

**THE EFFECT OF BASKETBALL WARM-UP ON VERTICAL JUMP,
SPRINT TIME AND SHOOTING ACCURACY**

A THESIS

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Abstract

A majority of basketball athletes do a warm-up up prior to playing basketball. This study examines the effects of aerobic warm-up, static stretching and dynamic movement on female athlete's basketball performance. Fourteen female NCAA Division III athletes were recruited to participate in this study. They were assigned different treatments on three different testing days. The treatments included different combinations of aerobic warm-up, static stretching and dynamic movement. They were tested for maximum vertical jump, sprint time and shooting efficiency. There were no differences between warm-up treatments for any of the tests. Therefore by completing a warm-up prior to playing basketball, the female basketball player is ready for anaerobic performance.

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CHAPTER I

Introduction

There has been considerable research on athletic warm-up. Brooks, Fahey, White and Baldwin (2000) state that the goal of the warm-up is to warm muscle tissue, prevent injury, fine-tune motor skills and prepare psychologically. These goals are widely accepted. However, the methods to accomplish the goals vary by sport and athlete. Brooks et al. (2000) assert that a warm-up needs to be activity specific, utilize the major muscle groups used during the activity and progress at an increasing intensity. Therefore there are many variables to consider when creating a warm-up.

The nature of the specific sport plays an important role in the construction of a warm-up. For example the sport of basketball is a fast paced game. On average female basketball players perform 652 ± 128 movements per game which corresponds to a new movement every 2.82 seconds (Matthew & Delextrat, 2009). In addition “a combination of factors including the small dimensions of the playing court, the short and rapid accelerations necessary to the game, and the nature of the movements like jumps, along with significant number of recovery phases during free throws and time outs, tend to call on anaerobic, rather than aerobic, energy sources during active phases of the game” (Sellet, Perrier, Ferret, Vitelli, & Baverel, 2005, p. 294). Therefore to prepare an athlete for basketball the focus of the warm-up should be anaerobic movements such as sprinting and jumping.

The athlete and coach also play an important role in the construction of a warm-up. Athletes and coaches create warm-up routines based on personal beliefs, myths, anecdotal evidence, professional opinions and science. Shehab, Mirabelli, Gorenflo, and

Fletters (2006) surveyed a group of Michigan High School coaches and found that a majority of coaches believe that pre-exercise stretching (PES) is beneficial by decreasing injury rates, increasing mental preparation and is without obvious drawbacks. According to the coaches, their beliefs about PES are influenced by personal experience and scientific research. Yet over ten years ago researchers determined that static stretching was not beneficial (Pope, Herbert, Kirwan, & Graham, 2000), may be harmful (Faigenbaum, Kang, et al., 2006; Fletcher & Jones, 2004; Nelson, Driscoll, Landin, Young, & Schexnayder, 2005; Sayers, Farley, Fuller, Jubenville, & Caputo, 2008) and was not correlated with injury reduction (Pope et al., 2000). It is evident that there is a large gap between the results of the research and its application by athletes and coaches.

Team sports add the additional difficulty of developing a warm-up because one routine must be effective for an entire group of athletes. Finding research to aid in the construction of a team warm-up for female team sports can be challenging. Since the passage of Title IV, the rate of female athletes participating in sport has increased exponentially. Today 15,152 women play NCAA basketball (DeHass, 2008). But women are still greatly under-represented in research with respect to warm-up. For example, of the four articles in peer reviewed journals about basketball warm-up and female athletes, three of them involve components of warm-up, ballistic stretching (Woolstenhulme, Griffiths, Woolstenmulme, & Parcell, 2006), wobble board training (Emery, Rose, McAllister, & Meeuwisse, 2007) and weighted vests (Faigenbaum, McFarland, et al., 2006), that are not commonly used by basketball teams. The lack of basic research on female athletes and warm-up components used by basketball teams makes creating a properly designed warm-up difficult.

Statement of the Problem

There are no baseline studies on the effect of women's basketball warm-up and basketball performance. Teams use many different activities in their warm-up including, but not limited to: jogging, static stretching, dynamic movement and basketball drills, e.g. ball handling, shooting, etc. Additional research needs to be done to determine which activities to use for their warm-up and in what sequence. The most common components are jogging, static stretching and dynamic movement.

The null hypothesis was:

Static stretching and dynamic movement would have no impact on anaerobic performance of female basketball players.

Delimitations

There were three delimitations for this study.

1. Subjects were disqualified from this study if they had recently had an injury or acquired an injury during the study period, especially lower limb. A lower limb injury was defined as one which would inhibit the athletes from participating in a normal basketball practice or required new/additional bracing or taping.
2. Subjects were disqualified from this study if they failed to complete all three testing sessions.
3. The group studied was from a single NCAA Division III institution and therefore not a randomized population from all female basketball players. Therefore,

conclusions that arise from this study cannot be generalized for higher level female basketball athletes, all female team sport athletes or all female athletes.

Limitations

There were three limitations with this study.

1. The athlete's weight and height was not verified.
2. The athlete's intensity during the warm-up was not confirmed by heart rate or body temperature.
3. The athlete's physical activity training was not controlled or accounted for.

Assumptions

It was assumed that the athletes filled out the questionnaire truthfully. It was assumed that the athletes followed a similar routine on the testing days, e.g. wake up time, food consumed, physical activity, etc. It was assumed that the athletes were attempting maximum scores on the three tests.

Definitions

5-Step Jump Test: From a parallel stance behind the starting line, subjects maximally jump from both legs to land on the left leg. Without stopping, maximally jump to the right leg, back to the left-leg, back to the right leg and finally stopping with a 2-leg landing. The distance from the starting line to the back of the most rearward heel is recorded; The 5-step jump is a reliable measure that correlates well with vertical jump, long jump and isokinetic leg strength (McMillian, Moore, Hatler, & Taylor, 2006).

Acetylcarnitine: A metabolite formed during intense muscular contraction.

Active Warm-up: Movements designed to increase core temperature, blood flow and prepare the body for exercise (Fletcher & Jones, 2004).

Ballistic Stretching: Controlled, bouncing movements performed at the end of the range of motion of a stretch (Woolstenhulme, Griffiths, et al., 2006).

Dynamic Movement: Low-, moderate-, and high-intensity hops, skips and jumps, and various movement-based exercises for the upper and lower body (Faigenbaum, Kang, et al., 2006).

Forward: Players on a basketball team that are typically bigger than guards and smaller than posts. They are not quite as good ball handlers as guards and are typically quicker than posts (Smith, 1999).

Guard: Players on a basketball team that direct the offence and have superior ball handling skills. They are typically shorter than forwards and posts (Smith, 1999).

NCAA: National Collegiate Athletic Association

Passive warm-up: Using external devices such as heat packs or blankets to passively heat the working muscles.

PES: Pre-exercise stretching

Post: A player on a basketball team that is typically the tallest player and is responsible for defending the lane (Smith, 1999).

Postactivation potentiation (PAP): Enhanced twitch potentiation following a bout of heavy resistance training (Matthews, Matthews, & Snook, 2004).

Proprioceptive neuromuscular facilitation: A combination of passive stretching and isometric contractions.

Static Stretching: Stretching to the end range of movement and holding the stretch at that point (Faigenbaum, Kang, et al., 2006).

UWRF: University of Wisconsin River Falls

VO_{2max}: The maximum amount of oxygen the body can utilize during a specified period of usually intense exercise.

CHAPTER II

Review of the Literature

Basketball warm-up routines are created to prepare the athletes to play basketball. Everything from the individual athlete to the nature of the sport needs to be carefully considered. To create a warm-up, the first step is determining the nature of the sport. For example, basketball is an anaerobic sport. The second step is to decide on which components to include in the warm-up. Typically basketball warm-ups include static stretching and dynamic movement. Finally, the duration and intensity of the warm-up needs to be determined. Together these variables will affect injury rate and athletic performance.

Warm-up Intensity

The athlete's warm-up intensity determines heart rate and body temperature prior to performance. Stewart and Sleivert (1998) studied the effect of warm-up intensities on cycle sprint times in male athletes. They found that the athlete's total body temperature was a function of warm-up intensity and an increase in performance when an athlete's warm-up was at 60-70% of their VO_{2max} . Mohr, Krstrup, Nybo, Nielsen, and Bangsbo (2004) came to the same conclusion in their study of soccer players. They found that "high muscle temperature is important for performance during repeated sprints" (p. 159) and that this was true before the match and at the start of the second half, i.e. when they had the athletes warm up a second time during half time, the athlete's sprint performances were better in the second half than if they did not re-warm-up.

What differentiates the two studies is Stewart and Sleivert (1998) found that sprint performance was inhibited when the warm-up surpassed 80% $\text{VO}_{2\text{max}}$. They did not cite body temperature as the source of performance decline but rather the metabolic depletion of energy stores. By analyzing muscle biopsies and body temperature, Robergs, et al., (1991) came to the same conclusion. Gray and Nimmo (2001) found no difference in exercise time to exhaustion between active and passive warm-up groups, but did find a decrease in blood lactate response when an active warm-up was used. Blood lactate is a byproduct of glycolysis and is a biochemical response to powerful muscular contractions (Brooks, Fahey, White, & Baldwin, 2000). Their results support the previous researchers' findings that the decline in performance is due to a biochemical reaction not muscle temperature.

To identify the biochemical cause for increased performance following active warm-up, Gray, Devito, and Nimmo (2002) studied female athletes and found that completing an active warm-up prior to a cycle sprint test resulted in higher concentrations of muscle acetylcarnitine immediately prior to testing. They hypothesized that "accumulation of large pre-exercise stores of muscle acetylcarnitine provides the extra substrate for oxidative ATP production at the onset of exercise" (p. 2095). Not only did they find that the active warm-up resulted in higher acetylcarnitine concentrations, but also a higher oxygen uptake during the first thirty seconds of the test and lower relative blood and muscle lactate concentrations. These findings support the correlation between muscle acetylcarnitine concentrations and reduced muscles lactate concentrations during high intensity exercise.

Warm-up and Injury Prevention

In the past due to fear that subjects would become injured, researchers have declined to include a no warm-up control in their research. Faigenbaum, McFarland, et al. (2006) defend this practice by stating “because participation in warm-up activities before exercise or sport is a universally accepted practice, we considered it inappropriate for young athletes to participate in anaerobic performance tests in a completely rested state” (p.362). Thompsen, Kackley, Palumbo, and Faigenbaum (2007) cite similar concerns in their study by stating “it is inappropriate for athletes to participate in anaerobic performance tests in a completely rested state” (p.55). Therefore research on warm-up and injury prevention focuses less on the practicality of the warm-up but specific treatments that can be incorporated into the warm-up that decrease injury rates.

There are intrinsic and extrinsic factors that play a role in injury, e.g. an intrinsic factor is ligament laxity and an extrinsic factor is shoe type. Hartig and Henderson (1999) stated that when studying male army recruits, these injury factors include, but are not limited to, “volume of training,...past injuries, previous physical condition, physical anomalies, body weight, sex, training surface, equipment, training techniques, whether the subject smokes cigarettes, and hamstring flexibility” (p.175). A majority of the research focusing on warm-up, injury prevention and intrinsic factors examines the relationship between pre-event stretching, specifically static stretching and injury rates.

Shehab et al. (2006) found that 93% of coaches believe that pre-exercise stretching decreases injury rates. Their beliefs are corroborated with published research that link muscle flexibility and increased injury risk factors. Hartig and Henderson (1999) note in their study on hamstring flexibility that “flexibility demonstrates a significant U-

shaped relationship with the incidence of injury; subjects at both extremes of flexibility are at more risk than the average group” (p. 175). Their research links an increased rate of overuse injuries with hamstring inflexibility in male military recruits. They assert that daily static stretching will increase hamstring flexibility and thus decrease injury rates. They also state that their results can be applied to other populations including athletes.

Witrouw, Danneels, Asselman, D’Have, and Cambier (2003) identified hamstring inflexibility as an intrinsic risk factor for lower extremity injuries in professional male soccer players. The conclusions from their study and the Hartig and Henderson (1999) studies used different definitions for inflexibility and increased injury risk. Hartig and Henderson (1999) defined the neutral hamstring position as perpendicular to the subject’s body and defined the range of hamstring flexibility associated with an increase risk of injury at greater than or equal to 30°. Witvrouw et al. (2003) defined the neutral hamstring position as parallel to the subject’s body and defined the range of hamstring flexibility associated with an increase risk of injury at greater than or equal to 90° (0° by Hartig and Henderson scale). With the evident gap in ranges, 30°, the application of results from these studies is population specific. Additionally, the authors note that only measuring muscle flexibility and not other intrinsic and extrinsic risk factors is a limitation in this type of research.

In an effort to better understand the relationship between injury rates and hamstring flexibility, Pope et al. (2000) examined the relationship between injury factors, intrinsic and extrinsic including hamstring flexibility, and injury rates in army recruits. They found that there was no correlation between pre-exercise static stretching and injury rates, but that there was a strong correlation between age and/or physical fitness of the

recruits and injury rates. Knapik et al. (2001) also found that other factors, such as aerobic capacity and smoking, were better indicators of injury rates in army recruits than flexibility. Additionally, Knapik et al. (2004) found that educational courses on injury awareness and prevention and including agility components in the prescribed warm-up had a positive impact on injury reduction.

There are a lot of current commentaries and reviews on static stretching and injury prevention, but there are few current research studies on the same subject matter. However, the most recent research suggests there is no correlation between static stretching and injury prevention. Nevertheless the interpretation of these studies by athletes and coaches linking the intrinsic factor of muscle flexibility, specifically hamstring flexibility, with decreased injury rates is evident by current basketball team's warm-up routines including a static stretching portion.

Warm-up and External Devices

External devices such as weighted vests or free weights have been used during warm-up to increase anaerobic output. The pre-loading of an athlete's muscles to increase performance is based on the postactivation potentiation (PAP) theory (Matthews et al., 2004).

Matthews et al. (2004) examined the impact of utilizing heavy resistance training prior to a 20-meter sprint performance. The different warm-up routines they used included one or more of the following: jogging, running drills, dynamic movement and back squats. There was a significant decrease in sprint time for the warm-up that included back squats than the ones that did not. Burkett, Ziuraitis, and Phillips (2001) also used

free weights during warm-up and tested maximum vertical jump of NCAA Division I female athletes. They concluded that utilizing free weights during the warm-up positively impacted the athlete's vertical jump scores. However, Burkett et al. (2001) did not include a dynamic movement control in their research so it is uncertain if the results they observed would be comparable or favorable when compared to a dynamic movement warm-up.

Faigenbaum, McFarland, et al. (2006) tested high-school aged girls wearing weighted vests containing weight equivalent to 2% of the athlete's total body weight during the warm-up and how that effected vertical jump, long jump, seated medicine ball toss and 10-yard sprint. They found an increase in athlete's jumping ability, vertical and long, when weighted vests were used as compared to other warm-up methods. They stated that "stronger trained athletes may be better able to benefit from PAP, so one could expect the subjects in our study (primarily basketball players and track athletes) to benefit from our dynamic warm-up protocols" (p. 362). Thompsen et al. (2007) also utilized weighted vests and tested vertical and long jump in female athletes. They came to the same conclusions as Faigenbaum, McFarland, et al. (2006).

Further research needs to be conducted in this area of research due to concerns about their long term effects on athletes and limited resources of schools and universities. Burkett et al. (2001) note in their study that "the type and weight of resistance that may be used varies, and it is also dependent on what is available to the athlete at the time of testing" (p. 83). Thompsen et al. (2007) note that "the chronic effects of warm-up dynamic exercise with and without a weighted vest on injury rates and performance have not yet been examined" (p. 55).

Anaerobic Performance and Playing Position

Basketball players can be categorized by position: guards, forwards and posts. Warm-up routines for practice are traditionally indifferent to basketball position, e.g. the entire team does the same warm-up. However, before games, basketball teams typically have sections that are position specific. The position specific section focuses on skills most often used by players playing that position, e.g. guards and ball handling, posts and post moves, etc.

Sallet et al. (2005) examined the physiological differences in male professional basketball players based on playing position. Beyond the expected differences in height, weight and body fat percentages, with posts being taller and heavier, other physiological differences were observed. Guards and forwards performed better than posts in the maximal treadmill test and on the 30-second all-out sprint test. Physiological differences were also noted with soccer players based on their playing position (Mohr et al., 2004).

The findings by Sallet et al. (2005) and the fact that each basketball position has specific roles that rely more heavily on one type of anaerobic movement, suggest that teams could specialize warm-up routines for players based on playing position. However there is currently no published research on how a basketball athlete's warm-up should be structured based on playing position.

Anaerobic Performance and Caffeine Consumption

There have been a number of studies looking at caffeine ingestion and performance outcomes. The effects of caffeine are typically felt 60-90 minutes post

ingestion. Therefore caffeine ingestion is an easy variable to control in research.

However, the research suggests that unlike endurance events where caffeine may have an ergogenic effect (Brooks et al., 2000), when doing high intensity (power, speed) activities caffeine consumption is not beneficial. For example, Stuart, Hopkins, Cook, and Cairns (2005) found that caffeine could have an ergogenic effect on the outcome of an entire basketball game but the effect was primarily a result of the reduction of fatigue at the end of the game and not enhanced speed, power and accuracy throughout the competition. In addition, Crowe, Leicht, and Sparks (2006) found that caffeine ingestion was not beneficial when doing high intensity cycle ergometer exercise testing.

Anaerobic Performance and Menstrual Cycle

An athlete's menses does not need to be controlled for when testing anaerobic components like past researchers have suggested (Gray, Devito, & Nimmo, 2002). The most recent research looking at the menstrual cycle and athletic performance defines menstrual cycle phases by estrogen and progesterone levels. This distinguishes the current research from previous research. A majority of the researchers using these parameters have concluded that the phase of the menstrual cycle is insignificant with respect to high intensity testing, i.e. power or speed. For example, Smekal et al. (2007) found that the phase of the menstrual cycle did not affect lactate thresholds or ventilatory thresholds and Lynch and Nimmo (1998) found that exercise performance does not vary between the follicular and luteal phases of menstruation. This is in contrast to endurance exercise, especially in high temperatures, where researchers have concluded that

performance is impacted by the phase of an athlete's menstrual cycle (Lebrun, McKenzie, Prior, & Taunton, 1995; Sunderland & Nevill, 2003).

Warm-up and Speed

Sprinting is one of the most powerful movements a basketball player performs and it is also one of the first movements she will perform. In a basketball game, aside from the post player involved in the initial jump ball, a majority of players will sprint down the court to either play defense or offense. Therefore it's critical to examine how warm-up impacts sprint time.

There are an overwhelming number of published studies looking at the relationship of sprint time and warm-up. For example, the relationship has been studied in youth gymnasts (Siatras, Papadopoulos, Mameletzi, Geridimos, & Kellis, 2003), track athletes (Nelson et al., 2005), teenagers (Faigenbaum, Kang, et al., 2006), trained recreational athletes (Fletcher & Jones, 2004), elite rugby players (Stewart, Adams, Alonso, Koesveld, & Campbell, 2007) and elite professional soccer players (Sayers et al., 2008). A lot of this research focuses on the impact of static stretching and/or dynamic movement on sprint times.

In anaerobic sports with individual components, such as gymnastics or track and field, any change in speed can be catastrophic. Siatras et al. (2003) examined the relationship between static stretching, dynamic movement and vault speed in youth, male athletes. They found that the athlete's vault speed decreased following static stretching and did not change following dynamic movement. They concluded that "although static stretching is beneficial for gymnasts' flexibility development, in some events such as

vaulting, where success is related to running speed, it is not advisable to include static stretching exercises just prior to vault execution, as this might be detrimental to performance” (Siatras et al., 2003, p. 390). Nelson et al. (2005) examined the effect of static stretching on NCAA Division I male track and field athletes. When sprinting was coupled with static stretching it was correlated with a slower sprint time. Winchester, Nelson, Landin, Young, and Schexnayder (2008) also tested NCAA Division I track athletes, but included both male and female athletes. They found a decreased sprint time when the standard dynamic movement warm-up was coupled with static stretching and this was consistent for male and female athletes. Fletcher and Anness (2007) observed the same phenomenon with adult sprinters indicating that dynamic movement performed prior to the static stretching did not cancel the negative effect associated with static stretching.

Other researchers focus on athletes in team anaerobic sports, such as soccer and rugby, and how static stretching and dynamic movement effect sprint time. Stewart et al. (2007) studied rugby players and the effect of no warm-up (dynamic movement), warm-up and warm-up with static stretching on sprint time. They found that including a warm-up had a positive effect on sprint times and that no warm-up or static stretching alone had a negative effect. They were able to quantify their results in terms of distance traveled. With everything else being the same, the athlete that did a warm-up would be able to travel 0.97m farther than their no warm-up counterpart in a 5.5 second sprint. Fletcher and Jones (2004) also used rugby players to determine the relationship between warm-up and sprint time. They found that a warm-up including an active warm-up of dynamic movements was superior to a warm-up including static stretching because it resulted in

decreased sprint times. Finally, Sayers et al. (2008) examined the relationship between static stretching and elite female soccer player's sprint performance. For all treatment groups they used an initial warm-up that included dynamic movements. They found that sprint time (acceleration and velocity) decreased when the warm-up included static stretching. And they noted that the difference they observed was great enough that, especially for an elite athlete, the decreased acceleration and velocity could mean the difference between winning and losing.

Three different studies note that while significant results were obtained regarding static stretching and sprint time, it may not be advisable to remove static stretching from every athlete's warm-up. Nelson et al. (2005) noted in their concluding remarks that "the athletes in this study were very uneasy at the start of each of the no-stretch sprints. Thus, the negative impact of physiological/mechanical impacts of stretching must be greater than any negative psychological feelings in the no-stretch condition" (p. 453.). Fletcher and Jones (2004) note "care should be taken, for a minority of individuals may not exhibit the positive changes in performance that this study has demonstrated" (p.888). Finally, Fletcher and Anness (2007) conclude their practical application sections by stating "it is important to remember that the subjects' usual warm-up practice was to include static stretching, which could have led to a reverse placebo effect, as subjects may have felt unable to perform their best without going through their usual routine" (p. 787).

Warm-up and Jump

Five percent of the total movements of a female basketball player during a game are jumps (Matthew & Delextrat, 2009). This is a relatively low percentage of the total movements but it is one of the most forceful movements an athlete will do in basketball. A majority of jumps that a basketball player performs are vertical jumps. For example, at the start of every basketball game two opposing athletes stand facing each other and as the ball is sent upward by an official they vertical jump attempting to tip the ball to their teammate and gain control of the first offensive series. This same vertical jump motion is replicated throughout the game during rebounding, defense and offense. Therefore it is important to determine how an athlete's warm-up impacts vertical jump performance.

Power, Behm, Cahill, Corroll, and Young (2004) tested male adults for their ability to vertical jump after completing a series of static stretches. They found that that there was no correlation between vertical jump and static stretching. Church, Wiggins, Moode, and Crist (2001) examined the same relationship but included proprioceptive neuromuscular facilitation (PNF) as an additional treatment. They differed from the previous study because their subject population was NCAA Division I female athletes and they included some dynamic movements in their general warm-up. They, too, found that there was a lack of correlation between static stretching and vertical jump performance and they found that there was a negative correlation between PNF and vertical jump. Little and Williams (2006) examined the same relationship, static stretching and vertical jump, in adult male soccer players and found no impact of pre-test static stretching on jump performance. But it is important to note that in Little and William's (2006) protocol, the athletes did a series of sprint and agility runs after

completing the static stretching so the effects of the static stretching may have been masked by other components of the warm-up.

Vetter (2007) addressed the issue of masking by testing six different warm-up protocols that included individual or combinations of walk/jog, static stretch, jump or dynamic movement. Vetter found a correlation between static stretching and decreased vertical jump as compared to the walk/jog or the dynamic movement plus jump warm-up. Similarly, Faigenbaum, Kang, et al. (2006) found a decrease in vertical jump in children after doing static stretch. Since each of these studies used a different warm-up protocol, it is hard to directly compare the results, e.g. some included dynamic movement, agility, etc. However, most important was that none of the researchers concluded that static stretching prior to jumping was beneficial.

Dynamic movement, on the other hand, is correlated with an increase in vertical jump. In a study that utilized a 5-step jump test instead of a maximum vertical jump, the subjects, United States Military cadets, decreased their jump distance after static stretches but increased their jump distance after dynamic movements. (McMillian et al., 2006). Faigenbaum, Kang, et al. (2006) had children do dynamic movement and/or a combination of dynamic movement and static stretching before a maximum vertical jump test. They found an increase in vertical jump when dynamic movement was included in the warm-up by itself or in combination with static stretching. They stated “a unique finding from our study was the observation that pre-event static stretching followed by dynamic exercises was just as effective as dynamic exercise alone...the results from our study might lessen or even negate any adverse consequences resulting from pre-event

static stretching” (p.71). This may be the same phenomenon that Little and Williams (2006) observed in their study but had attributed to other variables.

Other researchers have focused on the longer term effects of stretching and vertical jump. Woolstenhulme et al. (2006) had adults static stretch or ballistic stretch over a six week period. They tested the adults after the warm-up and after 20 minutes of basketball play. They found that neither the static stretching nor ballistic stretching had an effect on vertical jump when tested before basketball play. But when they tested the athletes after basketball play, ballistic stretching was correlated with an increased vertical jump.

Warm-up and Power

While basketball is not considered a power sport, a number of activities that basketball players do are considered to have a power component, e.g. jumping (force x height), sprinting (force x distance), etc. Researchers examining power often make the connection between their research and practical applications, for example “leg extension power resembles the power produced during a jumping movement such as a vertical jump” (Yamaguchi & Ishii, 2005, p. 682). Therefore in addition to vertical jump and spring time, power needs to be reviewed with respect to basketball.

The research results for warm-up and power are inconclusive. Power et al. (2004) tested adult male’s maximum voluntary force after static stretching. They found a decrease in force production following static stretching. Yamaguchi and Ishii (2005) investigated leg extension power and static stretching for male college students. They found static stretching did not reduce leg extension power but that dynamic movement

increased leg extension power. Additionally, they noted that the change in power was greater in the subjects that had the highest initial power scores. Eagan, Cramer, Massey, and Marek (2006) found no relationship between peak torque or mean power output in NCAA Division I female basketball players. They hypothesize that the better trained the athlete, the less significant impact stretching would have on performance but that is in direct contradiction with the results of the Yamaguchi and Ishii study.

Attempting to determine which component or combination of components were most beneficial to power, Cè, Margonato, Casasco, and Veicstreinas (2008) had male subjects complete different warm-up routines comprised of active warm-up, passive warm-up and/or static stretching. They found an increase in power production when a dynamic warm-up was used and no effect in power production when static stretching was used immediately prior to testing as compared to the control group. However they did note that all beneficial effects of the dynamic warm-up were masked when static stretching was done after the dynamic warm-up but prior to testing. Finally, Behm, Bambury, Cahill, and Power (2004) were unable to find a correlation between static stretching and power output in adult males.

Summary

To create an effective warm-up routine, an athlete or coach needs to consider the nature of the sport and the desirable outcomes. Basketball is a fast pace anaerobic sport. The warm-up should prevent injury, prepare the athlete's muscle for contraction and increase anaerobic performance, e.g. vertical jump, sprint speed, etc. However there is limited published research on female basketball athletes and anaerobic performance.

For a non-sport specific athlete to decrease injury rate and increase anaerobic performance the published research recommends that the athlete actively warm-up at an intensity that increases heart rate and body temperature above baseline levels while staying below 80% VO_{2max} . The warm-up should include an aerobic component and may include dynamic movement. The inclusion of static stretching should be analyzed carefully by balancing the negative physiologically affect and positive psychosomatic affect of static stretch. If static stretching is included, the ordering of the warm-up components need to be carefully analyzed as the negative effect of static stretching may mask the beneficial effect of other treatments.

The impact of the same warm-up components on female basketball players is relatively unknown. The reason that more research has not been done on this population is unknown. Perhaps the perceived confounding variable, female menses, associated with working with female athletes makes this population more challenging. However the literature is clear that menstrual cycle does not impact anaerobic performance. Therefore testing the efficiency of a warm-up routine on anaerobic performance with female athletes is feasible.

CHAPTER III

Methods

Subjects

The participants of this study included athletes from the NCAA Division III University of Wisconsin River Falls (UWRF) women's basketball team. This population was selected because the athlete's were available, familiar with the warm-up components and testing apparatus. In addition, the testing could be done at the University of Wisconsin River Falls gymnasium so no transportation was required.

The study was introduced to the basketball coach at UWRF and she was asked for assistance in enlisting her athletes. At her team's fall meeting, she described the study and asked the athletes to consider volunteering. A total of fourteen athletes volunteered to be in the study.

Instruments

Biometric and basketball information was collected for each athlete by a questionnaire (Appendix B). The purpose of the questionnaire was to collect information such as height, weight and basketball position, which may be useful to stratify the data.

The gymnasium at the University of Wisconsin River Falls, Karges Center, was the site for all warm-up and testing. The basketball court in Karges Center is a standard NCAA basketball court (Figure 1).

The maximum vertical test was conducted on a Vertec (Sports Imports 1-800-556-3198). A Vertec consists of a vertical, telescoping, horizontal metal pole with a weighted base. Emerging from the top twenty-four inches (60.96 cm) of the vertical pole

are easily movable, plastic, color coated vanes spaced every half inch (1.27 cm) (Figure 2). The athlete, with both feet together, stands directly below the vanes and reaches with one arm to maximum standing height. The vertical pole is adjusted so that the bottom vane is positioned at maximum reaching height. The athlete then moves one foot backwards to prepare for her vertical jump. When ready, she brings her back leg parallel to her front leg and jumps vertically as high as she can while moving as many vanes as possible with her extended arm. The number of vanes moved is tallied, converted to inches (cm) and recorded. The vertical jump was recorded to the half inch (1.27cm). Each athlete performed two maximum vertical jumps with less than one minute between attempts.

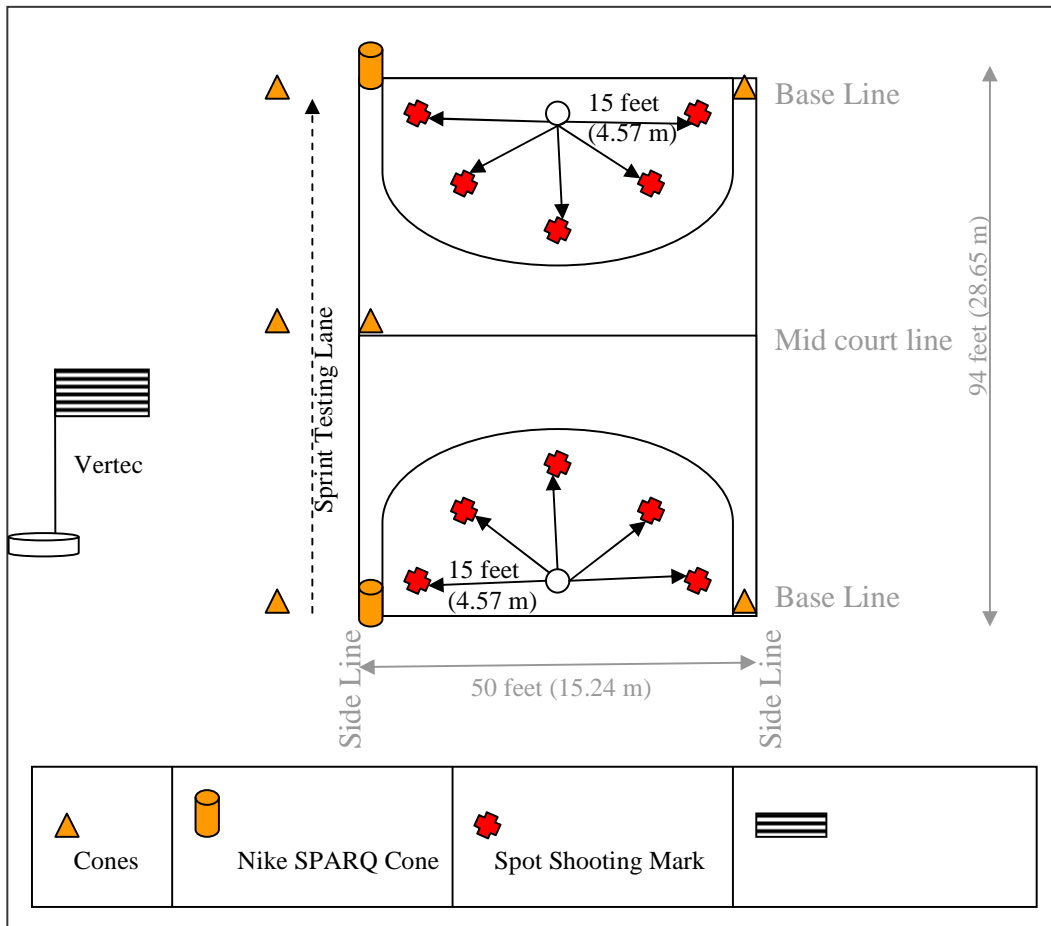
The sprint test was conducted using the Nike SPARQ System (Nike #7-0635, Batch # 2885223). The system consists of two 19 inch (48.26cm) cones and a wireless hand held timer (Figure 3). Each cone is equipped with an infrared emitter-detector beam that has a four foot (1.22m) range extending from the cone. The beam is set horizontal to the ground and at mid-calf to knee height. The first cone is placed at the start line so that the beam is parallel to the baseline. Using the sideline as one side of the running chute, the second cone is placed on the opposite baseline, the end line, so that its beam is parallel to that baseline. The athlete was instructed to stand in a ready position, with front foot right up to but not touching the start baseline. Upon receiving a signal that the apparatus was ready, the athlete started her sprint when she wanted to. The electronic timer starts when the athlete's leg breaks the start cone sensor beam. The timer stops when the athlete's leg breaks the end cone sensor beam. The sprint time was recorded to the one hundredth of a second. Each athlete performed two sprints; she completed her

first sprint, walked back to the start line, waited for the other subjects to complete their first sprints and then completed her second sprint. On occasion, an athlete would falsely trigger the start beam before she started her sprint or the timer would not start after she had crossed the start beam. For both of these cases, she was instructed to walk back to the start line and wait her turn to redo the sprint. This only happened one or two times per test day and never to the same athlete.

The final test, a basketball shooting drill based on the method created by the American Alliance for Health and Physical Education and as described by Woolstenhulme, Bailey, & Allsen (2004), tested each athlete's shooting accuracy. The test consists of seven specific shooting spots. Two of the spots are unmarked and are lay-up spots. The other five floor spot locations were measured on each test day with a retractable tape measurer (KomPro US Patent Number 6595451) and a protractor. They were 15 feet (4.57 meters) from the center of the basketball hoop (the center of the hoop is 63 inches (1.60m) from the baseline) and were located at a 0° angle, 45° angle, 90° angle, 135° angle and 180° angle from the baseline (Figure 4). The rules for the test are as follows: each athlete shoots a NCAA regulation women's basketball (Wilson Solution 28.5) for 60 seconds from the spots on the floor, each athlete rebounds her own basketball, she must shoot from each spot at least once, may take no more than four lay-ups, and may shoot no more than two lay-ups in a row. Each made shot is worth two points and were counted by the athletes waiting their turn to take the test. The total number of points after 60 seconds was recorded. The athletes started and stopped shooting on a signal and were timed on a hand held stop watch. After shooting once, the

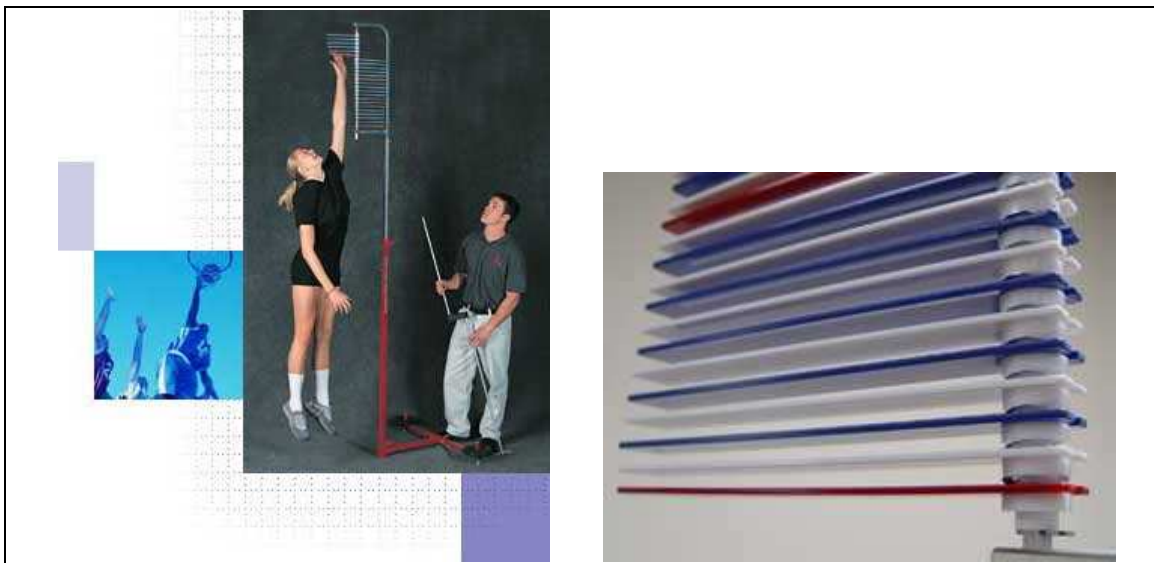
athlete sat out a 60 second testing period, i.e. 60 second test, 60 second rest, 60 second test.

Figure 1. *Gymnasium Setup for Testing*



Note. Figure not drawn to scale.

Figure 2. *Vertec System*



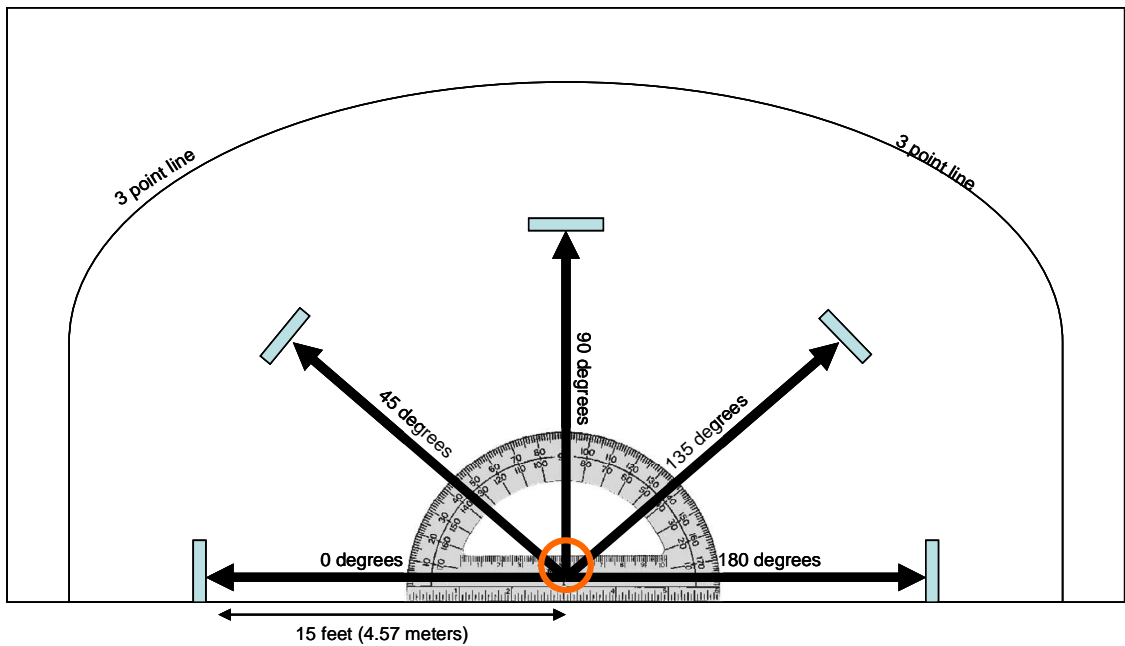
Note. ©JUMPUSA.com (<http://www.jumpusa.com/vertec.jpg> on 12/9/2008)

Figure 3. *Nike SPARQ XLR8 Digital Timing System*



Note. ©SPARQstore.com (12/9/2008)

Figure 4. *Floor Spot Placements for the Shooting Accuracy Test*



Note. Figure not drawn to scale.

Procedure

At the initial study meeting, the athletes were told why they were being recruited to participate in the study, e.g. NCAA Division III female basketball players between the ages of 18-25, and of any exclusion criteria, e.g. current injury, inability to participate in all testing days, etc. The study's three warm-up routines and testing procedures were described in detail. The athletes were currently using the warm-up components in their own warm-up routines and were familiar with the testing apparatus because they had previously used it for team testing. The athletes were told that participation was completely voluntary and if they were not interested in participating they were allowed to leave.

The remaining athletes went through the informed consent process. The informed consent form was read aloud and the athletes were encouraged to ask questions about

what they were being asked to do. After the questions were satisfactorily answered, the athletes were informed that a testing schedule would be sent to their coach and posted in the team locker room. They were asked to wear clothes, shoes and bracing or taping that they would normally wear to practice. They were also asked not to do anything unusual on the testing days, i.e. consistent wake up time, meal time, and caffeine and food ingestion. In addition, they were told that during the first test time they would be asked to sign the informed consent form (Appendix A) and fill out a short questionnaire (Appendix B).

For testing, the athletes were randomly assigned a position in the study design, i.e. a row in the Latin Square (Table 1), and divided into three treatment groups per test day. As Table 1 illustrates, the Latin Square consists of two repeated squares with two substitute subjects. One of the strengths of using this study design is it attempts to block for variability associated with subject and test day. This was ideal for these athletes because they were actively participating in training programs at the time of testing. Each test time was scheduled for thirty minutes and included a group of four or five athletes. For example, on test day number one, subjects 1, 4, 7, 10 and 13 completed the session together.

Table 1. *Latin Square Study Design*

	Test Day 1	Test Day 2	Test Day 3
Subject 1	Warm-up 1	Warm-up 2	Warm-up 3
Subject 2	Warm-up 2	Warm-up 3	Warm-up 1
Subject 3	Warm-up 3	Warm-up 1	Warm-up 2
Subject 4	Warm-up 1	Warm-up 3	Warm-up 2
Subject 5	Warm-up 2	Warm-up 1	Warm-up 3
Subject 6	Warm-up 3	Warm-up 2	Warm-up 1
Subject 7	Warm-up 1	Warm-up 2	Warm-up 3
Subject 8	Warm-up 2	Warm-up 3	Warm-up 1
Subject 9	Warm-up 3	Warm-up 1	Warm-up 2
Subject 10	Warm-up 1	Warm-up 3	Warm-up 2
Subject 11	Warm-up 2	Warm-up 1	Warm-up 3
Subject 12	Warm-up 3	Warm-up 2	Warm-up 1
Subject 13	Warm-up 1	Warm-up 2	Warm-up 3
Subject 14	Warm-up 2	Warm-up 3	Warm-up 1

One of the athletes that initially volunteered to be in the study, subject six, chose not to participate sometime between the initial meeting and before the first session. She did not give advance notice of withdrawing and since she was scheduled to participate in the final test session of the first day, another athlete was unable to substitute for her. In addition, subject seven chose not to participate in the final day of testing due to an academic conflict. Since she gave advance warning, subject 13 substituted for her as they had done the same warm-up routines on the same days. Therefore subject seven's data was excluded and subject thirteen's data was included in the final analysis.

On the first test day, each athlete signed the informed consent and filled out the athlete questionnaire. Then they were told which treatment their testing group would be

doing. On a signal they started the warm-up which was timed on a hand-held stop watch. The next three paragraphs describe each warm-up.

Warm-up one included only an aerobic component. Athletes were instructed to jog around the gym (Figure 1) at a leisurely pace that would allow them to carry on a conversation for ten minutes \pm thirty seconds. Upon completion of this warm-up the athletes were told to line up at the vertical jump testing station.

Warm-up two included both an aerobic and a dynamic movement component. Similar to warm-up one, the athletes were instructed to jog around the gym at a leisurely pace for six minutes. Next they were told to move to a sideline where they completed a series of organized dynamic movements (Table 2; Appendix C). The entire warm-up lasted ten minutes \pm thirty seconds. Upon completion of this warm-up the athletes were told to line up at the vertical jump testing station.

Warm-up three included an aerobic, a static stretching and a dynamic movement component. Like the other two warm-ups, the athletes began the warm-up by jogging around the gym. They did this at a leisurely pace for two minutes. Next, they were told to come together at center court and complete four minutes of organized static stretching (Table 3). Finally, they moved to a side line and completed the series of organized dynamic movements used in warm-up two. The entire warm-up lasted ten minutes \pm thirty seconds. Upon completion of this warm-up the athletes were told to line up at the vertical jump testing station.

Table 2. *Dynamic Movements from Warm-ups Two and Three*

Dynamic Movement	Time/Dynamic Movement	Number of Repetitions (Sideline to Sideline)	Total Time
High Knees	15 sec./movement	2	30 seconds
Butt Kicks	15 sec./movement	2	60 seconds
Hurdle Walk	30 sec./movement	1	90 seconds
Power Skip	15 sec./movement	2	120 seconds
Karaoke	15 sec./movement	2	150 seconds
Alternate Leg Bounds	15 sec./movement	2	180 seconds
Two Footed Jumps	15 sec./movement	2	210 seconds
One Footed Jumps – Stationary (10/foot)	30 sec./movement	N/A	240 seconds

Note. The time per dynamic movement is the max time allowed for a subject to complete the dynamic movement from one sideline to the other. If the subject finishes in less than the allotted time, they were instructed to rest on the sideline until the next dynamic movement.

Table 3. *Static Stretches from Warm-up Three*

Static Stretch	Time/Static Stretch	Total Time
Quadriceps – Standing	15 sec./leg	30 seconds
Hamstring – Sitting	15 sec./leg	60 seconds
Abductor – Outer Thigh	15 sec./leg	90 seconds
Adductor – Inner Thigh	30 sec.	120 seconds
Hip Flexors – Standing	15 sec./leg	150 seconds
Groin Stretch – Standing	15 sec./leg	180 seconds
Shoulder - Front	15 sec./arm	210 seconds
Triceps - Back	15 sec./arm	240 seconds

After completing their assigned warm-up, the athletes were tested for maximum vertical jump, sprint time and shooting accuracy. Each athlete did the same test in the same order each testing day: vertical jump, sprint time and shooting accuracy. The gymnasium was setup for the testing as illustrated in Figure 1. While waiting in line for testing the athletes were instructed not to do any additional warm-up activities, e.g. static stretch, dynamic movements, etc.

Data Design & Analysis

The athletes' biometric data was captured in the athlete questionnaire and the mean for each category was calculated. The test results were analyzed with SPSS version 14.0. As described previously, subjects six and seven did not complete the testing. Therefore their results were excluded from the analysis. In addition, in an attempt to keep the Latin Square balanced, subject 14 results were excluded from the analysis.

A univariate ANOVA was run for each of the dependent variables: vertical jump, sprint time and shooting score. The fixed factors were: subject, test day and treatment. A custom model was used that looked at the main effects for subject, test day and treatment.

CHAPTER IV

Results

Twelve of the 14 recruited athletes completed the study. Two athletes were disqualified from the subject for failure to complete the testing. A total of twelve NCAA division III female basketball players completed the study. All 12 athletes were from the University of Wisconsin River Falls women's basketball team.

The subject biometric information is listed in Table 4 and the means are displayed in Table 5.

Table 4. *Subject Biometric Data*

Subject Number	Age Years	Height Inches (m)	Weight Pounds (kg)	Number of years played NCAA Division III Basketball	Basketball Position (1-5)^a
1	19	67 (1.63)	145 (65.8)	1	1/2/3
2	18	69 (1.75)	155 (70.3)	0	4/5
3	21	66 (1.68)	133 (60.3)	2	2/3
4	18	69 (1.75)	157 (71.2)	0	2/3/4
5	20	66 (1.68)	140 (63.5)	1	2/3
6	DNP ^b	DNP ^b	DNP ^b	DNP ^b	DNP ^b
7	18	72 (1.83)	175 (79.4)	0	4/5
8	20	65 (1.65)	150 (68.0)	2	2/3
9	18	70 (1.78)	175 (79.4)	1	4/5
10	19	64 (1.63)	160 (72.6)	1	2/3
11	18	71 (1.80)	165 (74.8)	0	4/5
12	21	66 (1.68)	145 (65.8)	1	2
13	18	64 (1.63)	130 (59.0)	0	1
14	22	65 (1.65)	140 (63.5)	2	1

^a Basketball Positions are defined by the following numerical system: 1=point guard, 2/3=shooting guard/off guard, 4/5=power forward/forward.

^bDid not participate.

Table 5. Means of Subject Biometric Data

Number of Subjects	13
Mean Age – years	19.2
Mean Weight – pounds (kg)	151.5 (68.7)
Mean Height – inches (m)	67.2 (1.70)
Mean Number of Years Playing NCAA Division III Basketball – years	0.85
Number of Guards (1/2/3)	9
Number of Forwards (3/4)	4

Note. One subject voluntarily chose not to participate in any of the testing.

Vertical jump, sprint time and shooting scores and the means are displayed in
Table 6.

Table 6. Vertical Jump, Sprint and Shooting Test Results

Subject	Test Day	Warm-up	Vertical Jump #1	Vertical Jump #2	Sprint #1	Sprint #2	Shooting Score #1	Shooting Score #2	Vertical Jump - Mean	Sprint - Mean	Shooting Score - Mean
			inches (cm)	inches (cm)	Seconds	Seconds	Points	Points	Inches (cm)	Seconds	Points
1	1	1	21.0 (53.3)	20.5 (52.1)	4.49	4.60	18	24	20.8 (52.7)	4.55	21
1	2	2	19.5 (49.5)	20.5 (52.1)	4.53	4.53	10	14	20.0 (50.8)	4.53	12
1	3	3	21.5 (54.6)	22.0 (55.9)	4.54	4.62	22	28	21.8 (55.2)	4.58	25
2	1	2	19.5 (49.5)	19.0 (48.3)	4.73	4.81	24	28	19.3 (48.9)	4.77	26
2	2	3	18.5 (47.0)	19.0 (48.3)	4.75	4.80	18	18	18.8 (47.6)	4.78	18
2	3	1	18.0 (45.7)	18.0 (45.7)	4.77	4.75	12	12	18.0 (45.7)	4.76	12
3	1	3	21.5 (54.6)	21.0 (53.3)	4.67	5.04	16	22	21.3 (54.0)	4.86	19
3	2	1	21.0 (53.3)	22.0 (55.9)	4.82	4.92	22	18	21.5 (54.6)	4.87	20
3	3	2	22.0 (55.9)	22.0 (55.9)	4.76	4.91	24	16	22.0 (55.9)	4.84	20
4	1	1	19.0 (48.2)	19.0 (48.3)	4.64	4.58	18	8	19.0 (48.3)	4.61	13
4	2	3	20.0 (50.8)	20.0 (50.8)	4.71	4.84	18	20	20.0 (50.8)	4.78	19
4	3	2	19.5 (49.5)	20.0 (50.8)	5.14	4.89	14	16	19.8 (50.2)	5.02	15
5	1	2	22.0 (55.9)	22.5 (57.2)	4.56	4.43	18	16	22.3 (56.5)	4.50	17
5	2	1	20.0 (50.8)	20.5 (52.1)	4.94	4.70	22	24	20.3 (51.4)	4.82	23
5	3	3	22.5 (57.2)	24.0 (61.0)	4.68	4.70	22	26	23.3 (59.1)	4.69	24
6	1	3	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
6	2	2	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
6	3	1	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
13	1	1	20.0 (50.8)	20.0 (50.8)	4.60	4.58	20	18	20.0 (50.8)	4.59	19
13	2	2	21.0 (53.3)	21.5 (54.6)	4.51	4.74	22	24	21.3 (54.0)	4.63	23
13	3	3	21.0 (53.3)	22.0 (55.9)	4.68	4.66	26	32	21.5 (54.6)	4.67	29
8	1	2	17.0 (43.2)	17.5 (44.5)	4.90	4.75	22	18	17.3 (43.8)	4.83	20
8	2	3	19.5 (49.5)	19.0 (48.3)	4.95	4.86	22	16	19.3 (48.9)	4.91	19
8	3	1	18.5 (47.0)	19.5 (49.5)	4.86	4.95	14	20	19.0 (48.3)	4.91	17
9	1	3	15.5 (39.4)	16.0 (40.6)	4.96	5.05	16	22	15.8 (40.0)	5.01	19
9	2	1	16.5 (41.9)	17.0 (43.2)	5.22	5.27	16	16	16.8 (42.5)	5.25	16
9	3	2	17.5 (44.5)	18.0 (45.7)	5.09	5.04	8	24	17.8 (45.1)	5.07	16
10	1	1	20.5 (52.1)	20.0 (50.8)	4.49	4.46	20	30	20.3 (51.4)	4.48	25
10	2	3	20.0 (50.8)	21.0 (53.3)	4.79	4.80	24	18	20.5 (52.1)	4.80	21
10	3	2	20.5 (52.1)	20.0 (50.8)	4.60	4.93	20	26	20.3 (51.4)	4.77	23
11	1	2	21.5 (54.6)	21.0 (53.3)	4.94	5.09	10	20	21.3 (54.0)	5.02	15
11	2	1	18.0 (45.7)	18.5 (47.0)	5.06	5.23	22	24	18.3 (46.4)	5.15	23
11	3	3	19.5 (49.5)	20.0 (50.8)	5.44	5.19	20	14	19.8 (50.2)	5.32	17

Subject	Test Day	Warm-up	Vertical Jump #1	Vertical Jump #2	Sprint #1	Sprint #2	Shooting Score #1	Shooting Score #2	Vertical Jump - Mean	Sprint - Mean	Shooting Score - Mean
			inches (cm)	inches (cm)	Seconds	Seconds	Points	Points	Inches (cm)	Seconds	Points
12	2	2	19.0 (48.3)	18.5 (47.0)	4.84	4.93	18	20	18.8 (47.6)	4.89	19
12	3	1	18.5 (47.0)	19.0 (48.3)	5.03	5.03	20	26	18.8 (47.6)	5.03	23
7	1	1	20.0 (50.8)	20.5 (52.1)	4.70	4.58	16	20	20.3 (51.4)	4.64	18
7	2	2	22.5 (57.2)	23.0 (58.4)	4.68	4.69	24	20	22.8 (57.8)	4.69	22
7	3	3	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
14	1	2	21.5 (54.6)	21.5 (54.6)	4.58	4.70	14	20	21.5 (54.6)	4.64	17
14	2	3	21.0 (53.3)	20.5 (52.1)	4.81	4.61	20	18	20.8 (52.7)	4.71	19
14	3	1	20.0 (50.8)	20.0 (50.8)	4.81	4.78	20	24	20.0 (50.8)	4.80	22

Note. DNP = Did Not Participate

Prior to the ANOVA certain assumptions need to be met to validate the results: data is from a normally distributed population, homogeneous variance, independent observations and the dependent variable should be measured in an interval scale (Field, 2005).

To determine if the population was normally distributed, the data was checked for outliers and skew by creating box plots (Figure 5). There are no outliers, but some of the data was skewed. For instance, in the VerticalMean box plot, the Jog/Static/Dyn treatment mean on test day one is skewed to the right and the jog treatment mean on test day three is skewed to the left. The rest of the data in this subset have a normal distribution. In addition, the data in the box plots of SprintMean and ShootingMean have no outliers, but some skew. The skew may be due to the small number of observations and can impact the dependability of the statistical analysis.

To test the homogeneous variance assumption, the residuals were calculated for each independent variable and the residuals were graphed in scatter plots (Figure 6). The graphs show that the residuals were not skewed and were homogeneous. However, since the sample sizes were not equal for each treatment, there is an increased chance of having a Type I statistical error. A Type I error is when the null hypothesis is rejected but true. In the current study this would result in a treatment effect due to warm-up when there really was not one.

Figure 5. Box Plots of Test Results

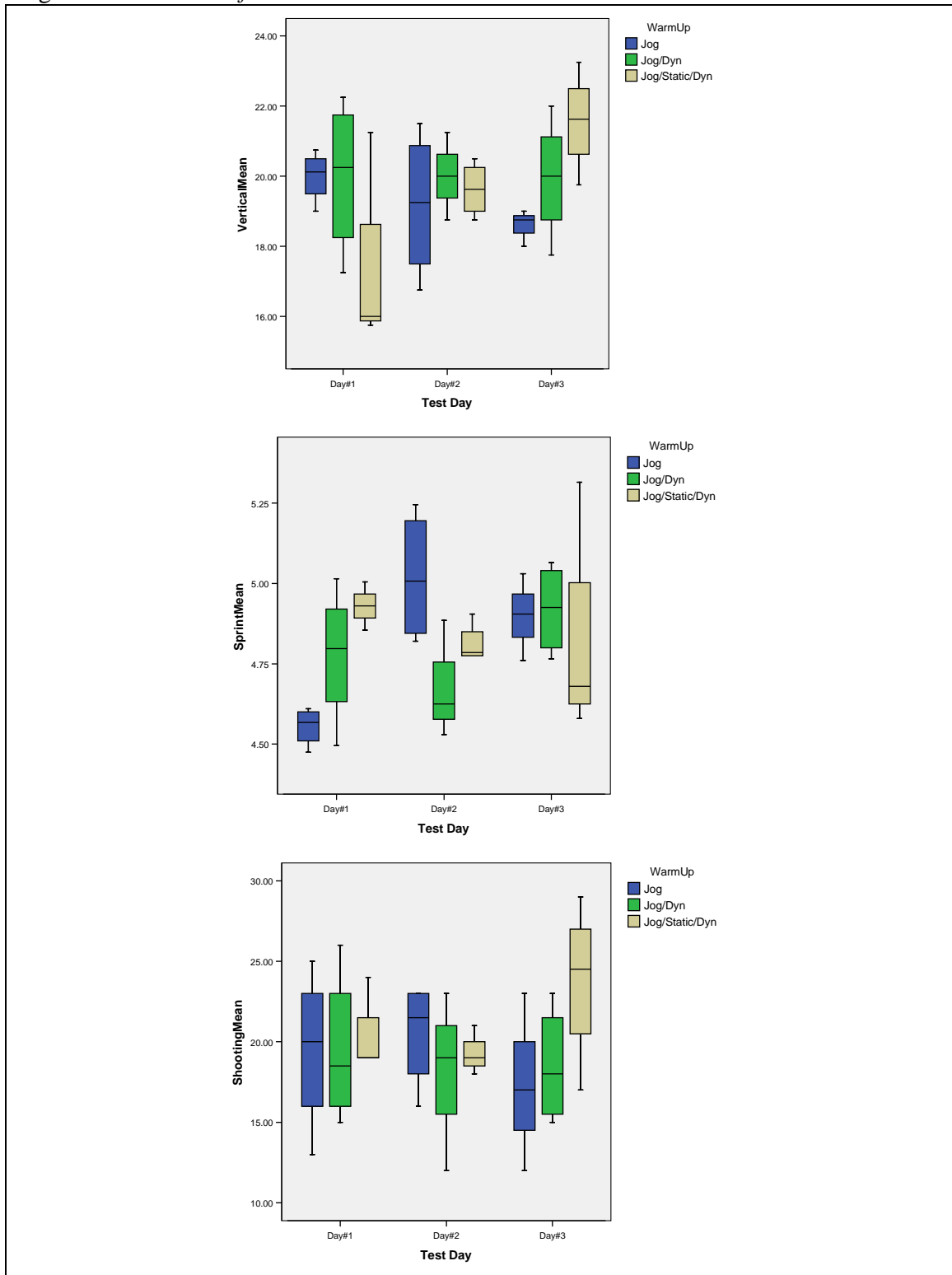
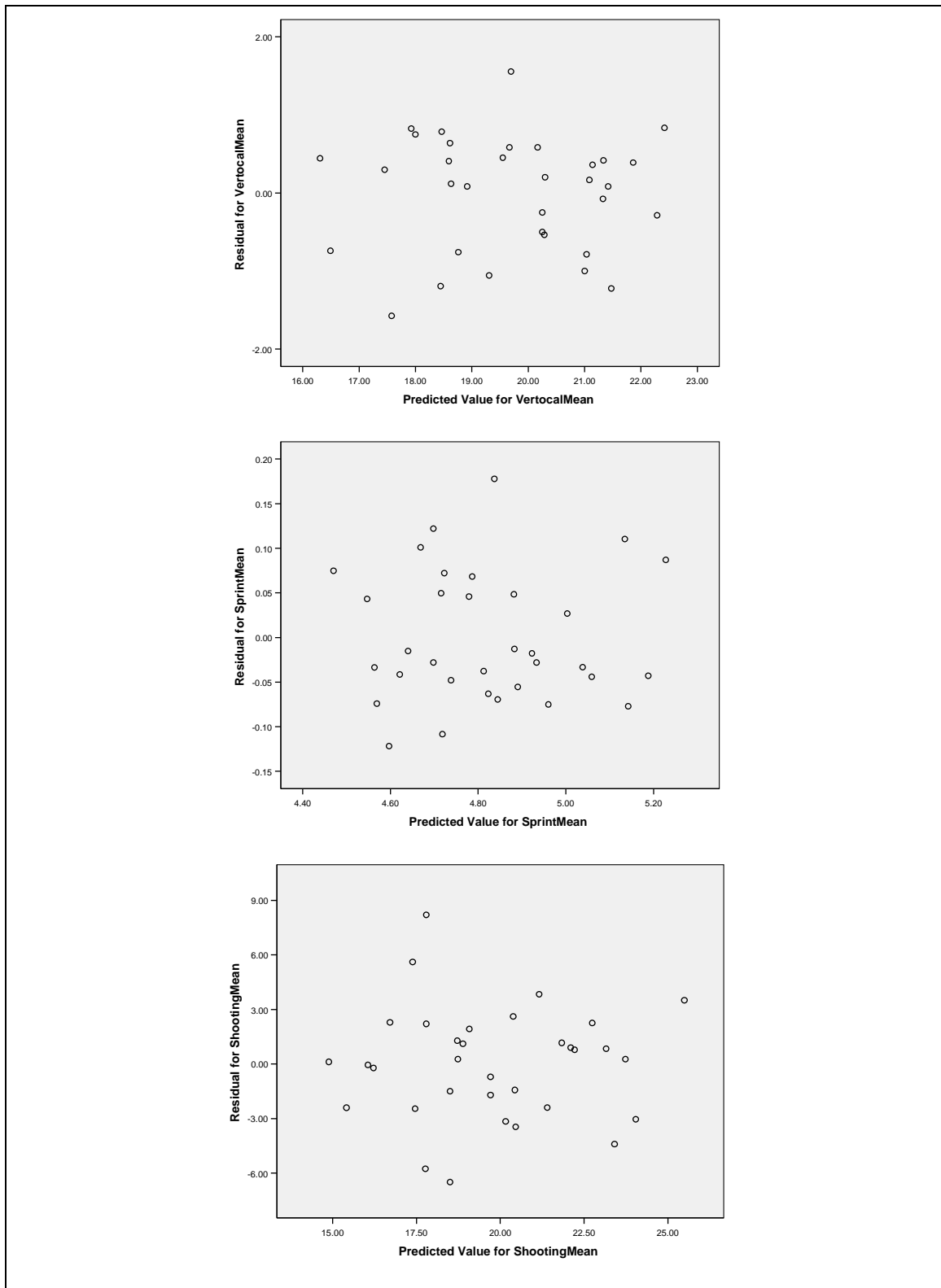


Figure 6. *Scatter Plots of Independent Variable Variance*



Next, the data from each dependent variable was run in a univariate ANOVA analysis. The results are shown in Figures 7, 8 and 9.

Figure 7. *Univariate ANOVA Analysis of Vertical Jump*

Tests of Between-Subjects Effects

Dependent Variable: VerticalMean

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	84.875(a)	14	6.062	6.337	.000
Intercept	12803.030	1	12803.030	13383.120	.000
Subject	79.011	10	7.901	8.259	.000
TestDay	3.314	2	1.657	1.732	.205
WarmUp	2.110	2	1.055	1.103	.353
Error	17.220	18	.957		
Total	12905.125	33			
Corrected Total	102.095	32			

a R Squared = .831 (Adjusted R Squared = .700)

Figure 8. *Univariate ANOVA Analysis of Sprint Time*

Tests of Between-Subjects Effects

Dependent Variable: SprintMean

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.240(a)	14	.089	9.332	.000
Intercept	767.199	1	767.199	80852.208	.000
Subject	1.115	10	.111	11.746	.000
TestDay	.115	2	.057	6.052	.010
WarmUp	.006	2	.003	.307	.740
Error	.171	18	.009		
Total	768.610	33			
Corrected Total	1.411	32			

a R Squared = .879 (Adjusted R Squared = .785)

Figure 9. *Univariate ANOVA Analysis of Shooting Accuracy*

Tests of Between-Subjects Effects

Dependent Variable: ShootingMean

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	230.244(a)	14	16.446	.955	.527
Intercept	12881.939	1	12881.939	748.426	.000
Subject	186.727	10	18.673	1.085	.422
TestDay	4.002	2	2.001	.116	.891
WarmUp	40.547	2	20.273	1.178	.331
Error	309.817	18	17.212		
Total	13422.000	33			
Corrected Total	540.061	32			

a R Squared = .426 (Adjusted R Squared = -.020)

CHAPTER V

Discussion

There were no differences between vertical jump, sprint time or shooting accuracy for any of the warm-up routines used in this study ($p>0.05$). This was unexpected. Other studies examining vertical jump and static stretching observed a significant difference when dynamic movement was used as a part of the warm-up (Faigenbaum, Kang, et al., 2006; McMillian et al., 2006). In addition, static stretching was correlated with increased sprint time (Faigenbaum, Kang, et al., 2006; Fletcher & Jones, 2004; Nelson et al., 2005; Sayers et al., 2008) and dynamic movement was correlated with decreased sprint time (Faigenbaum, Kang, et al., 2006; Fletcher & Jones, 2004). However these correlations were not confirmed in this study.

Another phenomenon observed in past studies is masking, completely or partially, of the negative impact of static stretching when it was followed by dynamic movement (Faigenbaum, Kang, et al., 2006; Fletcher and Anness, 2007). For this study, masking could explain why there were no negative effects observed with static stretching since it was used in combination with dynamic movement. However masking does not explain the lack of positive results associated with dynamic movement when it was used by itself or in combination with static stretching.

The lack of positive results associated with dynamic movement may be due to the warm-up design. In this study, the intensity of the athlete's warm-up was not monitored by heart rate or body/muscle temperature, and therefore the intensity may have been greater than 80% VO_{2max} . When studying warm-up and vertical jump, McMillian et al. (2006) and Faigenbaum, Kang, et al. (2006) utilized a jogging and dynamic movement

warm-up (Table 7). Comparable warm-ups were used in related studies examining sprint time (Faigenbaum, Kang, et al., 2006; Fletcher & Jones, 2004; Nelson et al., 2005; Sayers et al., 2008). The athletes in the current study did a greater number of jumping exercises in a shorter period of time. This combination may have fatigued their Type II muscles fibers resulting in an inability to achieve maximum vertical jump and/or minimum sprint time, i.e. masking the positive effects of dynamic movement. Stewart and Sleivert (1998) observed a similar trend with high intensity warm-ups. They found a decrease in performance when the athlete’s muscle temperature increased beyond a certain point. They hypothesized that this was due to metabolic depletion of energy stores.

Table 7. *Comparison of warm-ups for vertical jump testing*

	McMillian et al. (2006)	Faigenbaum, Kang, et al. (2006)	Current Study (2009)
Time (general warm-up)	5 min. (jog)	5 min. (walk-jog)	6 min. (jog or jog/static stretch)
Time (dynamic movement)	10 min.	10 min.	4 min.
# dynamic movements	9	9	8
# jumping movements	2	3	4

An additional confounding variable in this study was the athlete’s beliefs and attitude. Foremost, many of the athletes harbored strong beliefs about the necessity of static stretching. For example subject eight, after being told not to do anything while waiting in line for the sprint test, attempted to static stretch. Similarly, other athletes asked if they could static stretch prior to starting the testing if they did not static stretch during their warm-up. As Nelson et al. (2005) noted in their study “the athletes...were

very uneasy at the start of the no-stretch sprints. Thus, the negative impact of physiological/mechanical impacts of stretching must be greater than any negative psychological feelings in the no-stretch condition” (p. 452). In the current study the athlete’s psychological response may have impacted the results, especially on the sprint test. Second, the athlete’s mental attitude also appeared to impact the test results. This was especially evident during the shooting accuracy test. Some of the athletes would become visibly agitated after missing a lay-up or two shots in a row. As a result, their shooting form would change or they would stop hustling. Thus, the difference in their test outcome was probably more closely correlated with attitude than with warm-up.

In addition to a lack of treatment effect, the ANOVA results indicate that study design may have been flawed. The strength of using a Latin Square design is that it attempts to block confounding variables, in this case subject and test day, by randomizing the order and time tested across subject and test day. In this case, the design did not eliminate the influence of the individual subject. This may be in part due to the fact that the population consists of two differentiable subpopulations, guards and posts. There were eight guards and three posts in the test population. If the two populations are separated, the guards’ mean height was 65.9 inches (1.67m) and mean weight was 145 pounds (65.8kg). The posts’ mean height was 70 inches (1.78m) and mean weight was 165 pounds (74.8kg). The difference in mean height was only 4.1 inches (0.10m), but the difference in mean weight was 20 pounds (9.1kg). These differences resulted in observable differences in testing scores for the two sub-populations. The mean results for the posts and the guards were calculated (Table 7). While no statistical conclusion can be made from this analysis due to the uneven and small number of subjects in each group,

the guards have a higher vertical, faster sprint time and better shooting score than the posts. This corroborates the work by Sallet et al. (2005) who found a difference in anaerobic capacity of basketball players based on playing position.

Table 8. *Comparison of Population Means for Guards and Posts*

	Guards	Posts
Number of Subjects	8	3
Vertical Jump Population Mean	20.2	18.4
Sprint Population Mean	4.75	5.01
Shooting Score Population Mean	20	18

CHAPTER VI

Conclusion

The goal of this research study was to demonstrate to women's basketball coaches and athletes, the impact of their current warm-up on basketball performance. While in the current study there were no negative effects associated with static stretching, there were also no beneficial effects associated with dynamic movement. Therefore, as long as a basketball athlete does a warm-up that does not fatigue her muscles, she is ready to perform at her maximum capacity.

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APPENDIX A

IRB Informed Consent Form

(Margins altered to complement thesis format)

University of Minnesota
Dr. Stacy Ingraham 612-626-0067
Mara Reif-Wenner 651-214-6596

CONSENT FORM

**Effect of Basketball Warm-up on Vertical Jump, Sprint Time and
Basketball Shooting Accuracy**

This study is being conducted by researchers from the University of Minnesota's School of Kinesiology, Twin Cities Campus.

IRB Code # 0804M3023
Version Date: September 5, 2008

1 of 4

You are invited to participate in a research study of basketball warm-up routines and athletic physiological outcomes. You were selected as a possible participant because you were a National Collegiate Athletic Association (NCAA) Division III or high school varsity female basketball player during the 2007-2008 basketball season. I ask that you read this form and ask any questions you may have before agreeing to be in the study.

This study is being conducted by Mara Reif-Wenner, a graduate student at the University of Minnesota's School of Kinesiology.

Study Purpose

The purpose of the study is to determine how different basketball warm-up routines affect vertical jump, sprint time and basketball shooting accuracy.

Study Procedures

If you agree to participate in this study, you will be asked to do the following:

1. Fill out a brief questionnaire.
2. Participate in three different basketball warm-up routines consisting of jogging, static stretching and dynamic movement. Each routine will be performed on a different day.
3. Complete physiological testing consisting of maximum vertical jump, timed sprint (94 meters) and basketball shooting accuracy. All three tests will be performed with each warm-up routine.

Subjects will be randomly assigned the order in which they will do each warm-up routine. The total study will take three to four weeks. Each session will take approximately an hour.

Risks of Study Participation

The risks associated with this study are minimal and are the same as associated with participating in a basketball practice.

Benefits of Study Participation

The benefits to study participation are contributing to the understanding of basketball warm-up and performance.

Research Related Injury

In the event that this research activity results in an injury, treatment will be available, including first aid, emergency treatment and follow-up care as needed. Care for such injuries will be billed in the ordinary manner to you or your insurance company. If you think that you have suffered a research related injury, let the study physicians know right away.

Confidentiality

The records of this study will be kept private. In any publications or presentations, I will not include any information that will make it possible to identify you as a subject.

Voluntary Nature of the Study

Participation in this study is voluntary. Your decision whether or not to participate in this study will not affect your current or future relations with the University of Minnesota, the University of Wisconsin River Falls or the University of Wisconsin River Falls Women's Basketball Team. If you decide to participate, you are free to withdraw at any time without affecting those relationships.

Contacts and Questions

The researcher conducting this study is Mara Reif-Wenner. You may ask any questions you have now, or if you have questions later, you are encouraged to contact Mara Reif-Wenner at 651-214-6596 or Dr. Stacy Ingraham at 612-626-0067.

If you have any questions or concerns regarding the study and would like to talk to someone other than the researcher(s), you are encouraged to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; 612-625-1650.

You will be given a copy of this form to keep for your records.

Statement of Consent

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

Signature of Subject _____

Date _____

Signature of Investigator _____

Date _____

APPENDIX B

Sample Athlete Questionnaire

Effects of Basketball Warm-up on Vertical Jump, Sprint Time and Shooting Accuracy Questionnaire

Please fill in the blanks:

1.) Name: _____
(FIRST NAME) (LAST NAME)

2.) Age: _____ years

3.) Height: _____ feet _____ inches

4.) Weight: _____ pounds

For questions #5-6 please circle the best answer:

5.) What was your basketball position during the 2007-2008 basketball season? If you played more than one position, circle all that apply.

Point Guard (1) Off Guard/Shooting Guard (2/3) Power Forward/Forward (4/5)

6.) What seasons have you competed as a NCAA division III basketball player?

2002/2003 2003/2004 2004/2005 2005/2006 2006/2007 2007/2008

APPENDIX C

Descriptions of Dynamic Movements Used in Warm-Up Two and Three

High Knees	Using correct running form, drive knees towards chest as you move forward. Bring your knees as high as you can while minimizing contact time with the ground; alternate knee and arm should be drive upwards at the same time.
Butt Kicks	Using correct running form, drive heels towards butt as you move forward. Kick your heels back and up while minimizing contact time with the ground.
Hurdle Walk	While walking, alternate bringing one knee up towards chest, rotate hip joint outwards (as if bringing knee and lower leg over a hip height hurdle) and step forward.
Power Skips	Skip for maximum height; when hopping with the right foot drive the right arm and left knee upward to maximize vertical height.
Karaoke	Face the baseline instead of the sideline and move the lead foot one side step forward. Alternately move the other foot (trail foot) in front of or behind the lead foot e.g. lead foot step, front cross over trail foot step, lead foot step, rear cross over trail foot step, etc.
Alternate Leg Bounds	Bound off one foot and land on the other foot while maximizing the distance covered; similar to the first step in a lay-up.
Two Footed Jumps	Jump off both feet to achieve maximum height and distance; similar to a broad jump but with more emphasis on height than distance.
One Footed Jumps	Choose one spot on the ground and jump to near maximum vertical off of one foot, land on the same foot you pushed off from; similar to the push-off of the last step of a lay-up.

APPENDIX D

IRB Approval

UNIVERSITY OF MINNESOTA

Twin Cities Campus

06/20/2008

Mara S Reif-Wenner
1527 Poplar Drive
Red Wing, MN 55066

*Research Subjects' Protection Programs
(RSPP)*

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*D-528 Mayo Memorial Building
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Email: irb@umn.edu or

iacuc@umn.edu or ibc@umn.edu

RE: "Effect of Basketball Warm-up on Vertical Jump, Sprint time and Shooting Accuracy"
IRB Code Number: **0804M30323**

Dear Ms. Reif-Wenner

The Institutional Review Board (IRB) received your response to its stipulations. Since this information satisfies the federal criteria for approval at 45CFR46.111 and the requirements set by the IRB, final approval for the project is noted in our files. Upon receipt of this letter, you may begin your research.

IRB approval of this study includes the consent form dated June 14, 2008.

The IRB would like to stress that subjects who go through the consent process are considered enrolled participants and are counted toward the total number of subjects, even if they have no further participation in the study. Please keep this in mind when calculating the number of subjects you request. This study is currently approved for 14 subjects. If you desire an increase in the number of approved subjects, you will need to make a formal request to the IRB.

For your records and for grant certification purposes, the approval date for the referenced project is April 28, 2008 and the Assurance of Compliance number is FWA00000312 (Fairview Health Systems Research FWA00000325, Gillette Children's Specialty Healthcare FWA00004003). Research projects are subject to continuing review and renewal; approval will expire one year from that date. You will receive a report form two months before the expiration date. If you would like us to send certification of approval to a funding agency, please tell us the name and address of your contact person at the agency.

As Principal Investigator of this project, you are required by federal regulations to inform the IRB of any proposed changes in your research that will affect human subjects. Changes should not be initiated until written IRB approval is received. Unanticipated problems or serious unexpected adverse events should be reported to the IRB as they occur.

The IRB wishes you success with this research. If you have questions, please call the IRB office at 612-626-5654.

Sincerely,



Felicia Mroczkowski, CIP
Research Compliance Supervisor
FM/egk
CC: Stacy Ingraham

Driven to DiscoverSM