortening, during which the muscles attempt to overcome external forces. If there are additional forces that the muscle is unable to actively resist, the muscle lengthens involuntarily.

Voluntary Muscle Contractions

Voluntary muscle contractions or motor contractions originate in the central nervous system (CNS) and represent a conscious effort put forth by the individual to cause a muscle contraction. The coordination and strength of any contraction is dependent upon the total number of motor units (muscle fibers) called upon at one time, and the motor neuron firing frequency.

Involuntary Muscle Contractions

Involuntary contractions are a much simpler process than voluntary contractions. Skeletal muscles have "stretch receptors" embedded in the muscle fibers for the sole purpose of detecting sudden increases in the length and tension of the muscle (Gould, 1990). When this occurs, the receptors send an impulse that travels only to the spinal cord, then back to the muscle, causing the muscle to contract. This receptor, called a muscle spin-dle, facilitates the alpha motor neuron that control's the actuation of the muscle at hand. This facilitory receptor will increase the muscle's contrac-tile force.

Proprioceptors

In normal muscle function the concentric contraction is always preceded by a stretch placed upon the muscle. This is called eccentric-concentric coupling or the (SSC). This type of exercise incorporates the uses of both the elastic and contractile properties of muscle to generate force production. This technique engages the stimulation of the body's proprioceptors to facilitate an increase in muscle recruitment in a minimal amount of time (McCollum, 1994). The proprioceptors of the muscle are important for the following reasons:

1. They provide information regarding the tension placed upon the muscle.
2. They influence the tone of the muscle.
3. They are critical in performing motor skills.
4. They account for kinesthetic awareness.

In plyometric training the muscle spindle and the golgi tendon organ (GTO) are primarily responsible for proprioception (Tippet & Voight, 1995).

Muscle Spindle

Muscle spindles are located within the belly of a muscle, with the spindles lying parallel to the fascicles of the muscle fibers. They essentially function as a stretch receptor. Muscle spindles are responsible for sensing changes in the velocity of the stretch and reflexively producing a quick contraction of the agonistic and synergistic muscle fibers. The strength of the muscle spindle response is determined by the rate of stretch. The more rapidly the load is applied to the muscle, the greater the firing frequency of the spindle and the ensuing reflexive muscle contraction.

Golgi Tendon Organ

The GTO lies within the tendon at the site of the muscle's insertion into the tendon. The GTO has an effect opposite that of the muscle spindle in that it acts in an inhibitory fashion on the muscle by contributing to a tension-limiting reflex. Because the GTO lies in series with the contracting muscle fibers, they become activated with tension or stretch within the muscle. When the tension within the muscle reaches a potentially harmful level, the GTO fires, thereby reducing the firing frequency of the muscle. It is possible however, because the GTO's limiting factor is the stimulation threshold, that it can become desensitized over time due to the type of training stresses placed upon it. A desensitized GTO would allow a decrease in the level of muscle inhibition, which would permit a greater force production with increased loads applied to the musculoskeletal system.

Mechanical Characteristics

The mechanical characteristics of muscle are best represented by a three component model. A contractile component (CC), series elastic component (SEC), and parallel elastic component (PEC) interact to produce a force output (McCollum, 1994). The CC is typically the focal point of motor control, however the PEC and the SEC play an integral role in providing support and integrity to the individual fibers when a muscle is lengthened. During the lengthening phase of muscular contraction, energy is stored in the form of kinetic energy.

Concentric Contraction

A concentric contraction takes place due to the CC and the SEC. When a muscle is contracted in a concentric manner, most of the force produced comes from the actin and myosin myofilaments sliding past one another to create shortening of the muscle and consequently pull the insertion of the muscle closer to the origin. As this takes place the elastic energy stored in the SEC during the eccentric contraction is recovered and used to augment the shortening contraction. Best results for recovering the stored elastic energy with the ensuing concentric contraction will result if the variables of time, magnitude of stretch, and velocity of stretch are optimized.

Eccentric Contraction

The eccentric phase is a type of muscle loading that involves an external force application with resultant tension increase during physical lengthening of the musculotendinous unit (Albert, 1991). The duration of the phase is determined by the magnitude of impulse desired for the facilitation of the contraction. A greater amount of time spent in this phase results in the decreased ability to utilize the full potential of the myotatic reflex during the ensuing concentric contraction.

During the eccentric contraction, the load is transferred to the SEC and stored as elastic energy (McCollum, 1994). The stretching of the SEC allows for an increase in force production, and this also activates the muscle spindle.

Amortization Phase

The amortization phase is basically the pause between the eccentric and concentric contractions. It is during this pause that the muscle must switch from overcoming work to acceleration in the opposite direction. A significant amount of nerve conduction activity occurs during this phase.

When plyometrics are performed properly, and the amortization is kept short, a powerful response will be created by the agonist muscle groups. A slow amortization time will cause the energy produced by the SEC as potential energy to be given off as heat, and therefore limit the stretch reflex.

Muscle Function

When people are taught about muscle function and kinesiology they are typically taught that when a muscle contracts the distal end is pulled towards the proximal attachment. This is the normal type of contraction, occurring when the terminal joint is not fixed. This type of joint action is referred to as an open kinetic chain (OKC). However, when the human body functions in normal activities of daily living (ADL) the distal segment is fixed to the ground and the muscles have a negative function (reciprocal innervation), meaning that they are working to keep the body from succumbing to the effects of gravity. A closed kinetic chain (CKC) exists when the terminal joint of several successively arranged joints meets with external resistance, which restrains its free motion.

Rectus Femoris and Vastus Medialis Oblique

The quadriceps group as a whole is the primary shock absorber of the body (Gray, 1991). The rectus femoris (RF) is one of the quadriceps muscles however, it has one distinctive characteristic that separates it from the other quadriceps. The RF is biarticular, meaning that it has two distinct actions that take place at two separate joints; (This will be discussed later). The functions of the rectus femorus in an OKC is to either extend the knee, or flex at the hip. However, when performing an activity like that of jumping, when the foot contacts the ground, this muscle functions to eccentrically decelerate the flexion that occurs at the knee. The knee flexion that occurs as the foot contacts the ground is due primarily to control the forces of gravity.

The vastus medialis oblique (VMO) is also one of the muscles of the quadriceps group. It functions in a similar manner to that of the rest of the quadriceps in that it functions to decelerate knee flexion at ground contact. The VMO also helps to control the amount of medial force at the knee joint by decelerating the internal rotation.

The Hamstring Muscles

The hamstring muscles occur in two separate groups that have very similar functions but insert on opposite sides of the knee. The biceps femoris group (BF), which attaches laterally on the head of the fibula, has two heads, a long and a short. On the medial side of the knee is the semimembranosus/semitendinosus group (SS).

These muscles function to flex the knee joint and also to extend at the hip in an OKC activity. When the foot contacts the ground upon landing from a jump, the hamstrings function to decelerate hip flexion. As the lower leg momentum slows the hamstrings initiate hip and knee extension (Gray, 1991). They also provide some medial and lateral support.

The Gastrocnemius

The gastrocnemius (MG), like the RF is a biarticular muscle. It attaches proximally to the femur, and therefore, it has some function at the knee joint. The two functions of the gastrocnemius in an OKC are to plantarflex the foot and flex the knee. However, when the foot is bearing weight, flexion of the knee cannot take place unless the ankle is dorsiflexing at the same time. If this dorsiflexion is prevented, the weight-bearing knee is unable to flex. Under these circumstances, the MG contracts in a reciprocal fashion pulling the proximal attachments of the femoral condyles downward and backward. With the foot fixed, this allows the knee to extend (Luttgens & Wells, 1989).

High-velocity, movement-specific training exercises are performed to produce superior performance gains in strength and power-oriented sports (Stone, 1993). Explosive exercises are defined, for this discussion, as those exercises in which the initial rate of concentric force production is maximal or near maximal, and maximal or near maximal force production is maintained throughout a specified range of motion in keeping with the exercise technique involved.

Neuromuscular Considerations

Explosive movements are very highly dependent upon several factors, more so than normal movements. Exercise velocity in large part reflects the muscle length-tension curve, muscle force-velocity curve, neuromuscular coordination, reflex activity, and the use of elastic energy. The following factors and mechanisms need to be taken into consideration with force production, because gradation of strength is an important factor in coordinated specific movements (Stone, 1993): (a) motor unit recruitment,(b) rate coding (rate of electrical impulses of the motor unit resulting in contraction), (c) synchronization, (d) motor unit activation pattern, (e) whole muscle contraction pattern and stretch-shortening, (f) neural inhibition, (g) cross-sectional area of muscle, (h) motor unit type, and (i) biomechanics-anthropometrics.

Jump Height

There is much controversy about the best height for depth jumping. Because plyometric training is concerned with the rate at which the stretch-reflex occurs, jumping from various heights is ideal. The height of the depth jumped utilizes gravity and the athlete's body weight are used to exert a force against the ground. The height of the box determines the intensity of the exercise and the response of the ensuing muscular contractions. Verhoshanski was the first to use this form of training. He analyzed different jump heights and determined that 0.8 m was an ideal height for achieving maximum speed in switching from yielding to an overcoming work contraction (Tippet & Voight, 1995).

There is much disagreement over the optimal height for depth jumping. Verhoshanski and Chornonson (1967) concluded that jumping from a height greater than 42 in. was counterproductive, as the time spent in the amortization phase increased and the energy dissipated as heat (Voight & Draovitch, 1991). Yessis and Hatfield (1986) stated that the most effective jump height is 30-40 in. Katchajov, Gomgeraze, and Revson (1976) agreed with findings of Verhoshanski that 0.8 m was most effective in producing desired results. Asmussen and Bonde-Peterson (1974) determined that a maximal vertical jump rebound height occurred following a depth jump of 0.4 m. Komi and Bosco (1978) found the optimal jump height to be 0.5 m for females and 0.62 m for males. It is likely that the conflicts in data were due to the methods of testing, subjects used, and subject's divergent levels of jumping experience.

Vertical Jump

Vertical jumping (VJ) is a movement that uses the human body as a projectile dispersing the center of gravity (CG) as far as possible in the vertical plane. This is done by creating a high velocity at takeoff that propels the body from the ground surface and overcomes gravity.

Preparatory Phase

The preparatory phase is the controlled deceleration of the body that counteracts the effect of gravity, causing an eccentric contraction of the muscles of the lower leg, thigh, and trunk. This movement prepares the extensor muscles for the speed-dominated power movement that will later cause upward propulsion. The stretched muscles store elastic energy that contributes to the contraction force of the muscles involved. A slightly crouched posture increases the range and time over which the forces associated with propelling the body upward can be applied. The most efficient jump for height should involve only a linear displacement of the CG as produced by a series of angular motions taking place at the joints of the lower extremity and trunk (Semenick & Adams, 1993).

Takeoff

Takeoff is the coordinated movement of all the flexed joints of the lower extremity to forcefully extend, at the same time explosively propelling the body. The summation of forces is derived from concentric contractions of the hip, knee, and ankle extensors in concert. If timed properly, the forward and upward swing of the arms may lend momentum to the upward velocity of the body as a whole. The head and neck extends in unison with the "uncoiling" of joints of the lower extremity (Semenick & Adams, 1993).

Plyometric Jump

The plyometric style depth jump (DJ) is very similar kinematically to the VJ with a few exceptions. First, instead of beginning the jump from a static position on the ground, the person steps off a box of varying heights. This loads the muscles with a force greater than that of gravity alone. Second, there is a greater amount of kinetic energy stored due to the forced stretching of muscles. Third, the amount of flexion that occurs at the ankle, knee, and hip is less than in the VJ, and therefore the body is placed in a better position to propel the body vertically.

CHAPTER III

METHODS AND PROCEDURES

Vertical jumping is often used by coaches and trainers to determine the functional ability of athletes (Anderson et al. 1991). This movement demonstrates the ability of the athlete to coordinate muscle contractions in order to obtain a greater vertical displacement of their centers of gravity.

Plyometrics is often overlooked as a way of training the neuromuscular system in a more sport-specific manner. Because most athletic endeavors require an immediate response, the researcher believed that plyometric performance may better predict an athlete's actual athletic ability. The vertical jump takes a longer period of time to execute than the depth jump, due to the preparatory movements utilized by the athlete. In the time frame associated with the vertical jump there is little storage of elastic energy because it has been dispersed over a longer prepatory time period. However, in plyometrics the performance takes place in a smaller time frame allowing stored elastic energy to be utilized, which results in greater force production. In addition, a greater stretch is placed upon the muscles during the eccentric phase. This eccentric phase prior to movement is typical of actual athletic competition.

In this study, selected EMG and kinematic parameters were compared for two jumping styles: the VJ and the DJ. The researcher used surface EMG synchronized with two-dimensional video to analyze the EMG and kinematic response of six muscles in the body during all phases of the jumps.

The following topics will be covered in this chapter: (a) human subjects approval, (b) subject selection, (c) instrumentation process, (d) EMG and filming procedures, (e) data acquisition, (f) research design, and (g) statistical analysis.

Human Subjects Approval

Approval to conduct this study was required by Western Michigan University's Human Subjects Institutional Review Board (HSIRB). The appropriate forms were submitted by the principal investigator to the HSIRB. After clarification and changes, the board granted approval for this study (see Appendix A). No formal approval was needed from the Western Michigan University's football coaching staff.

Subject Selection

The 8 subjects participating in this study were NCAA Division I, male football players from Western Michigan University, Kalamazoo, MI. The athletes were 18 to 22 years old and played a specialty position of either defensive back or offensive receiver. Strong performances at these positions were characterized by the ability to quickly change direction from a sprint or lateral shuffle into a jump. These movements create a great deal of stored elastic energy, and the ability to transfer it quickly produces a plyometric effect (Fukashiro & Komi, 1987). The subjects were trained to generate and utilize stored elastic energy, without a lengthy preparatory phase.

The investigator screened the records of all potential subjects playing at these positions for injuries sustained in the 6 months prior to the study. Injuries judged serious enough to limit full participation or place the individual at further risk of injury were grounds for eliminating the individual from participation in the study.

Electromyography Procedures

The EMG responses in the following six muscles were measured during the execution of the plyometric jumps and the vertical jump: (1) rectus femoris (RF), (2) vastus medialis (VM), (3) medial head of the gastrocnemius (MG), (4) peroneal group (PG), (5) biceps femoris (BF), and (6) semimembranosus/semitendinosus group (SS). Bipolar surface electrodes, Medi trace, 1 cm, silver/silver chloride (ECE 1801 Graphic controls, Buffalo, NY) were placed at a point half the distance between the center of the innervation zone (motor point) and the distal tendon of the muscle. The electrode detection surfaces were spaced approximately 1 cm apart, parallel with the muscle fibers, and near the midline of the muscle. All placement sites were carefully identified, shaved, and prepped before electrode placement. Resistance levels were checked with a multi-meter. Successful placement was gauged by an electrode resistance of less than 10 Kohms.

The EMG electrodes were linked to a Myosystem 2000 EMG data collection system (Noraxon Phoenix, AZ) integrated with the analog-digital module in a Peak Motion Analysis hardware/software package (Peak Performance Technologies, Inc. Inglewood, CO). The integrated EMG signal was filtered using a Butterworth data smoothing procedure (6 HZ). The filtered EMG data were then transferred to the Myosoft EMG analysis located on a

Tenex 486 DX-2 personal computer. The EMG response for each muscle during the eccentric, amortization, and concentric phases of the muscle contraction were analyzed to determine the point at which peak recruitment takes place.

Filming Procedures

A two-dimensional video analysis of each jump was used to help separate the individual jumps into three phases. A Panasonic AG 450 video camera (Panasonic, Secaucus, NJ) set at 60 HZ was used to record the motion of each jump. Fuji S-VHS ST-120N videotape was used. The video data were synchronized to the EMG data through an event synchronization unit (ESU). The ESU unit was equipped with a switch to trigger a light-emitting-diode (LED) signal. The signal was simultaneously recorded on the video and the EMG outputs. Thus, the data from film were matched to the EMG data at a specific point in time.

The ESU controlled the EMG data collection. The LED was configured to be triggered by the breaking of a light beam. The light beam was positioned approximately 18 in. above the ground, parallel to the camera, so that when the jumping motion was initiated, the subject's body interrupted the beam and the data collection procedure was electronically triggered. EMG data were set to begin recording 1.0 s prior to the LED signal and to end recording 4.0 s following the signal. The EMG data were collected at a rate of 480 Hz. Thus, there were eight EMG data points for each video frame.

The video camera was set so that the focal length of the lens was perpendicular to the sagittal plane, right side, of the jumper. The camera lens was 40 ft from the subject and 1 m above the ground. Subjects performed in front of a contrasting background, so that bony landmarks of the athlete could be seen and digitized.

Data Collection Procedures

Data collection took place in the Biomechanics Laboratory in the University Recreation Center, Western Michigan University, Kalamazoo. Subjects were instructed to wear light-colored shorts cut above the knee, athletic court shoes, and low-cut socks. Subjects' shirts were removed for the data collection. All information collected was recorded on a data sheet (Appendix B).

Written instructions were read to each subject prior to his participation, and an informed consent form was read and signed (Appendix C). The instructions were as follows:

1. You will be given a 5-min warm-up prior to your jumps. Your warm-up will consist of the following: (a) a 3-min ride on a stationary cycle at 50 RPM with a resistance of 1 Kp, (b) specific stretches for the lower extremities, and (c) medium intensity rope jumping for 2 min. All stretches are performed twice for a count of 20 to 30 s. The stretches include a sitting straight leg toe touch for the hamstrings; a supine, knee to chest, while medially rotating the lower leg for the gluteals; and a standing, straight leg stretch facing and leaning in toward the wall for the gastrocnemius.

2. During the data collection, you will complete three trials for each of four different jumping conditions, a total of 12 trials for the day.

3. For the depth jump conditions, you should rebound as high as you can as soon as you touch the ground. (Pretend that you are jumping onto hot coals and you need to rebound as quickly as possible).

4. For the vertical jump condition, you can use any jumping style with which you are comfortable; again jump as high as you can.

5. In each trial, I will indicate to you when you should jump.

Video Digitizing Analysis

Jump Heights

After data collection, the digitizing process was initiated. It was necessary to digitize 20 anatomical points to establish the total body CG. The anatomical points were the distal metatarsals, lateral malleoli, knee joint midlines, greater trochanters of femurs, distal metacarpals, midlines of the wrists, elbow joint midlines, greater tuberosities of humeri, sternum, tragus of ear, top of head, and crotch. Both the left and right sides of the body were digitized.

First, each subject was digitized in a standing position to establish the height of the standing CG. Second, the trials for each subject were digitized to determine the maximum vertical displacement of the CG. Jump height was calculated by subtracting the vertical coordinate for standing height CG from the vertical coordinate representing maximal vertical displacement of the CG. The best jump of the three trials for each condition was selected for further analysis.

Video Analysis

The best jump of each condition was then digitized for analysis purposes. The analysis began three frames prior to the LED signal and ended three frames after peak height of CG. This insured that all EMG and kinematic data would be analyzed. At this time the trial was saved on the computer for further analysis.

For a second analysis only five anatomical landmarks were digitized: (1) distal metatarsals, (2) lateral malleolus, (3) knee joint midline, (4) greater trochanter of femur, and (5) sternum, respectively. All anatomical landmarks were digitized from the right side of the body. During the digitizing process, four significant movement events were marked as they were seen by the investigator from the video. The events were: (1) ground contact, (2) cessation of downward motion, (3) beginning of upward motion, and (4) takeoff. After all the jumps were digitized, data were smoothed using a Butterworth filter (6 Hz).

Calculated Angles

The researcher was interested in analyzing three joints: the ankle, the knee, and the hip. Each joint angle was defined by two adjacent segments and the articulating joint. For each joint, a hypothetical line was drawn from the distal end of each segment to the articulating joint. For the ankle joint, a line was drawn from the right metatarsal to the ankle joint, and a second line was drawn from the right knee to the ankle joint. The ankle angle was measured on the anterior side of these two intersecting segments.

For the knee joint, a line was drawn from the lateral malleolus to the knee joint midline, and a second line was drawn from the greater trochanter of the femur to the knee joint midline. The knee angle was measured on the posterior side of these two intersecting segments.

For the hip joint, a line was drawn from the midline of the knee to the greater trochanter of the femur, and a second line was drawn from the sternum to the greater trochanter of the femur. The hip angle was measured on the anterior side of these two intersecting segments.

Event Frame Verification

Because the exact event frames for cessation of downward motion and beginning of upward motion were hard to identify during the digitizing process, stick figures were matched to coincide with the angles of the ankle, knee, and hip throughout the entire digitized motion. The researcher was able to manually control the computer to move one frame at a time until a previously selected event frame was reached. This frame was matched to joint angle displacement data. If needed, event frames were adjusted according to the following criteria:

1. Cessation of downward motion was based on the angular displacement data. A frame was selected that represented the end of downward motion using a value of ± 2° across three consecutive frames as the standard.

2. Beginning upward motion was based on the angular displacement data. A frame was selected that represented an increase in the joint angles (ankle, knee, hip) of a minimum of + 2° across the remaining frames.

Phases of Motion

Phases of motion were defined by the following event verification frames:

1. Eccentric phase began at ground contact and was terminated at end of downward motion. The time spent in this phase was then obtained by taking the time that downward motion stopped and subtracting this from the time at ground contact.

2. Amortization phase began at the end of downward motion and was terminated when upward motion began. The

time spent in this phase was then obtained by taking the time that upward motion began and subtracting the time when downward motion ended as verified by the marked frame.

3. Concentric phase began at the beginning of upward motion and ended at takeoff. Time for this phase was calculated by subtracting the time at takeoff from the time when upward motion began.

EMG Analysis

All EMG data were transferred to the Myosoft system for analysis. The integrated EMG wave form was marked at the greatest peak recruitment that occurred after ground contact, prior to takeoff. From this marker, time to peak recruitment was calculated. The time was positive if peak recruitment occurred after ground contact and negative if it occurred before ground contact.

Data Analysis

Independent Variables

The independent variables for this study were as follows:

1. Four levels of jumps: vertical jump (VJ), and depth jumps performed at 0.15 m (DJ 0.15), 0.30 m (DJ 0.30), and 0.46 m (DJ 0.46);

2. The six muscles: biceps femoris, vastus medialis, rectus femoris, gastrocnemius, soleus, and semitendinosus/semimembranosus; and

3. Subjects were divided in groups bases on jump performance. Two groups were created, a high jump group and low jump group.

A split-plot factorial analysis of variance (ANOVA) was used to analyze all independent variables in one design.

Dependent Variables

The dependent variables for this study were as follows:

1. Time of phases; eccentric, amortization, and concentric;

2. Amortization time; and

3. Time to peak EMG.

CHAPTER IV

RESULTS AND DISCUSSION

The problem was to compare and describe both the kinematic and electromyographic differences among NCAA Division I male college football players performing DJ from varying heights. This chapter will address: (a) the overall time spent in each phase of muscular contraction during the jumps, (b) the amount of time spent in the amortization phase and the corresponding height jumped, (c) time to peak EMG activity of the six muscles monitored, and (d) kinematic similarities and differences among jumpers.

Characteristics of Subjects

The 8 subjects were NCAA Division I, male, college football athletes. The subjects consisted of 5 defensive backs and 3 receivers. The subjects were not compared by position, but were separated into two groups based on their jump performance. Of the 8 athletes 6 were on the 60-man travel team and 4 were designated starters. The subjects ranged in age from 18 to 22 years, with an average of 20.0 years. All class ranks were represented with the exception of 4th-year senior. The average height for the athletes was 70.6 in., with a range of 66 to 73 in.

After all the kinematic data were analyzed the athletes were separated into two categories, the high-jump group and the low-jump group. All 8 athletes were truly skillful performers as exemplified by the ability to execute all jumps with great neuromuscular control, efficiency of movement, and the capacity to generate power. The characteristics of efficient bodily motion are the absence of wasted movements, the use of the correct muscles with no more than the needed amount of force, and the relaxation of all muscles that do not contribute either directly or indirectly to the task at hand.

All of the athletes displayed distinct adequacy in relation to these factors, and both groups were considered skillful with respect to jumping ability. The high-jump group jumped an average of 0.807 m, and the low-jump group jumped an average of 0.681 m across all trials. The jumping performances of the subjects are listed in Table 1.

Table 1

Description of Subjects' Jump Heights

Subject	VJ	DJ 0.15	DJ 0.30	DJ 0.46	*M*
High Jump Group					
1	0.789[a]	0.747	0.783	0.776	0.774
2	0.840	0.850	0.853	0.812	0.839
5	0.827	0.826	0.865	0.845	0.841
6	0.735	0.782	0.779	0.790	0.772
Low Jump Group					
3	0.652	0.640	0.659	0.604	0.639
4	0.715	0.707	0.734	0.704	0.715
7	0.692	0.665	0.700	0.699	0.689
8	0.678	0.697	0.687	0.661	0.681
Grand Mean					0.744

[a] All jump heights reported in meters.

Results

Phase Time

A split-plot factorial ANOVA was calculated to determine if the time spent in the phases of a jump were different across the jump conditions. The ANOVA consisted of three factors: (1) four jump conditions: VJ and DJs from heights of 0.15 m, 0.30 m, and 0.45 m; (2) three phases of the jump: eccentric, amortization, and concentric; and (3) two jump groups, high and low. The ANOVA summary is reported in Table 2.

Table 2

ANOVA Summary For Time of Phases

Source	*SS*	*df*	*MS*	*F*
Jumps (J)	0.0035	3	0.0012	0.28
Height (H)	0.0458	1	0.0458	10.89*
J X H	0.0073	3	0.0024	0.58
Error	0.1010	24	0.0042	
Phases (P)	0.1510	2	0.0755	49.32*
P X J	0.0029	6	0.0005	0.32
P X H	0.0001	2	0.0001	0.04
P X J X H	0.0044	6	0.0007	0.48
Error	0.0735	48	0.0015	

*$p < .05$.

The following results were deemed important by the investigator:

1. No significant differences were found for phase time among the four jumps, VJ and DJs from a height of 0.15 m, 0.30 m, and 0.46 m, $F(3, 24) = 0.28$, $p > .05$.

2. A significant difference was found for phase time between the grouping variable, height jumped, $F(1, 24) = 10.89$, $p < .05$. The means were 0.158 and 0.114, for the high-jump group and the low-jump group, respectively.

3. A significant difference was found for phase time among the three phases, $F(2, 48) = 49.32$, $p < .05$. The means were 0.175 s, 0.082 s, and 0.152 s, for the eccentric, amortization, and concentric phases, respectively.

4. No significant differences were found for the first-and second-order interaction effects.

Amortization Time

A split plot-factorial ANOVA was calculated to determine if the time spent in the amortization phase was different across the jump conditions. The ANOVA consisted of two factors: (1) four jump conditions, VJ and DJs from heights of 0.15 m, 0.30 m, and 0.46 m; (2) two jump groups, high and low. The results of this ANOVA are reported in Table 3.

Table 3

ANOVA Summary For Amortization Time

Source	*SS*	*df*	*MS*	*F*
Jumps (J)	0.0013	3	0.0004	0.14
Height (H)	0.0161	1	0.0161	5.43*
J X H	0.0024	3	0.0008	0.27
Error	0.0709	24	0.0030	

*$p < .05$.

The following results were deemed important by the investigator:

1. No significant differences were found for amortization time among the four jumps, VJ and DJs from height of 0.15 m, 0.30 m, and 0.46 m, $F(3, 24) = 0.14$, $p > .05$.

2. A significant difference was found for amortization time between the grouping variable, height jumped, $F(1, 24) = 5.43$, $p < .05$. The means were 0.104 s and 0.059 s, for the high-jump group and the low-jump group, respectively.

3. There were no significant differences found for the interaction effects.

Time to Peak EMG

A split-plot factorial ANOVA was calculated to determine if the time to peak EMG recruitment was different across the jump conditions. The ANOVA consisted of three factors: (1) four jump conditions, VJ and DJs from heights of 0.15 m, 0.30 m, and 0.46 m; (2) two jump groups, high and low; and (3) the six muscles. The results of this ANOVA are reported in Table 4.

The following results were deemed important by the investigator:

1. No significant differences were found for time to peak EMG recruitment among the four jumps, VJ and DJs from height of 0.15 m, 0.30 m, and 0.46 m, $F(3, 24) = 0.85$, $p > .05$.

2. No significant difference was found for time to peak EMG recruitment between the grouping variable, height jumped, $F(1, 24) = 0.06$, $p > .05$.

3. A significant difference was found for the time to peak EMG recruitment among the six muscles, $F(5, 120) = 2.90$, $p < .05$. The means were 0.012 s, 0.022 s, 0.031 s, 0.064 s, 0.076 s, and 0.082 s, for the semimembranosus/semitendinosus, vastus medialis, biceps femoris, rectus femoris, gastrocnemius, and peroneal group, respectively.

4. No significant differences were found for the

Table 4

ANOVA Summary for Time to Peak EMG

Source	*SS*	*df*	*MS*	*F*
Jumps (J)	0.0972	3	0.0324	0.85
Height (H)	0.0022	1	0.0022	0.06
J X H	0.1963	3	0.0654	1.72
Error	0.9122	24	0.0380	
Muscles (M)	0.1430	5	0.0286	2.90*
M X J	0.1042	15	0.0069	0.70
M X H	0.0866	5	0.0173	1.76
M X J X H	0.1369	15	0.0091	0.93
Error	1.1833	120	0.0099	

*$p < .05$.

first-and second-order interaction effects.

Discussion

Jump Performance

In a study by Komi & Bosco (1978), the utilization of stored elastic energy in 50 men and women was studied. Male subjects consisted of two groups of 16, a group of physical education students and a group of Finnish men's volleyball players. Results indicated that the squat jump technique was less efficient than the DJ technique. They also indicated that the drop heights of the DJs influenced jumping performance in all the groups studied.

The majority of the athletes in this investigation performed their best depth jump from a height of 0.30 m. This is very similar to the results reported in a study by Bobbert, Huijing, and Van Ingen Schenau (1987). They studied six subjects who performed DJs from heights of 20, 40, and 60 cm. No differences were found in VJ achievement between drop jumps from the different heights. This is in disagreement with the results obtained by Asmussen and Bonde-Peterson (1974) and Komi and Bosco (1978).

Phase Time

Yessis and Hatfield (1986) indicated that the key to attaining maximal explosive push-off in jumping was the production of maximal muscular force in the shortest period of time. This is accomplished by a forceful eccentric contraction followed immediately by an ensuing concentric contraction of the extensors of the ankle, knee, and hip. The DJ technique was designed to accomplish this by utilizing the weight of the body, momentum, and gravitational forces from the height jumped. The result is a powerful and quick eccentric muscular contraction that elicits a maximal stretch reflex and allows an ideal storage of series elastic energy in the cells and connective tissue of the muscles.

The results of this investigation indicated no significant differences existed in phase times (eccentric, amortization, or concentric) among any of the jumps (VJ, DJ 0.15 m, DJ 0.30 m, DJ 0.46 m). A study by Asmussen and Bonde-Peterson (1974) indicated that a maximal rebound jump height should not exceed a depth of 0.4 m. However, Komi and Bosco (1978) indicated that a drop height (rebound jump height) of 0.62 m was optimal for the males. The researchers in the present investigation believed that as the DJ height increased there would be an increased amount of downward momentum of the body. Therefore, a faster eccentric contraction would store a greater amount of kinetic energy. It is possible that the small differences between the drop heights used in the present investigation (0.15 m) prevented the detection of differences in phase time associated with the jumps. It should be noted that the subjects in the present investigation were all excellent jumpers. The homogeneity of performance by the jumpers may have masked existing differences in phase times between the jumps.

A significant difference was found in the present investigation between the time that the jumpers spent in the eccentric, amortization, and concentric phases of the jumps. The researcher failed to find any data in the literature relating to the time spent in these phases. Wilk and Arrigo (1993) mentioned that, if the amortization time is kept short, a powerful response will be created by the agonist muscle group. They also indicated that if the amortization time is long in duration, the stored elastic energy will be lost as heat, thereby, discouraging the stretch reflex. The results indicated that the jumpers spent the greatest amount of time in the eccentric phase and the least amount of time in the amortization phase of all jump conditions.

In the present investigation, a significant difference in the time spent in the phases of the jumps occurred between the high-and low-jump groups. The high-jump group spent more time in each of these phases. The researcher was unable to find any previous research related to this issue, however, several authors (Chu, 1992; Komi & Bosco, 1978; Tippet & Voight, 1995; Yessis & Hatfield, 1986) placed a great deal of emphasis on an eccentric contraction of short range performed quickly and without delay prior to the concentric effort.

Again, it should be noted that the subjects in the present study were excellent jumpers, and their efforts may not relate to the other literature. It is also possible that previous researcher defined amortization time differently than this investigator. The amortization time occurred when the body assumed a static position. The muscles develop moments at the ankle, knee, and hip to counteract the forces of gravity. However, with multiple muscle groups and three joints, there are an infinite number of combinations of actuator forces that will generate these moments (Pandy & Zajac, 1991). Amortization could be defined in relation to a specific muscle, the action of a specific joint, or as an entire phase within a motion. Each definition would result in a different time and/or duration.

Lees (1981) reported that it takes approximately 0.15 to 0.20 s to stop the downward motion after foot contact in preparation for the ensuing jump. This time was consistent with that of the researcher, in the current investigation, for the eccentric phase time of all jumps. From this, the researcher believes that it takes the subjects generally that entire time to complete the impact absorption prior to generating a concentric contraction great enough to overcome their momentum. Therefore, if the subjects spend more time in the eccentric phase, they spend more time in the next two phases to complete the jump properly. The subjects who try and minimize this eccentric phase may not achieve the greatest results in height jumped as noticed with the low-jump group.

Amortization Time

No significant differences in amortization time were found across jump conditions (VJ, DJ 0.15 m, DJ 0.30 m, DJ 0.46 m) in this investigation. The previous research contained no objective data concerning the time spent in the amortization phase associated with either the DJ or the VJ. It is Komi and Bosco (1978) contention that the time spent in this phase would decrease as the DJ starting height increased. It is possible that the small differences, 0.15 m, between the DJs starting heights used in the present investigation prevented the detection of differences in amortization time associated with different depth jump starting heights.

A significant difference was found between the high-jump and low-jump groups with respect to the amortization phase. The athletes were separated into two groups based upon their ability to obtain consistently higher jumps (Table 1). The time spent in the amortization phase was greater for the high-jump group than for the low-jump group, 0.104 s and 0.059 s, respectively.

The results of this investigation relating to amortization time are not consistent with the findings of previous investigations. Although the researcher could not find information relating to the actual time spent in the amortization phase, a number of previous investigations indicated that improvement in jump performance is dependent upon the time spent between the ecccentric and concentric contraction (Albert, 1991; Chu, 1992; Gambetta, 1993; Komi & Bosco, 1978; Yessis & Hatfield, 1986).

It should be noted that the time spent in the amortization phase is extremely small. Because the researcher could not find any data that listed actual times for the amortization phase, the times found in this investigation for all the subjects could have been less than the times associated with less talented subjects. Also the athletes tested were football athletes who had great explosive jumping ability. However, they were not trained primarily in plyometric jumping. These results could change if athletes who trained specifically with plyometrics were studied.

Time to Peak EMG

No significant differences in the time to peak EMG recruitment were found across the jump conditions of the high-and low-jump groups for the six muscles studied in this investigation. The time to peak recruitment between the muscles was significant. The mechanical power flow of the lower limb during VJ and counter movement jumping was studied in an investigation by Fukashiro and Komi (1987). They indicated that a rank firing order existed from proximal to distal (hip, knee, ankle). In a similar study by Garhammer and Gregor (1992), the sequence of lower-extremity muscular activation proved to be proximal to distal (i.e. hip, knee, ankle).

The muscle firing pattern observed in this investigation of plyometric jumping was consistent with the information presented by Fukashiro and Komi (1987), and Garhammer and Gregor (1992). Depth jump starting height had no effect on this pattern of recruitment.

The differences in time to peak EMG were likely due to the motor program that coordinated the muscles involved in jumping. The researchers did find that the vastus medialis peak EMG occurred very early in comparison with the other muscles. This was probably due to the fact that the vastus medialis worked to control the amount of knee flexion that occurred eccentrically. This muscle also provided medial support for the patella. This explanation is supported by Luttgens and Wells (1989), who mentioned that the vastus medialis oblique was the most active quadriceps muscle used throughout the entire range of motion of the knee.

Kinematics

Two additional points concerning the kinematics associated with this investigation need to be considered. First, in comparison with the DJ, the VJ took almost twice the total time to complete. More flexion occurred in the hip, knee and ankle during the eccentric phase of the motion in the VJ than in the DJ. Also during the eccentric phase the researcher observed that the subjects' backs were nearly horizontal. Second, once the body had finished descending during the eccentric phase, the knee continued to move somewhat downward and forward. The researcher believed that this movement placed a greater stretch on the extensor muscles and also placed the knee in a more appropriate position for propulsion. These findings were consistent across all subjects and conditions.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study was conducted to determine if there were temporal differences between two different power training techniques, the vertical jump and depth jumps of varying heights. Plyometrics is a method of training that helps heighten the excitability of the neuromuscular system. This increases the body's ability to utilize elastic energy to achieve a greater level of athletic proficiency.

Eight Western Michigan University, NCAA Division I football athletes performed both the vertical jump and depth jumps from heights of 0.15 m, 0.30 m, and 0.46 m. Temporal data were collected concerning: (a) the duration of time spent in all the phases of the jumps--eccentric, amortization, and concentric; (b) jump performance as it relates to amortization time; and (c) time to peak EMG recruitment.

Separate ANOVA's were conducted on the following dependent variables: (a) phase time, (b) amortization time, and (c) time to peak EMG recruitment.

Findings

Relevant findings for the study included the following:

1. A significant difference was found for phase time among the grouping variable, height jumped, $F(1, 24) = 10.89$, $p < .05$. The means were 0.158 and 0.114 for the high-jump group and the low-jump group, respectively.

2. A significant difference was found for phase time between the three phases, $F(2, 48) = 49.32$, $p < .05$. The means were 0.175 s, 0.082 s and 0.152 s, for the eccentric, amortization, and concentric phases, respectively.

3. A significant difference was found for amortization time between the grouping variable, height jumped, $F(1, 24) = 5.43$, $p < .05$. The means were 0.104 s and 0.059 s, for the high-jump group and the low-jump group, respectively.

4. A significant difference was found for time to peak EMG recruitment among the six muscles, $F(5, 120) = 2.90$ $p < .05$. The means were 0.012 s, 0.022 s, 0.031 s, 0.064 s, 0.076 s, and 0.082 s, for the semimembranosus/semitendinosus, vastus medialis, biceps femoris,

rectus femoris, gastrocnemius, and peroneal group, respectively.

Conclusions

The findings led this investigator to suggest the following conclusions:

1. The subjects who jumped the highest spent more time in each of the phases of the jump. All of the jumpers spent the greatest duration in the eccentric contraction and the least in the amortization phase.

2. The subjects in the high-jump group had a longer amortization time than the subjects in the low-jump group.

3. A distinct pattern existed in the rise to peak motor unit recruitment in the muscles selected for analysis. Recruitment occurs in a proximal to distal direction.

Recommendations

The following recommendations for future research in this area need to be considered:

1. A larger sample size would increase external validity.

2. Research could be conducted using elite athletes who train specifically for participation in organized

jumping sports, i.e., high jumpers, long jumpers, and triple jumpers.

3. A wider range of depth jump heights could be studied.

4. For this study a film speed of 60 frames per second was used. Because of the speed of jumping, higher frame rates may be more beneficial. This would allow for a more accurate determination of the jump phases.

5. A single amortization time for the lower extremity was used in the present investigation. The amortization phase of each muscle used in jumping might provide a different profile.

6. Other muscles involved in jumping need to be studied. The gluteal group and the erector spinae group are possible choices.

Appendix A

Human Subjects Institutional Review Board Approval

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-3899
616 387-8293

WESTERN MICHIGAN UNIVERSITY

Date: September 23, 1994

To: Robert M. Conatser

From: Christine Bahr, Acting Chair JT. for C. Bahr

Re: HSIRB Project Number 94-08-09

This letter will serve as confirmation that your research project entitled "A comparative analysis of the vertical and plyometric style depth jump using electromyography (EMG)" has been **approved** under the **expedited** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you must seek specific approval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date. In addition if there are any unanticipated adverse or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: Sept. 23, 1995

xc: Zabik, HPER

Appendix B

Data Collection Sheets

DATA SHEET EMG STUDY

Subject Number ______________ Date of Filming ______________________

EMG RAW Data Files

Condition ______________________ Condition ______________________

Trial 1 ________________ Trial 1 ________________
Trial 2 ________________ Trial 2 ________________
Trial 3 ________________ Trial 3 ________________
Trial 4 ________________ Trial 4 ________________

Condition ______________________ Condition ______________________

Trial 1 ________________ Trial 1 ________________
Trial 2 ________________ Trial 2 ________________
Trial 3 ________________ Trial 3 ________________
Trial 4 ________________ Trial 4 ________________

Jump Height

Condition ______________________ Condition ______________________

Trial 1 ________________ Trial 1 ________________
Trial 2 ________________ Trial 2 ________________
Trial 3 ________________ Trial 3 ________________
Trial 4 ________________ Trial 4 ________________

Condition ______________________ Condition ______________________

Trial 1 ________________ Trial 1 ________________
Trial 2 ________________ Trial 2 ________________
Trial 3 ________________ Trial 3 ________________
Trial 4 ________________ Trial 4 ________________

Digitized Files

Spacial Model ________________ Project File ______________

Condition ______________________ Condition ________________

Condition ______________________ Condition ________________

Data Smoothing ________________ Hertz Level ______________

<u>Event Frames Confirmed:</u> Use Peak5 ADA and CDA files

Condition: Standing Vertical Jump

	Frame Number	Time (ms)
Light		
Ground Contact		
End Downward Motion		
Begin Upward Motion		
Takeoff		

Data Matched YES NO

Condition: **Depth Jump - 0.5 ft**

	Frame Number	**Time (ms)**
Light		
Ground Contact		
End Downward Motion		
Begin Upward Motion		
Takeoff		

Data Matched YES NO

Condition: **Depth Jump - 1.0 ft**

	Frame Number	**Time (ms)**
Light		
Ground Contact		
End Downward Motion		
Begin Upward Motion		
Takeoff		

Data Matched YES NO

Condition: **Depth Jump - 1.5 ft**

	Frame Number	**Time (ms)**
Light		
Ground Contact		
End Downward Motion		
Begin Upward Motion		
Takeoff		

Data Matched YES NO

Appendix C

Informed Consent Form

Division of Intercollegiate Athletics

Kalamazoo, Michigan 49008-3872
616 387-3120

WESTERN MICHIGAN UNIVERSITY

Western Michigan University
Department of health Physical Education, and Recreation
Principal Investigator: Roger Zabik
Research Associate: Robert M. Conatser

I have been invited to participate in a research project entitled "A Comparative Analysis of the Vertical and Plyometric Style Depth Jump Using Electromyography (EMG)." I understand that this research is intended to study two styles of jumping and how they both affect performance. I further understand that this project is Robert M. Conatser's Master's Thesis.

My consent to participate in this project indicates that I will be asked to attend two, half hour private sessions with Robert Conatser. I will be asked to meet Robert in the Physical Education laboratory at the Gary Center on the Western Michigan Universities campus. The first session will involve specific information about the testing and directions of how to perform the jumps. At this session a total of six jumps will be performed and data recorded. At this session I will provide information about myself such as age, height, weight, and position played in football. The second session will involve the remainder of the six jumps. I understand that my performance will be videotaped for the purpose of analysis. I also understand that surface electrodes will be attached to my legs for recording EMG data. Both the EMG and kinematic data will be stored on computer disk and video tape respectively.

As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken: however, no compensation or treatment will be made available to me except as otherwise specified in this consent form. I understand that one potential risk of my participation in this project is that I may sprain an ankle if I land wrong or possibly strain a muscle during the effort. I understand however that Robert Conatser is a Certified Athletic Trainer and is able to provide the medical attention necessary if this situation should arise.

I understand that the current testing may be of no benefit to myself, however the results of the study may provide information to help increase the knowledge of individuals in the Physical Education field to better train athletes in the future.

Division of Intercollegiate Athletics

Kalamazoo, Michigan 49008-3872
616 387-3120

WESTERN MICHIGAN UNIVERSITY

I understand that all the information collected from me is confidential. That means that my name will not appear on any papers on which this information is recorded. The forms will all be coded, and Robert will keep a separate master list with the names of the participants and the corresponding code numbers.

Once the data are collected and analyzed, the master list will be destroyed, All other forms will be retained for three years in a locked file in the principal investigator's laboratory. At the end of the three year period all recorded data (computer disks and videotapes) will be erased.

I understand that I may refuse to participate or quit at any time during the study without prejudice or penalty. If I have any questions or concerns about this study, I may contact either Robert M. Conatser at 372-0376 or Roger Zabik at 387- 2711. I may also contact the Chair of Human Subjects Institutional Review Board at 387-8293 or the Vice president for Research with any concerns that I have. my signature below indicates that I understand the purpose and requirements of the study and that I agree to participate.

Signature Date

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