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The Effects of Static Stretching on Vertical Jump Performance

Tom Evans
evanstommy@hotmail.com

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By

Tom Evans

Dr. Dan Martin, Ed. D., Committee Chairperson
Dr. Jeff Chandler, Ed. D.
Gary Mcilvain, M.S.

Marshall University

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ABSTRACT

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By Tom Evans

The vertical jump can play a significant role for many athletes in various competitive sports. The purpose of this study was to determine the effect that passive static stretching has on various athletes from various sports. The athletes were asked to perform a certain amount of jumps with no stretching routine and a set of jumps with a stretching routine. The results calculated for this study did show to have a statistically significant difference between jumping with stretching and jumping without stretching.

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Chapter 1

Introduction

Is stretching beneficial to athletes when performing explosive type activities? This question has become a hot debate topic among exercise professionals over the past few years (Kurz, 2000). The vertical jump is an explosive activity a number of athletes are required to perform in many different sports. Some professionals believe that stretching does not help increase vertical jump performance, while others believe stretching has no bearing on vertical jump performance and is just a result of proper form during execution of the jump (Knudson, Bennet, Corn, Leick, and Smith, 2000, Bosco et al., 1982). There are many factors that play a role in vertical jump performance. In this study, the effects of static stretching on vertical jump performance in college-aged athletes will be examined.

Statement of the Problem

Athletes are always striving to gain any edge they can against their competition. In sports such as basketball, soccer, and volleyball, an increased vertical jump can possibly give those athletes that extra advantage they are always trying to achieve. It is not clear from prior research what the effects of stretching have on an athletes vertical jump performance (Knudson et. al., 2000). The objective of this research is to examine if there is a difference in vertical jump performance of athletes who are put through a static stretching regimen and athletes who do not perform any stretching exercises.

Null Hypothesis

1.) Static stretching does not have an effect on standing, double-leg vertical jump performance.

2.) Static stretching does not have an effect on sitting vertical jump performance.

Operational definitions

Passive static stretching- Static stretching is defined in this study as a passive movement of the muscle orchestrated by the tester to the maximal length that is comfortable to the athlete and held for a period of 30 seconds (Kurz, 2000).

Vertical Jump Performance- The maximal height an athlete can achieve, in inches, on a double-leg takeoff vertical jump. The jump is measured by a Vertec, which is designed specifically to measure vertical jump height (Knudson, Bennett, Corn, Leick, and Smith, 2000).

Counter-movement- Muscles are eccentrically stretched, and then rapidly shortened to accelerate the body in the opposite direction and achieve the reverse desirable action (Kraemer and Newton, 1994).

College aged athletes- Male and female NCAA-1A eligible athletes, ages 18-24.

Chapter 2

Literature Review

Vertical jump plays a key factor in many sports. There have been numerous ways developed over the years to help athletes improve, the height of their vertical jump, which correlates with the speed at which they achieve the jump. There are many factors that are involved in an athlete's vertical jump and many factors that are involved in improving an athlete's vertical jump (Kraemer and Newton, 1994). An example of training to increase vertical jump performance is the use of plyometrics. Plyometrics are exercises that are used to help enhance an individual's jump height (Gheri et. al, 1998, Miller, 1986). One question that has been raised is whether static stretching before a vertical jump performance is beneficial for the athlete (Kurz, 2000).

The height that is achieved on the vertical jump has a direct correlation with the amount of force that is produced by the muscle fibers. The greater force production of the muscle fibers that are involved in the vertical jump relate to a greater maximum height achieved during jump performance (Kurz, 2000). This force is created by a phenomenon known as the stretch-shortening cycle of muscle fibers. The stretch-shortening cycle is a natural reaction by muscle fibers to slow the body from fast movements and prevent injury to the individual involved (Kraemer and Newton, 1994).

The stretch-shortening cycle involves a counter-movement when a muscle fiber is rapidly stretched creating tension within the muscle. A counter-movement is when the muscles to which the rapid movement is being applied to stop that movement and contract to move the individual in the opposite direction. To accomplish this, the muscles act eccentrically to slow the body and initiate the reverse desirable movement (Kraemer and Newton, 1994). This cycle is critical to vertical jump performance. As the individual flexes the knees to jump, the stretch shortening cycle is activated and the athlete explodes into the jump. As the individual increases the degrees of flexion at the knee joint on the way down, there is an increase of stiffness within the muscle. The muscle is applying a natural resistance to the rapid stretch. The result of this cycle is an increase in force production and an increase in the storage of elastic energy within the muscle or muscle group. This cycle also increases neural stimulation to the muscle fibers (Kraemer and Newton, 1994).

Aura and Komi (1986) observed this elasticity and neural stimulation in leg extensors. The research included 25 healthy males. The subjects were put through a number of stretch-shortening cycle exercises. The pre-stretch activity varied throughout the study. EMG also measured nervous system activity throughout each activity performed. Research supports the suggestion that pure muscle elasticity plays a large role in potentiating performance in stretch-shortening cycle exercises (Aura and Komi, 1986). The EMG readings of the leg extensor muscles suggested the nervous system plays an essential role in regulating muscle stiffness and thus the utilization of muscle elasticity in stretch-shortening cycle activities (Aura and Komi, 1986).

There have been countless hours devoted to researching this stretch-shortening cycle phenomenon. Komi (2000) observed normal and fatigued muscle function during stretch shortening cycle activity in leg extensors. This study used EMG readings to monitor the activity within the muscle fibers. It was found that the force produced by the muscle varied with the fatigue of the muscle. It wasn’t fully determined whether moderate fatigue had any bearing on the amount of force produced by the leg extensors, but it was concluded that exhaustive stretch-shortening activity dramatically reduced the force output of the muscles. The study concluded that a decrease in the stretch reflex of the muscle and a decrease in the stiffness of the muscle caused a dramatic decrease in the force potentiation mechanisms (Komi, 2000). The decrease in force potentiation was determined by low EMG activity within the muscle.

Young, Wilson, and Byrne (1999) published a similar study to that of Komi. This research involved 29 males with experience in jumping activities. There were a number of jumping activities performed by these subjects, but the only jump that is a concern here is the standing vertical jump, also referred to as the double-leg takeoff (Young, et. al., 1999). This study examined the load and speed placed on the stretch-shortening cycle during the standing vertical jump. The findings showed that the greater stretch-load placed on the leg extensors during the jump produced a greater jump. This finding suggests that the faster the vertical jump is performed, which would produce a greater load on the stretch-shortening cycle, has a bearing on the height achieved by the individual (Young, et. al., 1999).

The force produced by the muscle during vertical jump performance plays an essential role in the results (Kraemer and Newton, 1994). This may seem like common sense, but research has shown that producing greater force during the jump is not as easy as it sounds. Some think that the force produced during muscle contractions is more a product of the load being placed on the muscle (Newton, Murphy, Humphries, Wilson, Kraemer, and Hakkinen, 1997). Newton et. al. (1997) has shown that there may be an even more important factor to producing more forceful contractions. The research that they conducted came to the conclusion that force output did increase as a function of load, but lighter loads also produced more force because of the speed that the muscle was contracting (Newton et. al., 1997). The research also concluded that explosive movements, such as vertical jump, might be limited by the ability of the muscle to produce force during fast contraction velocities (Newton et. al., 1997).

Another aspect involved with the speed of contractions is the concept of coupling time. Coupling time is the time between stretch and shortening during the stretch-shortening cycle. Research conducted by Bosco and Rusco (1983) stated that if the time between stretch and shortening during the stretch-shortening cycle is too long, elastic energy could be wasted. This can be detrimental to actions that require explosive type contractions, such as the vertical jump. The three types of muscle fibers in the body are Type I (slow twitch), Type IIA and Type IIB (both considered fast twitch). Type IIA and Type IIB are the muscle types more highly recruited for explosive type movements. This research suggested that coupling time limited recoil for elastic energy in fast-twitch fibers (Bosco and Rusko, 1983). This information introduces another concept that is important with muscle contractions and stretch-shortening cycle activities. This concept is the sliding filament and cross-bridge theory in muscle fibers (Rassier, MacIntosh, and Herzog, 1999).

The sliding filament and cross-bridge theory is the most accepted theory determining what makes a muscle fiber contract or lengthen. The cross-cross bridges bring the filaments of the muscle fiber closer together, therefore, producing a contraction. This produces an overlapping of the filaments. Rassier states that when maximal filament overlap is produced, maximal force is also produced within that muscle fiber (Rassier et. al., 1999). The opposite is true when the cross-bridges release from the filaments. The force that was produced by maximal overlap is proportionately decreased when that overlap diminishes (Rassier et. al., 1999). This theory supports the results of the Bosko and Rusko (1983) study in fast-twitch fibers and coupling time. The cross-bridge lifetime in fast-twitch fibers is very short. This makes fast-twitch more sensitive to coupling time and the loss of elastic energy in stretch shortening cycle activities (Bosco and Rusko, 1983). Research that is worth noting that supports the notion about fast-twitch muscle fibers was accomplished by Almeida-Silveria, Pyerot, Pousson, and Goubel (1994). The rat soleus muscle was put through a 12-week stretch shortening cycle training program. The results mentioned a larger number of Type IIB muscle fibers after the 12-week program. Type IIA muscle fibers have been shown to convert to Type IIB muscle fibers with specific training (Almedia-Siveria et. al., 1994). The increase of Type IIB muscles had a direct effect on the contraction time of the muscle and the maximal velocity at which the muscle contracts. The contraction time showed a decrease, while the maximal velocity achieved was greater. This smaller contraction time and greater velocity correlates to a larger force output by the rat soleus muscle (Almedia-Silveria et. al., 1994).

Recent information has shown that Type IIb fibers can be converted to Type IIa fibers with certain training (Staron, Karapondo, Kraemer, Fry, Gordon, Falkel, Hagerman, and Hikida, 1994). The study showed that if Type IIb fibers are activated enough, they convert to Type IIa fibers in a short period of time. The study was composed of male and female subjects as they were put through an 8-week, heavy-resistance training program. Type IIb fibers were shown to decrease after two weeks of training in women and after 4 weeks of training in men (Staron et. al.. 1994). After the 8-

week training program was completed, it was found that the total amount of Type IIb fibers had decreased to a mean of 7 % of the total muscle fibers. It is not known whether those changes contribute to strength, but it is thought that it might contribute to force production of the muscle (Staron et. al., 1994).

Coupling time and stiffness was also observed during stretch-shortening cycle jumping activities in the sartorius of a frog (Lensell-Corbeil and Goubel, 1990). The sartorius in the frog is the major muscle used for jumping. The frogs were put through various pre-stretches before the jumps were completed. The results indicated that an increase in stiffness within the muscle and tendon juncture have a greater potential for force production. The stiffness within the muscle creates a better transmission of force throughout the muscle. It was concluded that the better transmission of force had an effect on the coupling time of the stretch-shortening cycle contraction. The coupling time was shown to be lower when the stiffness of the muscle increased (Lensell-Corbeil and Goubel, 1990).

As previously stated, coupling time can have a large impact on the force generated by stretch shortening cycle contractions. In a study by Ettema, Huijing, van Ingen Schenau, and de Haan (1990), the force generated by stretch-shortening cycle contractions were compared by controlling the coupling time of each contraction in the rat soleus muscle. The coupling time varied between 20 and 200 milliseconds and each rat performed an active pre-stretch. Active pre-stretch is accomplished during a standing vertical jump when the subject squats down before the jump. The results of this study are consistent with previous information on coupling time (Lensell-Corbeil and Goubel,1990 and Ettema et. al., 1990). The rats had a greater work output and more elastic energy was released with smaller coupling times. The smaller coupling times resulted in more explosive forces created by the soleus muscle (Ettema et. al., 1990).

Rassier (1999) discusses that another concept that relates to the stretch-shortening cycle is the force-length relationship within the muscle fibers. Muscle fibers that are longer produce a greater force when maximal filament overlap is accomplished. Rassier states that, "force-length relationship is a static property of skeletal muscle and does not predict dynamic muscle contractions" (Rassier et. al., 1999). Force-length relationships typically function in stretch-shortening cycle contractions on the ascending limb and the muscles on the descending limb function in a shortening-stretch cycle. This can be directly applied to the vertical jump. In a standing vertical jump, the hamstrings perform a shortening-stretch cycle contraction, while the quadriceps (leg extensors) performs a stretch-shortening cycle contraction. A shortening-stretch cycle contraction is primarily an eccentric muscle action, while a stretch-shortening cycle contraction is primarily a concentric muscle action (Rassier et. al., 1999).

Another aspect that is considered when studying vertical jump is the elastic properties of tendons when a jump is being performed. In research by Kubo, Kawakami, and Fukunaga (1999), the elastic properties in tendons were studied during vertical jump performance with and without countermovement. Countermovement refers to a stretch-shortening cycle contraction where the subject performs a downward "squatting" motion and upward explosion during a standing vertical jump. A jump without countermovement would have the subject sitting and exploding directly into the jump. That eliminates the stretch-shortening cycle (Kubo et. al., 1999). Stiffness of the vastus lateralis (leg extensor) muscle was directly measured by ultrasonography on 31 male subjects. It was concluded that stiffness was not related to the absolute jump height in either vertical jump (Kubo et. al., 1999). What was related, albeit inversely, was the difference in height achieved when the vertical jumps with and without countermovement were compared. The results of this research suggest that the stiffness of the tendon structures during the vertical jump with countermovement have a positive effect on the outcome of the jump and the stretch-shortening cycle. This suggestion is possibly due to the storage and recoil of elastic energy within the tendon structure. This may also have to do with the muscle spindles being "set" at a shorter length, so the spindles fire at a different time then in a stretched muscle (Kubo et. al., 1999).

There are many other factors that can affect stretch-shortening cycle contractions during a vertical jump. Cooling the muscle has been found to have a great impact on the stretch-shortening cycle (Oksa, Rintamyak, Myakinen, Martikkala, and Rusko, 1996). A study by Oksa et. al. (1999) had 12 males cool the muscles involved in jumping for 60 minutes at 27 degrees Celsius. The subjects performed the jumps before and after the muscles had been cooled. An EMG was used to measure the neural activity of the muscle during both trials. The results of this study showed that the muscles involved in stretch-shortening cycle jumping activities had less EMG activity during the jump after they were cooled (Oksa et. al., 1996). The reason for this decrease has been attributed to alterations in motor unit recruitment within the muscle fibers (Oksa et. al., 1996). This research concluded that cooling causes a prolonged stretch-shortening cycle contraction and a decrease of force production within the muscles used during jumping exercises (Oksa et. al., 1996).

Stretch-shortening cycle contractions play a very important role in vertical jump performance. Twelve male and twelve females volunteered to be subjects in a study to test various stretches placed on a muscle before a stretch-shortening cycle contraction. Peak force and the time to peak force in the quadriceps were measured on a Biodex dynamometer during three different conditions. The first condition, which is most relevant to this research, had the subjects perform a passive, static stretch before a stretch-shortening cycle contraction. An isometric stretch, also referred to as a preload, was the second condition the quadriceps were measured under. The third condition the subjects performed was an eccentric stretch before the stretch-shortening cycle contraction (Hegelson and Gajdosik, 1993). The first comparison that was discussed was the difference or absolute peak force between men and women. The men achieved a much greater peak force than the women. This result is consistent with the conception that men have larger muscle fibers than women and are able to generate more elastic energy. The results most concerning this research were the difference between the three conditions and the effect on stretch shortening cycle activities. The isometric stretch and the eccentric stretch were found to have an impact on peak force and time to peak force. The time to peak force significantly decreased and a greater peak force was achieved in conditions two and three (Hegelson and Gajdosik, 1993). Condition one, which involved passive, static stretching, was found to have a slower time to peak force and did not create a greater peak force as compared to conditions two and three (Hegelson and Gajdosik, 1993).

Research on stretching and vertical jump is limited, but what has been done show some very intriguing results. It has been debated whether static stretching before stretch-shortening cycle contractions, such as vertical jump, reduce the force production of the muscle (Kurz, 2000). A thirty-second static stretch on the calf muscles (gastrocnemius and soleus) has shown to reduce the force production within that muscle (Rosenbaum and Hennig, 1995). The decrease in force production resulted in a lesser height achieved during a vertical jump (Rosenbaum and Hennig, 1995). Other research has found the muscles are impaired for several minutes after 30 seconds of static stretching (Kokkonen, Nelson, and Cornwell, 1998). This research even goes as far as saying that static stretching my also reduce the strength of the muscle for several minutes after the stretch (Kokkonen et. al., 1998). Some research professionals have the feeling that static stretching may put the subject at a greater risk of injury (Kokkonen et. al., 1998).

A study by Knudson et. al. (2000) did an in-depth observation of the effects of static stretching and vertical jump performance (Knudson et. al., 2000). Recent studies had shown that static stretching decreased the dynamic strength of the muscle. The dynamic strength is the strength of the muscle through a specific movement, such as stretch shortening cycle contractions. The study by Knudson et. al. (2000) involved 10 male and 10 female subjects on a volunteer basis. Each subject performed vertical jumps with and without static stretching. The stretching regimen consisted of three, 15-second stretches of the quadricep, hamstring, and calf muscle groups. Each subject performed three jumps with stretching and three jumps without stretching. The jumps were conducted from a double-leg takeoff position with the hands on the hips. A mean of the three jumps were used for statistical purposes. There were four variables measured in this study: peak vertical velocity, degrees of flexion in the knee during the jump, the duration of the eccentric phase, and the duration of the concentric phase. It was concluded that each variable was statistically different by five percent or more with and without static stretching (Knudson et. al., 2000). The subjects who performed the jump without the stretching routine were found to achieve a greater peak vertical velocity. This can be accounted for by previous research that demonstrates more force production in the unstretched muscle (Rosenbaum and Hennig, 1995). The research also concluded that the shorter the duration of the eccentric and concentric phases of the jump (stretch-shortening cycle), the greater height was achieved (Knudson et. al., 2000). That result is consistent with previous research conducted on coupling time, where the greater coupling time produced a smaller force generation (Ettema et. al., 1990, Bosco and Rusko,1983, Almedia-Silveria et. al., 1994, and Lensell-Corbeil and Goubel, 1990).

In conclusion, the effect of using static stretching before vertical jump performance is still up for subjective interpretation. Some research favors the use of stretching while some research does not. From the research reviewed, static stretching would seem to hamper the force production of the muscles and the velocity at which the muscle contracts used during a vertical jump. From that point, it would seem that maximal vertical jump height could not be achieved after a static stretching regimen.

Chapter 3

Methodology

Instrumentation

The only piece of equipment used for this study was the Vertec (Appendix A). This instrument measured each subject's vertical jump in inches. The Vertec has bars that move horizontally when pressure is applied and certain heights are color-coded. Every blue bar represents six inches between them. Between the blue bars, there are alternating red and white bars, with each bar representing one-half of an inch. Each bar represented a certain height achieved during the vertical jump. The distinct bar the subject reaches was translated into the inches the subject accomplished for his or her vertical jump.

Procedures

The subjects were asked to sign an informed consent (Appendix B) to participate in this experiment. Each subject was also asked to stay somewhat "inactive" for 24 hours prior to the test. Examples of "inactive" were not to perform strenuous activity 24 hours prior to the test or not drinking alcohol the night before they were asked to perform the vertical jump.

Each subject performed the vertical jump without stretching first. Each subject had to set their individual Vertec height before the jumps were performed. Each subject stood parallel to the Vertec and placed their right index finger on a black line that was exactly twelve inches below the first color-coded bar, which was blue. Each subject then extended their right arm as high as they possibly could without coming off the ground. Once all of this was completed, the subject was ready to perform the vertical jump.

Once the subjects were ready to complete the vertical jump routine, the time it took them to start the first jump was approximately 30 seconds. The subject was then asked to perform six separate jumps. They each conducted two sets of three jumps . The first set of three jumps was conducted from a seated position on a folding chair. The subject was asked to explode into the vertical jump from the seated position. This jump was repeated three times. The color-coded Vertec bars were reset after each jump. The second set of jumps was conducted from the standing position. The subject was asked to squat down and immediately explode into the vertical jump. The results from all six jumps were recorded in inches. Three jumps from each position were used to let the subject get accustomed to the form that was needed to perform the vertical jump. Only the highest number for each sitting jump and each standing jump was used for the data analysis.

Each subject had completed the first set of jumps without stretching they were then prepared for the set of jumps after stretching. Each subject was put through a static stretching regimen of five muscle groups: the glutes, hamstrings, adductors, quadriceps, and calf. Each muscle was stretched by the researcher for a period of two 30-second intervals. The total amount of time the stretching took was 7 minutes and 30 seconds. To control as many factors as many possible, each subject preformed the set of jumps 8 minutes and 30 seconds after the first set of jumps was complete. The specific muscle that was stretched in the group of glutes is the gluteus maximus. Placing the subject supine on the table and bringing his or her knees to their chest stretched this muscle. The muscles that were stretched in the hamstring group were the semitendonosis, semimembranosis, and biceps femoris. To stretch this group of muscles, the subject was supine on the table with the knee at 0 degrees of flexion and his or her leg was raised in a vertical motion until movement was prevented. This procedure was performed on each leg. The adductors muscles that were stretched were the adductor longus, adductor brevis, adductor magnus, and gracillis. These muscles were stretched by having the subject sit with his or her plantar portions of the feet touching ("Indian style"). The tester then stretched the subject by pushing downward on the subject's knees, as to externally rotate the hips, and holding the position for 30 seconds. The quadriceps muscle group consists of the rectus femoris, vastus medialis, vastus intermedius, and vastus lateralis. The subject was placed prone on the table. The knee was flexed maximally to about 135-145 degrees. The tester raised the subject's leg grasping at the knee joint and applying downward pressure to the sacroiliac joint to isolate the quadriceps and held the stretch for 30 seconds. The last group of muscles that was stretched were the calf muscles. The two muscles involved with this stretch are the gastrocnemius (gastroc) and soleus. Having the subject stand on an incline board with knees fully extended stretched the gastroc. The incline board placed the foot in dorsiflexion, therefore, stretching the gastroc muscle. The soleus was stretched in a different manner. The subject was placed on the table in the prone position and the knee was flexed to approximately 90 degrees. Flexing the knee to 90 degrees isolated the soleus muscle. The tester then applied dorsiflexion to the subject to stretch the soleus muscle.

When each subject was finished with the stretching regimen, it was time to perform the other part of the vertical jump test. All of the subjects were placed in one group. Again, the time between the end of the setting of the Vertec to the execution of the first jump was approximately 30 seconds. The test was administered in the same manner that the jumps without stretching were conducted. The data was collected and, again, the highest jump for each subject's sitting and standing performance was used for the data analysis. All 26 athletes were asked to perform the jumps without stretching first. Each subject was then stretched and asked to perform the set of jumps again.

Subjects

Subjects that volunteered for participation in this study included 9 male soccer players, 2 male baseball players, 10 female soccer players, 3 female softball players, 1 female track athlete, and 1 male track athlete (mean age – 20.5 years). There were 12 male athletes (mean age – 20.8 years) that participated in this study and 14 female athletes (mean age – 20.2 years). All athletes were in-season of their respective sport during the testing period.

Chapter 4

Results

The procedure that was used to analyze the set of data that was collected was a Paired samples T-test (Appendix C), which is used to compare the means of two variables. The data set was separated into six different pairs, with each pair comparing two different jumps. Variable 1 was the mean of the jumps that were conducted from the seated position without passive static stretching. Variable 2 was the mean of the jumps that were conducted from a standing position without passive static stretching with a counter-movement. Variable 3 was the mean of the jumps that were conducted from the seated position after passive static stretching had been administered, while Variable 4 was the mean of the standing vertical jumps, with a counter-movement, that were conducted after passive static stretching had been administered. The mean and standard deviation were calculated for each variable.

The results of the data collected were found to be statistically significant in all sets of correlations except pair 3, in which the two variables being compared were Variable 1 and Variable 4. For any comparison to be deemed significant, the significance value has to be less than 0.05.

Variable 1 was found to have a mean of 21.2692 and a standard deviation of 4.03294. Variable 2 was calculated as having a mean of 23.3077 and a standard deviation of 4.44764. The mean of variable 3 was calculated at 20.3269, while the standard deviation was determined to be 4.26132. Variable 4 was found to have a mean of 21.8654 and a standard deviation of 4.31638.

The first set of variables compared was variable 1 and variable 2. The level of significance that was calculated was found to be 0.000. This result is not surprising since variable 1 was a vertical jump from the seated position without a counter-movement, while variable 2 was a jump from the standing position with a counter-movement. The next comparison involved variable 1 and variable 3. This comparison was one of the key components to this study. The level of significance that was calculated was also found to be 0.000. This level of significance leads to rejecting the null hypothesis.

The third set of variables compared was variable 1 and variable 4. The level of significance was calculated at 0.136. This was the only comparison of the six that was deemed statistically non-significant. This result, though, is interesting because variable 1 does not involve a counter-movement and variable 4 does involve a counter-movement. The fourth set of variables compared was variable 2 and variable 3. The level of significance that was determined was 0.000.

The fifth set of variables compared was the other key component of this study. Variable 2 and variable 4 were compared and the level of significance was calculated at 0.000. This level of significance also led to rejecting the null hypothesis. The last set of variables to be compared was variable 3 and variable 4. The level of significance that was calculated from these variables was determined to be 0.001.

The overall results conclude that, in this study, there was a statistical significance between passive static stretching and vertical jump performance. There was a statistical significant difference in all of the comparisons except one. The two comparisons that were most relative to this study showed a great statistical significance that there is an effect on vertical jump performance when passive static stretching is applied.

Chapter 5

Discussion

As indicated by the previous chapter, the results of this study were shown to be statistically significant. The results have indicated to reject both of the null hypotheses. From the data collected and the results that were calculated, it was shown that there was a statistical significance between passive static stretching and vertical jump performance from both the seated and standing positions. There was statistical significant difference in 5 out of the 6 pairs of comparisons during vertical jump performance.

There were some trends seen in a few aspects of the results. One aspect that was consistent was the phenomenon of the stretch-shortening cycle. The jumps that were completed from the seated position were geared to eliminate stretch-shortening cycle activities, therefore, reducing the height achieved by the subject compared to the standing vertical jump. The data collected was consistent with information presented by Kraemer and Newton (1994). The seated jump eliminates the counter-movement produced by the muscles during a standing vertical jump because there is no downward movement. The results of this study demonstrated the activity of the stretch-shortening cycle. The mean heights achieved were lower for the seated jumps than the mean heights achieved for the standing, double-leg jumps in the respective categories of stretch and non-stretch. These results coincide with Kraemer and Newton (1994) and the phenomenon of the stretch-shortening cycle. There is no counter-movement being produced while jumping from the seated position, therefore, the force production by the muscle is decreased resulting in a lower height achieved during the vertical jump (Kramer and Newton, 1994).

Another possibility for rejecting the null hypotheses that relates to force production could be the sliding filament theory. Rassier et. al., (1999) states that maximal force is produced only when maximal overlap is achieved within the muscle fiber. Rassier et. al., (1999) also states that if cross-bridge release is lengthened in time, force production and elastic energy can be wasted, therefore, the subject is not able to create a maximal force production during a vertical jump performance. This could have been a reason for rejecting the null hypotheses. The force and jump height produced by the subjects could have been maximal because of the aforementioned reasons.

Another aspect that could have led to rejecting the null hypothesis is muscle fiber types within each individual. It was not known what percentage of each muscle fiber type each individual had. Almedia-Silveria et. al. (1994) presented information that muscles fiber types during explosive movements, such as vertical jump, play a big role in the height achieved while jumping. If some subjects were predominant with Type I muscle fibers, they were less likely to jump higher because they could not explode as fast as subjects with predominantly Type IIa and Type IIb muscle fibers. Type I muscle fibers contract at a slower velocity than Type IIa or Type IIb fibers, therefore reducing the height of the jump achieved. A possible connection to this theory is many of the subjects may have had more Type IIa and Type IIb fibers. That theory may contradict this study since many of the subjects that were tested were soccer players. Training for the sport of soccer is mostly aerobic and there is not much explosive movement except for jumping. This could have affected the results because their Type IIa and Type IIb muscle fibers are not recruited as well because the training for soccer is more aerobic (Almedia-Silveria et. al., 1994).

A major aspect that could have led to rejecting the null hypothesis is two-fold: coupling time and stiffness of the muscle fibers (Lensell-Corbeil and Goubel, 1990). Coupling time could have played a huge role because everybody has a different speed at which they jump. The stiffness of the muscles used during vertical jump can have a great impact on a maximum height a subject could have achieved. This information contradicts with research done by Lensell-Corbeil and Goubel (1990) and the stiffness of muscles. Stiffness of the muscle has shown to decrease the coupling time of contractions. A subject that has a great deal of flexibility is not going to have much stiffness in the muscle, therefore, increasing the coupling time of the contraction. That theory does not seem to apply to this situation because subjects that are more flexible, passive static stretching may not effect them as much as subjects who are not as flexible. A subject that has a stiff muscle structure may be affected much more than a subject who does not have a stiff muscle structure. Therefore, subjects who are not as flexible may exhibit a larger difference between jumping without static stretching and no stretching at all than subjects who are fairly flexible (Lensell-Corbeil and Goubel, 1990). Flexibility was not measured in this study.

Research that does correlate with the results of this study was done by Kubo et. al. (1999). The research deals with the stiffness of the tendon and the counter-movement involved with the vertical jump. The jumps that were done from the seated position eliminated the counter-movement involved with the muscle contraction. It was found in this research and research by Kubo et. al. (1999) that jumps without a counter-movement produced less force, therefore, not reaching a maximum jumping height. The jumps with a counter-movement produced a mean greater jump height than the jumps that did not involve a counter-movement. The suggestive reasoning for this could be the storage and recoil of elastic energy that is produced when a vertical jump is conducted with a counter-movement (Kubo et. al., 1999).

Fatigue may or may not have played a major role in the results of this study. Subjects were asked to stay relatively inactive for a period of 24 hours before they were asked to perform the vertical jump. This was extremely hard to control because these are NCAA Division I athletes and many of them were in-season during the testing period. This reasoning would disagree with research by Komi (2000). It was found that fatigued muscle had less force production than muscles that were not fatigued (Komi, 2000). With many of the athletes being in practice, there is a possibility that many of the muscles were fatigued in some of the subjects and not fatigued in other subjects and it may be possible force production was not at its greatest in some athletes at the time the subject was tested for vertical jump performance. This fatigue of the muscle could have dramatically decreased the force output of the muscle in stretch-shortening cycle activities. Furthermore, the fatigue of the muscle could have lengthened the coupling time of the contraction decreasing force output by an even larger margin (Komi, 2000). Subjects were asked to stay inactive for 24 hours prior to the testing time, but in reality, that is extremely difficult to control with NCAA Division I athletes.

There is another aspect involving fatigue that may have played a role in rejecting the null hypotheses. The time of day that the subject was tested may contribute to the statistical significance. This factor was controlled as much as possible. While many subjects were tested around the same time of the day, the time of day varied the subject was tested varied around the subjects availability. Some subjects were tested in the morning, while other subjects were tested in the afternoon and early evening. Since these are Division IA athletes, many of the subjects that were tested in the afternoon and early evening generally had some type of activity planned during the day. This could have led to some fatigue of the muscles, therefore, the subject was not able to achieve a maximal jump height. It also might have mattered even if the subject did not have any activity during the day. The athletes that were tested in the morning did not have any activity before the jumps were completed. The subjects that were tested in the afternoon and early evening, even if they didn't have any activity planned, had still been active throughout the day and could have led to some possible fatigue, even if it was only minor activity. This was extremely hard to control being these are Division 1A athletes.

Bosco et. al. (1982) presents information that says stretching has no bearing on the height achieved during a vertical jump performance. This theory contradicts the results of this study. Bosco et. al. (1982) states that " stretching has no bearing on the outcome of the vertical jump, but proper form has the most bearing on the outcome of vertical jump performance." This may be the case with this study because many of the athletes are not familiar with the proper execution of a vertical jump. Some of the athletes have a tendency to try and jump up to the highest bar on the Vertec and really do not concentrate on proper form. Controlling this was difficult because the subject was shown the proper form to execute the jump, but when it was time to test the jump, the athlete usually refers back to the habitual form they are used to. This also correlates with this research because the athlete may have concentrated on using proper form during one set of jumps, but no during the other set of jumps. This could have skewed the results.

One problem with Bosoc et. al.'s statement is it is over 20 years old and may not be valid in this day.

A possible intriguing factor that could have led to the statistical significance of this research could have been during the stretching phase of the experiment. Some athletes tend to guard against passive stretching and do not relax throughout the stretching process. This was attempted to be controlled by having two 30-second intervals of stretching instead of one 30-second interval of stretching. If this were the case with some of the athletes, the stretching would not benefit them as much as other athletes who are more receptive to passive stretching. This could have led to a greater height achieved during the set of jumps that involved stretching. This may also not have had an impact at all on the results of this research.

The temperature of the muscle at the time the vertical was performed could have played a role in rejecting the null hypotheses. This coincides with information presented by Oksa et. al., (1999). Depending on the time of day the subject was asked to jump and what kinds of activities they had done before they arrived to perform the vertical jump test, the muscles used for vertical jump performance could have been at different temperatures. Oksa et. al., (1999) presented information that showed neural activity within a cooler muscle fiber was diminished, therefore, the subject was not able to achieve maximal motor unit recruitment and, therefore, not able to produce maximal force. Whether this played role at all is hard to say. The probability of this making a difference in the results is minimal, but could have played a minor role.

The data that was collected for this research correlates with information that was presented by Knudson et. al., (2000). Research by Knudson et. al., (2000) did show a significant difference in jumps that were completed with and without static stretching. One difference between Knudson et. al.'s research and this research is the stretching regimen was not a vigorous or lengthy as it was in this research. The study by Knudson et. al., (2000) had more variables that were measured than the research that was conducted here. It is possible that the variables measured in Knudson et. al.'s study could have been similar to the results of this research. The other variables that were measured in the study were peak vertical velocity, degrees of flexion in the knee during the jump, the duration of the concentric and eccentric phase (coupling time) during the jump (Knudson et. al., 2000). It is not known whether these variables would have correlated between the two sets of research. The research by Knudson et. al. (2000) also only had a set of standing vertical jumps. Of the variables that were measured in this study, the results do correlate with the research done by Knudson et. al., (2000).

In conclusion, the results of this study showed there to be a statistical significant difference between stretching before vertical jump performance and not stretching before vertical jumps performance. These results led to rejecting both the null hypotheses. However, there were many limitations to this research that were difficult to control during the testing period. The biggest limitation to this study would probably have to be the fact the most of the athletes were in-season during the testing period. As stated previously, this probably caused fatigue in the muscles of many of the athletes, therefore, not resulting in maximal effort during some of the vertical jump performance tests. If the athletes could have been placed in a more controlled environment, the results of this research may have been different. Placing the athletes in a more controlled environment would allow the researcher to examine every physical exertion the athlete does. Being that this research was done during season and while school was in session, it was impossible to control the physical exertion of all 26 athletes.

Suggestions for further research on this topic would include trying to control what the athlete does prior to performing a vertical jump test. This would probably be easiest during the summer months because most athletes are not in season during those months. Another suggestion would be to measure more than just the height of the jump that the athlete achieves. There are many more measures that can be made throughout a vertical jump performance. Measuring more variables might give more statistical significance to the data that is collected. While the results of this study were deemed statistically siignificant, further research needs to be done on the effects of static stretching on vertical jump performance.

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Appendix A

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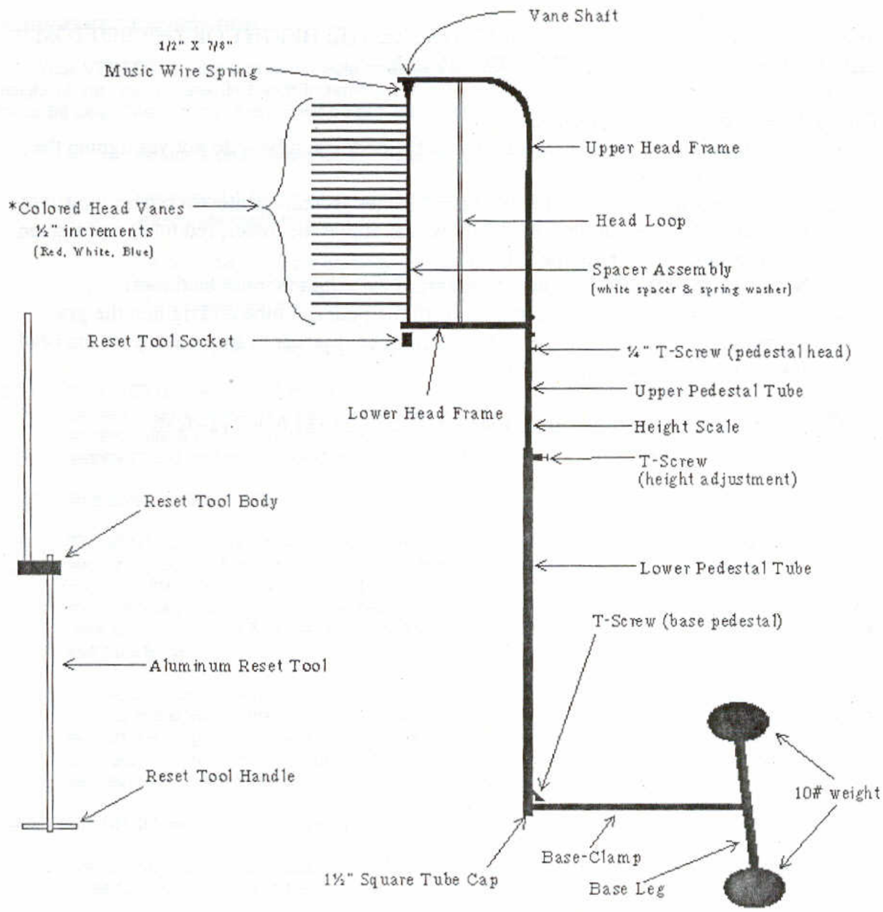
Model: VER Vertec Jump Trainer



* Vanes are open on one end so they can pop in & out of head assembly without dismantling head.

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PLEASE READ FIRST

BEFORE FIRST TIME USE, PLEASE MEASURE THE HEIGHT OF THE BOTTOM RED VANE TO ENSURE HEIGHT ACCURACY.

This is done in the following manner…

1. Place upper head frame with vanes into the pedestal tube – do not yet tighten the gray thumb screw.
2. Set the pedestal tube height at 6 feet/ 72 inches (screen printed in red on the silver pedestal tube – height line should show just above the lower, red tube) and tighten red thumb screw to hold the height.
3. Move the lowest red vane out and measure its height (should be 6 feet)
4. If too low, adjust the head frame up from the pedestal tube and tighten the gray thumb screw to hold in place. Use a permanent marker to make a line on the head frame tube to indicate how far to insert.

Call Sports Imports with any questions – 800-556-3198 / 614-771-0246

VERTEC INITIAL ASSEMBLY, DAILY SET-UP & BASIC OPERATION

ALIGNMENT & CALIBRATION

1. Your **VERTEC** is (and with reasonable treatment will remain) a precise and reliable instrument. The height of the bottom vane (in 6-inch increments) is indicated by the scale on the side of the upper (inner) pedestal tube. The readings thereon will be accurate when:

   a) the unit is properly aligned (the base holds the pedestal perpendicular to the floor);

   b) the pedestal height-scale is calibrated (the head is inserted to, and stopped at the appropriate depth on top of the upper pedestal tube);

   c) the pedestal tubes are correctly oriented to the base (the **SPORTS IMPORTS** label on the lower tube faces forward, away from the base) and to each other (the lock-screw at the top of the upper tube is pointed backward);

   d) the three lock screws (base-pedestal, height-adjust & pedestal-head) are tightened.

2. Your **VERTEC** was carefully aligned and calibrated at the factory. The pedestal was aligned - perpendicular to the floor - by adjusting and locking the two rear base-leg feet. If the respective locking bolts & nuts are not disturbed (and the rest of the unit is not damaged/deformed, etc.), the alignment and calibration should be retained indefinitely.

INITIAL ASSEMBLY (ONE-TIME)

1. The **VERTEC** is shipped with the two base sections disassembled. Using two 7/16" or adjustable wrenches, loosen & remove the lock-nuts from the two bolts that have been inserted through the center of the 3'-long rear base-leg (near the middle), but leave the bolts in place. Hold the front (pedestal-supporting) section of the base so that its bottom tube-cap faces down, and the holes in its back flange align with & fit over the threaded ends of the rear base-leg bolts. Replace & tighten the lock nuts firmly.

2. Put the base on the floor, and place the two disk weights over the pilot tubes. Then carefully center and tap in the two, flanged tube-caps supplied. Once on, the caps are difficult to remove and guard against the weights becoming lost, or falling on someone's foot when carrying the base separately; they also ensure that the weights will always be in place on the base whenever the pedestal is subsequently inserted - so that the unit will not tip over.

DAILY SET-UP (if head and/or pedestal are separated from base for storage)

1. Loosen the base-pedestal lock-screw, insert the pedestal (the pedestal label - **SPORTS IMPORTS** - faces forward), and tighten the lock-screw firmly (by hand, do not use a wrench).

2. Pick up the head, slide the clear vinyl tube back, push or shake the vanes forward, and reposition the vinyl tube about half-way back on the head frame. Loosen the head lock-screw on the pedestal, insert the head as far as possible, and re-tighten the lock screw by hand.

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HEIGHT ADJUSTMENT

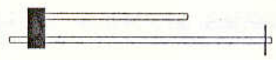
1. Loosen the height-adjust lock screw, raise the pedestal until the desired bottom vane height is indicated (when the associated horizontal line is just showing over the top of the lower pedestal tube). Re-tighten the lock-screw by hand (moderate pressure is sufficient here). NOTE: two spring-loaded buttons inside the pedestal impart just enough friction to the inner tube so that it cannot slide freely down of its own weight. This makes it easier to adjust the pedestal height (using both hands) and guards against the pedestal sliding down unexpectedly.

2. Remember to heed the warning at the lower end of the height scale, and do not overextend the pedestal, or the buttons will pop out. If this ever happens, you will need to remove the height-adjust lock-screw and squeeze in the two inner buttons, small end in, with channel-lock pliers in order to re-insert the upper pedestal tube (with its lock screw facing opposite to the lower tube **SPORTS IMPORTS** label.) NOTE: the pedestal may be a little stiff at first, but will wear in with usage. If necessary, rest your foot on a base leg when raising the pedestal.

RESET TOOL SET-UP AND USAGE

1. To set-up the reset tool: loosen and remove the wing-nut & screw holding the shorter tube, remove the tube, and re-insert it as in the drawing below. Replace and re-tighten the screw and wing nut.

   a) as shipped



   b) operational

2. The reset tool can be used for presetting or resetting some or all of the vanes as desired, simply by holding the tool free-hand, and pushing the vanes (in easy 6-inch groups) ahead or back with the tip of the tool. When there are a large number of vanes to be reset, the extended upper-tip of the handle tube can be inserted into the socket under the head and the upper tube rotated around this axis. If the upper tube deflects slightly at the top, orient the tool a little ahead of vertical to compensate. NOTE: If it seems that there is somewhat more resistance than usual when rotating the entire stack of vanes around with the reset tool, it is a sign that the vanes could use a little light lubrication. This is easily applied by BRIEFLY spraying the attached ends of the vanes and associated spacers with a light aerosol lubricant (a smooth sweep from top to bottom is ample). We recommend "WD-40" or a silicone spray-lubricant.

READING HEIGHT SCORES

1. With a little practice, jump-height scores can be read quickly - knowing the bottom vane height, and remembering the vane color code: red & blue vanes - full inches, with red vanes every 6th inch; white vanes - half inches. To determine the height of the highest touched/displaced vane, simply look towards the axis area of the vane stack, and scan your eyes upwards from the bottom - first looking for any higher displaced 6th inch red vanes, then for full-inch blue vanes, and finally for (one) half-inch white vane, if any. For example, with the head adjusted for a bottom-vane height of 9 feet, and one higher red, three blue, and one white vanes displaced, the score would be 9' 9 1/2".

2. When figuring a number of NET vertical jump values (distance gained over standing reach) you may find it easier to convert both the standing and jump reach values into straight inches, and then perform an easy subtraction. The new **VERTEC** pedestal height-scale lists the 6-inch bottom-vane increments in straight inches, as well as in feet & inches to facilitate this, or you can use the conversion table included with this manual.

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SAFETY CONSIDERATIONS

Vertical jump measurement/practice instruments are certainly one of the safer types of athletic equipment to use - when used normally and sensibly. Muscle or joint injuries incurred in the act of jumping itself would appear to be extremely rare, and even those that do occur are far more likely to result from inadvertent or forced unnatural jumps or landings during game actions, than when executing planned jumps during practice sessions. Moreover, considerable thought was put into the design of the **VERTEC** to ensure, among other things, that the pedestal and base would be amply clear of the normal jumping & landing area - so that jumpers could fully concentrate on improving their jump execution, and not have to worry about their safety. But the **VERTEC** is not a toy to be used casually, and without guidelines. You will soon discover that athletes and others find it irresistible to regularly test their jump prowess on the **VERTEC**, given the opportunity - which in fact is part of the secret of its training advantages. However, the following common-sense suggestions are offered:

1. Do not leave the unit out where it is likely to be used by individuals who have not received any guidelines and/or basic rules as to its usage.

2. Prohibit jump approaches by more than one individual at a time, or from other than a normal right-angle direction, e.g. not from an impromptu circuitous/off-line approach; it is helpful, when locating the unit on a gym floor, to position it so that a particular floor stripe marks (at right angles) the very outer edge of the extended vanes, and represents the optimal approach line for the CENTER of the body - the up stretched arm will then naturally intersect with the outer-half of the vane(s).

3. Prohibit usage without proper footgear, i.e. no street shoes, socks, bare feet, and do not use on a surface with unpredictable traction, e.g. a wet floor.

4. Prohibit (pointless) usage by tired individuals, or after a maximum of ten consecutive practice efforts without a rest (2 minutes nominal).

MOVING, STORING THE VERTEC

1. The **VERTEC** can be readily moved while fully assembled, from one location in a gym to another, by tipping the unit backwards over the base, and lifting and carrying the unit by the lower pedestal. For longer moves, it is usually better to disassemble and carry separately, if collectively, the base, pedestal & head sections, and then reassemble them, without fear of disturbing the calibration.

2. When storing the unit, it may be advisable to remove and place the head back in its' inner shipping carton, if these is any chance that the unit could get pushed over, or be damaged by some other piece of equipment. NOTE: while the **VERTEC** vanes are very resilient, they are not impervious to catching on doorways, etc. When storing, transporting (or using) the unit, keep it away from water, excess moisture, etc. If moisture does however enter into the telescoping pedestal, you should promptly separate the upper & lower tubes, dry each inside & out, spray a rust-inhibiting aerosol lubricant like "WD-40" inside the lower (outer) tube, and re-insert the upper tube - following the instructions noted under the second paragraph of the "HEIGHT ADJUSTMENT" section above.

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JUMP HEIGHT MEASUREMENT WITH THE VERTEC

1. To measure maximum jump reach and also compute the net vertical jump (distance actually jumped over the standing reach), it is usually best to make the standing reach measurement first (on the entire group to be tested). This can be readily done on the **VERTEC** also, but if there are a large number of individuals to be tested, and/or only a limited amount of time available, consider making the simple, static, standing-reach measurement against a wall-mounted (or other vertically supported) tape measure which works well for this purpose, and frees your **VERTEC** to simultaneously begin making the actual jump measurements.

2. We suggest making level, two-handed measurements of the standing reach because they are less subject to individual variations in the degree of one-arm, one-sided stretching, and therefore allow for better current and future comparisons of actual jumping ability. Also, it is doubtful that individuals are able to achieve their full one-arm stretching potential during the brief final instant of actual jumps.

3. The athlete must be BOTH comfortably warmed up AND loosened up to jump to his or her true current capacity, so a preparatory bout of calisthenics and stretching is desirable prior to any important vertical jump test. On the other hand, fatigue will significantly reduce jumping ability so it is best to not conduct a jump test well into or after intensive athletic practice session (unless an athlete's FATIGUED jump height capability is in fact what you want to determine).

4. If the jump test is conducted on a gym floor (or other striped area), position the **VERTEC** so that the outer edge of the target vanes is marked at right angles - by some particular floor stripe. This then will be the normal approach line for the center of the body, and the up-stretched arm will intersect naturally with the outer portions of the vanes.

5. Conventional jump tests as conducted with the **VERTEC** can entail natural standing jumps, one or two-step jumps, or full-speed running jumps. If necessary, demonstrate the appropriate or desired approach to the group before beginning. Of course, tests of jump-height capability with other unique situation approaches, techniques, etc. can be conducted any way you would like, and devise.

6. The 24-inch **VERTEC** head/vane span can usually be positioned at a height that will accommodate most, if not all, of the jump-reach capabilities of any group of similar jumpers. If you know, or can predict the probable range, adjust the pedestal height so that the bottom vane height will accommodate the lowest jumper(s), because it is normally preferable to have to raise the unit to accommodate someone better than the general group, than vise versa.

7. With all the vanes extended and aligned, instruct each jumper to make one preliminary jump, to gently tap forward a few vanes marking his/her approximate jump reach limit. Then, while the jumper waits, use the reset tool to push all the vanes, up to and including the highest touched vane, out of the way.

8. Following the preliminary jump (plus one or two more familiarization jumps if it is the athlete's first time using the **VERTEC**), allow the jumper to make some specified number of attempts to better the initial mark, or allow them to continue their jump trials as long as they keep improving on the mark, and then cannot touch any higher vanes in two successive attempts. There is no need to reset the touched vanes between efforts in this type of jump test.

9. With some first-time **VERTEC** users, after they have made some initial jumps to familiarize themselves, you may want to advise them to shift their attention from contacting the **VERTEC** vanes, to concentrating on attaining their best possible jump action (with a maximum terminal vertical velocity and jump height). Also, with certain current or would-be volleyball "power hitters,"

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you may want to suggest that, for this purpose, a better vertical jump mark might result if they focused more of their abundant energy into their lower-limb jumping muscles, rather than into using their arm muscles to needlessly "smash" the **VERTEC** vanes forward. If possible, have some good jumpers lead off to demonstrate good, efficient jumping form. Finally, if practical with first-time jump test subjects, allow a second test bout after a minimum of five minutes rest, or in the following day(s).

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Appendix B

INFORMED CONSENT TO PARTICIPATE IN THE STUDY:

Title: The Effects of Static Stretching on Vertical Jump Performance

Researcher: Thomas Evans (principal investigator), Dr. Dan Martin, Dr. Jeff Chandler, and Gary McIlvane

Overview: This study is designed to see if static stretching has an influence on vertical jump performance. I will be asked, as a subject, to perform a series of measured vertical jumps. The data collected in this study will be examined to determine what the effects of stretching, if any, are on vertical jump performance.

Procedure: I will be asked to perform six vertical jumps on two different occasions for a total of twelve. Before on set of six jumps, I will be asked to go through a stretching routine. On the other six jumps, there will be no stretching involved. I will be asked to come on two separate occasions. One time for each group. It should take no more than 15 minutes of my time.

Risks: The risks for this study are very minimal. There is chance that I could strain (pull) a muscle while conducting this experiment. There is a very small chance you could tear a muscle while performing the vertical jump.

Confidentiality: All data that is collected will be kept confidential to the extent the law and institutional policy allows. Any information obtained about me will also be kept confidential. The Marshall University Institutional Review Board and/or appropriate State and Federal agencies have the right to view my information.

Voluntary Participation: Participation in this study is completely voluntary. I can refuse to participate in this study or drop out at any time.

Contact Persons: If I have any questions or concerns about my rights as a participant in this study, I may contact the Institutional Review Board Chairperson, Dr. Henry Driscoll, at (304) 696-7320. If I have any additional questions or felt as if I have been injured during this study, please contact Thomas Evans at (304) 736-1603.

Compensation Clause: In the unlikely event illness or injury should incur as a result of participation in this study, I understand no compensation, financial or otherwise, will be provided by the investigators or Marshall University.

A copy of this form will be given to me.

If I agree to participate in this study, I will sign my name on the line below.

IRB APPROVAL EXPIRES MAY 1 2002

Participant Signature Date

Witness Signature Date

IRB MAY 1 2001 APPROVED

Principal Investigator Date

Appendix C

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	VAROOO01	21.2692	26	4.03294	.79092
	VAROOO02	23.3077	26	4.44764	.87225
Pair 2	V AROOO01	21.2692	26	4.03294	.79092
	VAROOO03	20.3269	26	4.26132	.83571
Pair 3	VAROOO01	21.2692	26	4.03294	.79092
	V AROOO04	21.8654	26	4.31638	.84651
Pair 4	VAROOOO2	23.3077	26	4.44764	.87225
	V AROOO03	20.3269	26	4.26132	.83571
Pair 5	V AROOO02	23.3077	26	4.44764	.87225
	V AROOO04	21.8654	26	4.31638	.84651
Pair 6	VAROOOO3	20.3269	26	4.26132	.83571
	VAROOO04	21.8654	26	4.31638	.84651

Legend

Variable 1	**Sitting jump with no stretch**
Variable 2	**Standing jump with no stretch**
Variable 3	**Sitting jump after stretch**
Variable 4	**Standing jump after stretch**

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	VAROOO01 & V AROOO02	26	.895	.000
Pair 2	VAROOO01 & V AROOO03	26	.968	.000
Pair 3	VAROOO01 & V AROOO04	26	.890	.000
Pair 4	VAROOO02 & V AROOO03	26	.910	.000
Pair 5	VAROOO02 & VAROOO04	26	.969	.000\
Pair 6	V AROOO03 & V AROOO04	26	.895	.000

Paired Samples Test

			Paired Differences				
					95% Confidence Interval of the Difference		
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t
Pair 1	VAROOO01 - VAROOO02	-2.0385	1.98456	.38920	-2.8400	-1.2369	-5.238
Pair 2	V AROOO01 - VAROOO03	.9423	1.07077	.20999	.5098	1.3748	4.487
Pair 3	VAROOO01 - VAROOO04	-.5962	1.97494	.38732	-1.3938	.2015	-1.539
Pair 4	VAROOO02 - V AROOOO3	2.9808	1.85731	.36425	2.2306	3.7310	L 183
Pair 5	VAROOO02 - VAROOO04	1.4423	1.10749	.21720	.9950	1.8896	6.641
Pair 6	VAROOO03 - VAROOO04	-1.5385	1.96430	.38523	-2.3319	-.7451	-3.994

Paired Samples Test

		df	Sic. (2-tailed)
Pair 1	V AROOO01 - V AROOO02	25	.000
Pair 2	V AROOO01 - V AROOO03	25	.000
Pair 3	V AROOO01 - V AROOO04	25	.136
Pair 4	VAROOO02 - V AROOO03	25	.000
Pair 5	V AROOO02 - V AROOO04	25	.000
Pair 6	V AROOO03 - V AROOO04	25	.001