ABSTRACT

THE EFFECTS OF STATIC AND DYNAMIC STRETCHING ON COMPETITIVE GYMNASTS’ SPLIT JUMP PERFORMANCE

by Erin N Harper

The purpose of this study was to evaluate the effects of acute stretching on 12 competitive gymnasts’ performance of a split jump. Split jump trials were recorded following three different stretching protocols (no stretch, static stretch, dynamic stretch) on separate days. Performance was evaluated by measuring the degree of split, vertical displacement, and flight time with the use of motion capture and a force platform. The results indicate no significant difference between the three stretching protocols for any of the measures. However, the mean for each measure favors the stretching conditions over no stretching and pairwise comparisons revealed improved performance for dynamic stretching over no stretching for Change in Center of Mass Height ($p = .002$), Max Split Angle ($p = .048$), and Flight Time ($p = .013$). This lends support for the common practice of gymnasts including stretching in their pre-competition/practice warm-up regimens.
THE EFFECTS OF STATIC AND DYNAMIC STRETCHING ON COMPETITIVE GYMNASTS’ SPLIT JUMP PERFORMANCE

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The Effects of Static and Dynamic Stretching on Split Jump Performance in Competitive Gymnasts

Stretching is a technique used by athletes to improve flexibility, performance, and reduce the risk of injuries (LaRoche & Connolly, 2006; Rosenbaum & Henning, 1995). The way in which athletes and coaches employ the use of stretching varies greatly from sport to sport and often from practice to competition. Recently researchers, such as Winchester, Nelson, Landin, Young, and Schexnayder (2008), Kistler, Walsh, Horn, and Cox (2010) and Power, Behm, Cahill, Carroll, and Young (2004), have found that static stretching preexercise has a negative effect on performance variables, such as maximal voluntary strength, sprinting, and vertical jump. Additionally, the research conducted to date on the value of stretching prior to practice or competition on injury prevention has revealed inconsistent results (Small, McNaughton, & Matthews, 2008).

Thus, athletes and coaches are left without a clear judgment on how and when to best incorporate stretching into their training. Therefore, more research studies are needed, particularly those that are sport-specific. The purpose of the proposed study is to evaluate the effects of no stretching, static stretching, and dynamic stretching on split jump performance in competitive gymnasts. To provide a context for this study, the relevant research is reviewed in the following sections.

Stretching and Flexibility

Muscles are unable to lengthen or stretch themselves. Some outside force such as gravity, momentum, or an antagonist muscle must be used to lengthen the muscle (Alter, 2004). The ability of a muscle to lengthen and move through the range of motion (ROM) of a joint can be defined as flexibility. Stretching has proven successful in lengthening a muscle therefore improving flexibility (Hartig & Henderson, 1999; Kokkonen, Nelson, & Cornwell, 1998; Roberts & Wilson, 1999). The mechanism thought to allow for increases in flexibility is the addition of sarcomeres to the muscle fibers as a result of chronic stretching (Brooks, Fahey, White, & Baldwin, 2000).

The ability to move smoothly and easily through the ROM required for each sport’s demands is important for performance (Brooks et al., 2000). Training to enhance flexibility requires overloading the neuromuscular system to achieve the desired results. The concept of
overloading is equally as important to stretching as it is to other aspects of physical training. The frequency and/or duration of a stretching program must increase if the goal is to increase flexibility. The body will adapt to the heightened demand. Similarly, a decrease in frequency or duration will result in a decrease in flexibility (Alter, 2004).

For instance, Santonja Medina, Sainz De Baranda Andújar, Rodriguez Garcia, López Minarro, and Cantreras Jordana (2007) found that 2 sessions of hamstring stretches per week for the length of 31 weeks improved hip flexion ROM by 9.3° in children 10 to 11 years old while the group that participated in 4 hamstring stretches per week improved 16.9°. Thus, Santonja Media et al. (2007) was able to show a difference between frequencies of stretching. Roberts and Wilson (1999) compared the effects of stretching for 5 or 15 seconds three times a week for five weeks on lower extremity ROM. Conclusions state that holding stretches for 15 seconds, as opposed to 5 seconds, will results in larger improvements in ROM. Acute stretching also improves range of motion. Participants in both Brandenburg (2006) and Kokkonen et al. (1998) studies experienced a greater ROM immediately after the intended stretching protocol.

**Stretching and Performance**

In recent years, there has been new evidence to show static stretching preexercise produces deficits in some performance variables. Static stretching is when a position is held for a period of time at the end point of the ROM with little or no movement and with maximum control (Alter, 2004). Winchester et al. (2008) reported a 0.10 second increase in 40 meter sprint times after adding 10 minutes of static stretching. Similarly, Siatras, Papadopoulos, Mameletzi, Gerodimos, & Kellis (2003) found that two 30 second static stretches of the lower legs was enough to produce a decrease in running velocity. Nelson, Driscoll, Landin, Young, & Schexnayder (2005a) concluded that static stretching can negatively affect activities that require high power output such as those using repeated concentric contractions, like a take-off from a starting block and other explosive sprinting activities.

Researchers have also made recommendations to not stretch prior to activities that require maximal force production (Brandenburg, 2006; Gurjão, Goncalves, De Moura, & Gobbi, 2009; Kokkonen, Nelson, & Cornwell, 1998; Nelson, Kokkonen, & Arnall, 2005b; Power et al., 2004; Siatras, Mittas, Mameletzi, & Vamvakoudis, 2008; Winchester, Nelson, & Kokkonen, 2009). In college aged students, static stretching produced an 8.1% decrease in knee extension 1-RM
(repetition maximum) force (Kokkonen et al., 1998) and a 9.5% decrease in maximal voluntary contraction of the quadriceps (Power et al., 2004). Fowles, Sale, & MacDougall (2000) found that 30 minutes of stretching to cause a 28% reduction in maximal voluntary contraction of the plantarflexors. Although the 30 minutes of static stretching focused on the plantarflexors exclusively might be excessive and not practical, the results show a definite cause and effect relationship with stretching and force production. Reports show as little as 30 seconds of static stretching to reduce peak force production (Brandenburg, 2006; Siatras et al., 2008; Winchester et al., 2009) and the effects of static stretching lasting up to 120 minutes (Power et al., 2004).

Muscle strength endurance is also affected by acute static stretching. Nelson et al. (2005b) found a 24% reduction in the number of leg extension repetitions participants could complete at 60% of their 1-RM.

Other studies have displayed stretching to decrease vertical jump performance measures (Power et al., 2004; Young & Behm, 2003; Young & Elliot 2001). Although not significant, decreases in drop jump heights ranged from 5.1% to 6.5% and decreases in concentric jump height ranged from 2% to 5.4% over a two hour post static stretching testing period. These results were found after a more realistic stretching duration of 4.5 minutes for a muscle group was undertaken (Power et al., 2004) as opposed to a prolonged stretching session of 30 minutes for one muscle group (Fowles et al., 2000) which may not be a realistic stretching duration for athletes. Additionally, Young and Elliot (2001) were able to determine after 3 repetitions of 15 seconds for each muscle group in the legs that static stretching decreased drop jump performance.

Fowles et al. (2000) discussed several sources that might be responsible for the adverse acute effects stretching have on performance. The sources include activation failure by the neuromuscular feedback responses such as the Golgi tendon reflex, mechanoreceptors, nociceptor pain feedback and fatigue responses. Moreover, a portion of the reduction might originate from the muscle which would involve changes in the length-tension relationship and plastic deformation of the connective tissue. As seen in Fowles et al. (2000) study the participants experienced a decrease in musculotendinous unit stiffness following the static stretching protocol which may have lead to the decreased maximal voluntary contractions. Wilson, Murphy, and Pryor (1994) posit that a stiff musculotendinous unit may aid in force
production due to an improved contractile component length and rate of shortening. Additionally the transmission of force from the contractile component to the skeletal structures may be facilitated by a stiffer musculotendinous unit.

The physiological changes following static stretching may have implications for those seeking optimal performance in sporting activities. As seen in the above research, these physiological changes following an acute bout of static stretching impair running velocity, maximal voluntary contraction, muscular endurance, and vertical jump height.

**Stretching and Injury Prevention**

One could argue that the benefits of injury prevention outweigh the negative consequences of stretching on performance. Historically, a fundamental reason to partake in preexercise stretching was to prevent injury during physical activity. An overall increase in flexibility to meet the demands of the activity might be the solution for staying injury free. Many sporting events require a specific ROM and if that ROM is not available the athlete might be at risk for injury. Hartig and Henderson (1999) added 3 extra hamstring stretching sessions daily to an experimental group of military basic trainees. It was found that the experimental group increased their hamstring flexibility by 7 degrees and had significantly less lower extremity overuse injuries than the control group. Likewise, when stretching interventions were added to regularly scheduled practice sessions for Division III football teams lower extremity musculotendious strains were reduced (Cross and Worrell, 1999).

Not all research agrees that stretching intervention programs lessen the incidence of injuries. Arnason, Andersen, Home, Engebretsen, and Bahr (2008) did not find differences in hamstring strains in elite soccer players between teams that added flexibility training and those that did not. Also, there were no differences in injury rates from the previous year. Many researchers have conducted thorough reviews of the literature to determine the benefits of stretching on injury prevention. Conclusions state that one can not relate stretching to injury prevention (Gilchrist, Stroup, & Thacker, 2004; Small et al., 2008). On the contrary, another review of the literature completed by Woods, Bishop, and Jones (2007) reported that although there is conflicting evidence some research shows protocols beneficial in preventing injury therefore a stretching routine should be used prior to exercise.
When extracting studies regarding preexercise (acute) stretching rather than chronic stretching, once again, there is not clear evidence to support stretching prevents injuries. Pope, Herbert, and Kirwan (1998) and Pope, Herbert, Kirwan, and Graham (2000) concluded that their research did not find any evidence that stretching will reduce the rates of injury. However, Hadala and Barrios (2009) found lower numbers of injury in America’s Cup yachting crew after adding a stretching intervention prior to competition, especially in the positions that involve higher work intensities. Witvrous, Mahieu, Danneels, and McNair (2004) argue that the benefit of stretching preexercise lies in the type of exercise. Those requiring higher amounts of explosive type movements would benefit from stretching and those consisting of lower levels of intensity in stretch shortening cycle movements, like jogging and cycling, would not benefit from stretching.

Often the arguments made for the benefit of stretching for injury prevention lie in either mechanical or neurological mechanisms. Mechanically, stretching causes an increase absorbing capacity of the muscle (Rosenbaum & Hennig, 1995; Witvrouw et al., 2004) brought about by the decrease in muscle stiffness. This would allow for forces to be absorbed over a greater range and time period. Consequently reducing stress on the muscles and tendons (McNair & Stanley, 1996). Alter (2004) states a hypothesis that a decrease in stiffness can also occur via neurological mechanisms such as a reflex inhibition.

While the efficacy of stretching on injury prevention remains unclear, it is a difficult decision for athletes and coaches regarding the continuation of stretching during preexercise warm-up. In light of the possible disadvantage stretching provides on performance variables questions have been raised regarding different modes of stretching. One might wonder whether all types of stretching have the same results on performance and if there is one method that is most advantageous.

**Static Versus Dynamic Modes of Stretching**

Two methods of stretching that are often employed by athletes are static and dynamic. As stated earlier, static stretching is when a position is held for a period of time at the end point of the ROM with little or no movement and with maximum control (Alter, 2004). Dynamic stretching is actively moving through a joint’s entire ROM (Fletcher & Jones, 2004). Dynamic stretching tends to incorporate sport specific movements, thus allowing for appropriate ROM for
the activity (Baechle & Earle, 2000). In both cases stretching should be done to the point of discomfort or tension but not pain (Alter, 2004; Brooks et al., 2000).

More recently, researchers have been investigating the differing effects on performance between static and dynamic stretching preexercise. Commonly dynamic stretching proves to have less severe effects on performance variables than static stretching (Moran, McGrath, Marshall, & Wallace, 2009; Siatras et al., 2003; Yamaguchi & Ishii, 2005). Siatras et al. (2003) found running speed to be significantly slower after static stretching than after dynamic stretching. Additionally, Yamaguchi and Ishii (2005) tested leg extension power after different stretching protocols and concluded the static stretching protocol decreased power and the dynamic protocol increased power. The no stretching group also experienced a decrease in power from the before and after testing but not to the same extent as the static stretching protocol. Interestingly several other studies obtained results showing dynamic stretching to improve performance rather than act as a detriment. In experienced golfers, dynamic stretching produced greater ball and club head speed over static stretching and no stretching, as well as more central impact points and straighter club swing paths. It is proposed that those intending to improve distance and accuracy should utilize dynamic stretching prior to playing golf (Moran et al., 2009).

Dalrymple, Davis, Dwyer, and Moir (2010) noted a trend, although not significant, of higher peak jump heights after a dynamic stretching protocol compared to the peak jump heights after a static stretching protocol in female collegiate volleyball players. In this case the no stretching protocol elicited the highest peak jump heights on average. Similarly, Sim, Dawson, Guelfi, Wallman, and Young (2009) reported dynamic activities following a 1000 meter jog to elicit faster 20 meter sprint times than static stretching followed by dynamic activities or dynamic activities followed by static stretching.

As researchers continue to analyze the effects of different stretching protocols, dynamic stretching has thus far proven successful in preparing the body for performance while minimizing the detriments seen with traditional static stretching (Moran et al., 2009; Siatras et al., 2003; Sim et al., 2009; Yamaguchi & Ishii, 2005). Coaches and athletes would benefit from research that looks at the effects of stretching on sport specific movements beyond general performance measures, as seen in the Moran et al. (2009) study of the golf swing. With the
requirements of every sport varying greatly it is important to analyze additional movements to allow coaches and athletes to make a better decision on what to incorporate into a preexercise warm-up to optimize performance. One such sport that would benefit from movement specific research is women’s artistic gymnastics.

**Stretching and Gymnastics Performance**

Gymnastics is a sport requiring a very high level of coordination, strength, and flexibility. A large number of Americans participate in the sport every year. In 2010, USA Gymnastics had a total of 75,746 athletes participating in their women’s program (USA-Gymnastics, n.d.a). USA Gymnastics is an organization that oversees, regulates, and supports the progress of gymnastics in the United States. USA Gymnastics also serves a role in managing competition from beginner to Olympic levels. A variety of outlets for participation include local YMCAs, school programs, and private clubs.

Gymnasts often spend a number of years practicing to become proficient in the skills and level of difficulty needed to compete. It is common for gymnasts to begin training at a very young age and practice upwards of 20 hours per week year round. Along with tumbling, event specific skills, and strength, flexibility is an integral part of training. Numerous skills require a considerable range of motion for successful completion. One such skill is a split jump. Although it is of a low level of difficulty among experienced gymnasts, it fulfills special requirements on the balance beam and can be progressed into similar leaps or jumps of higher difficulty for the balance beam and floor exercise. Furthermore, the split jump is a compulsory skill at lower levels and used as a progression to reach higher levels of competition.

To participate in USA Gymnastics Women’s Artistic Levels 7-10 competition, gymnasts must include “one leap or jump that requires a 180° cross or side split” (pp. 143) on the balance beam and “a leap requiring a 180° cross or side split position” (pp. 221) for the floor exercise (Maloney, 2009). The skills that meet the special requirement are judged based on height, split position, and body posture (Maloney, 2009). Therefore successful completion of the requirement relies on the gymnast’s ability to produce enough force to complete a jump at a sufficient height to not only avoid getting a deduction for amplitude but to also allow time for the legs to pass through the desired split position mid air. Currently the USA national team warm-up includes a
series of static and dynamic stretches to be used prior to practice or competition (USA-Gymnastics, n.d.b).

It is important to note a recently published study that looked at a set of gymnastics skills similar to the split jump following two different warm-ups. Di Cagno, Baldari, Battaglia, Chiara Gallotta, Videira, Piazza, and Guidetti (2010) used empirical and subjective evaluation of rhythmic gymnastics technical leaping performance, which is likely the first study to evaluate the effects of stretching on a skill that has an aesthetic component. The two warm-up protocols consisted of typical rhythmic gymnastics warm-up exercises and the other a 20 minute session of static stretching. Results showed ground contact times and flight times to be decreased following the static stretching protocol. For the subjective evaluation the technical leaps were scored by 3 judges. The average score from the 3 judges was lower for each of the technical leaps following the static stretching protocol. While this research does look at a similar movement to the artistic gymnastics split jump the performance demands and training of a rhythmic gymnast and an artistic gymnast vary greatly. Also, it is very rare for an athlete to only participate in static stretching prior to performance without any type of additional muscular warm-up as seen in the research methods of the Di Cagno (2010) study. Thus, there was a need to continue to examine the effects of different types of stretching on gymnasts’ performance of specific tasks.

The purpose of this study was to evaluate the effects of static and dynamic stretching on a sport specific skill, specifically on young gymnasts’ performance of a split jump. Based on previous research conducted with other sport tasks, it was hypothesized that static stretching would be most detrimental to the performance of a split jump, specifically vertical jump displacement and degree of split, while no stretching would have less detrimental effects and dynamic stretching the least. The results of this study should allow for conclusions to be made between the differing effects of each stretching protocol.

**Methods**

To evaluate the effects of static and dynamic stretching on young gymnasts’ performance of a split jump, participants were asked to come to the lab to complete three different stretching protocols. Following each stretching protocol the participants completed three split jump trials on a force plate with simultaneous motion capture data collection.

**Participants**
Participants included 12 female USA Gymnastics competitive gymnasts (age, $M = 11.8$, range = 8-17 years; height, $141.6 \pm 10.8$ cm; mass, $35.5 \pm 10.0$ kg). Each gymnast was at the competitive skill level of USA Gymnastics that allowed for sufficient experience and expertise of the split jump (Level 5, N = 3; Level 6, N = 1; Level 7, N = 4; Level 8, N = 3; Level 10, N = 1). Participants were free of injuries that would have interfered or possibly would be aggravated by partaking in the study for at least 8 weeks prior. The gymnasts were members of 3 different gymnastics clubs located in Cincinnati and surrounding areas. Parental and participant informed consent was completed prior to beginning data collection. Approval from Miami University IRB was received prior to participant recruitment.

**Research Design**

A with-in subject experimental design will be used to evaluate the effectiveness of the three different stretching protocols on the split jump performance of the young gymnasts. Each participant performed on three separate days under each of three conditions: no stretch, static stretch, dynamic stretch. The order of conditions was randomly counterbalanced across participants.

**Instrumentation**

The kinematics of each split jump were analyzed using an 8 camera Nexus 1.5 motion capture and analysis software [Vicon, USA] including: The maximum range of motion (degree of split) achieved by measuring the sagittal angle from knee to knee through the hips, and vertical displacement from take off to maximal height of both the Center of Mass (COM) and Sacral (SACR) markers. Fifteen reflective markers were placed on anatomical landmarks and anthropometric measurements were taken for use with motion capture software. Flight time was measured using the information from the force platform [Bertec, USA].

**Data Collection and Procedures**

Participants were recruited by contacting local gymnastics clubs, then with permission of the club, through email and phone calls to the participants’ families to alert them of the invitation and provide participant information. Due to the distance between the lab and the homes of the participants there were not any visits to the lab for familiarization with the equipment prior to beginning the data collection. Within one week before the first day of testing the primary investigator met with the gymnasts in their gymnastics facility to cover testing day procedures.
Also, introduction and practicing of stretching protocols took place prior to testing day. Testing took place at the participants’ convenience (at least 72 hours apart) within a 5 week time span. Upon arriving at the lab on the first day of testing the anthropometric measurements were taken, including height and weight. Height and weight measurements were repeated on the last day of testing for each participant to ensure no changes occurred during the testing time period.

Each day of testing began with placement of the markers needed for the motion capture system. To reduce marker placement errors the lead investigator checked each participant’s markers prior to the split jump trials. Participants wore only a gymnastics leotard for testing but could wear shoes and shorts during the warm-up portion. The stretching protocols were staggered so there was equal waiting time between the stretching and testing for each participant. The warm-up took place in the lab on a treadmill. The participants were instructed to select a walking pace which would allow their muscles to feel warmed up but not fatigued following the 5 minutes walking period. The self selected pace was then used for all three days of testing. Immediately following the warm-up, the stretch protocol (Table 1) was completed. To ensure consistency the same research assistant supervised all of the stretching.

After the stretching protocol, participants completed 3 split jump trials while standing on the force platform situated in the middle of the motion capture collection area. Participants were instructed to make their best effort for each of the three split jump trials as they would if they were performing in front of a judge. To simulate a more realistic performance surface, the force platform was covered with carpet bonded foam. While carpet bonded foam is not the same as the floor exercise or balance beam surface it is commonly used in gymnastics facilities and provided a surface the gymnasts are more familiar with to complete their split jump trials on. Furthermore, the carpet bonded foam provided a softer landing for the gymnasts’ bare feet.

**Results**

All data was collected and entered into an SPSS (Version 18) data file. Data were screened to assess for normality and linearity. Preliminary repeated-measures analyses of variance procedures were used to test for day and/or trial effects. No statistically significant differences were found for day or trial. See Table 2 for results. Therefore, the mean of the three trials on each day was used for further analysis.
The means and standard deviations for the study measures are presented in Table 3. A series of four one-way repeated-measures ANOVAs were conducted to determine if the participants’ performance of the four dependent measures (ΔCOM Height, Δ SACR Height, Max Split Angle, and Flight Time) would differ as a function of the type of stretch condition they used. The results of the ANOVAs indicate that the three stretching protocols were not significantly different for any of the measures (Table 4). However, pairwise comparisons revealed a significant difference between the no stretch and dynamic stretch protocols for ΔCOM Height \[F(1,11) = 17.155, p = .002, \text{Cohen’s d = 1.196}\], Max Split Angle \[F(1,11) = 4.948, p = .048, \text{Cohen’s d = .642}\], and Flight Time \[F(1,11) = 8.669, p = .013, \text{Cohen’s d = .850}\].

**Discussion**

The purpose of this study was to assess the acute effects of stretching on a sport specific skill. This skill has an aesthetic component only seen in one previous research study on the effects of stretching on performance (i.e., Di Cagno et al., 2010). In particular, the split jump was chosen due to interest in the conflicting requirements of high power output (i.e., needed for jumping) and maximal range of motion. These conflicting requirements result from the components of the split jump that are judged during competition. Among general form and technique requirements, a gymnast performing a split jump needs to show amplitude and reach a certain degree of split based on the level of the gymnast. These are the two main criteria for the judging of this skill. Furthermore, the stretching protocols (types of stretches and duration of stretching) were designed to closely mimic those used regularly for gymnastics training and during pre-competition/practice warm-up. This ensured a more practical application of the study’s findings.

The main finding of the study was that there were no statistically significant differences in performance between the static and dynamic stretching protocols. These research findings seem to be contradictory to current recommendations of not static stretching prior to athletic performance (e.g., Di Cagno et al., 2010; Kistler et al., 2010; Siatras, 2008) as there were no statistically significant differences between the no stretching (control condition) and static stretching protocols. Furthermore, these findings do not confirm the recommendation of utilizing dynamic stretching in place of static stretching as a means to enhance performance as suggested
previously by researchers such as Hough, Ross, & Howatson (2009) and Yamaguchi & Ishii (2005).

Although, the results seem to suggest that utilizing either static or dynamic stretching prior to split jump performance will slightly enhance performance beyond the no stretch condition. This is seen with the slight differences in group means between the no stretch and stretching (static and dynamic) conditions also with the statistically significant pairwise comparisons (no stretch compared to dynamic). These pairwise comparisons have relatively large effect sizes indicating that the lack of statistical significance in the repeated-measures ANOVAs are likely due to small sample size (Cohen, 1988). This seems to lend support to the common practice for gymnasts to include stretching in their pre-competition/practice warm-up regimens and points towards utilizing dynamic over static stretching as seen in previous research.

While the results from these 12 gymnasts do not strongly indicate a performance enhancement through the use of one stretching method over the others for performance of a split jump if there had been clear measurable differences between the variables for each stretching condition that could have lent insight to the potential neurological or mechanical mechanisms related to changes in performance of this skill following stretching. As mentioned earlier the split jump was chosen do to the conflicting demands of an explosive jump and rapid limb movement but also a large ROM. It is possible that static stretching would benefit the skill over dynamic stretching due to the increased ROM achieved following acute bouts of static stretching. The increased ROM could result from increased compliance of the musculotendinous unit and possibly temporary changes in neurological activation allowing the athlete to reach a greater ROM (Alter, 2004). Conversely, for high speed and explosive movements (i.e., jumping and rapid limb movement) the body is best prepared with an excitatory neuromuscular system. Therefore, a more compliant musculotendinous unit and decreased neural activation is not ideal. Dynamic stretching may be better suited as a preparatory tool for these types of performance demands as it tends to improve stimulation of the neuromuscular system (Yamaguchi & Ishii, 2005). Additionally, dynamic stretching can enhance muscular performance with elevated muscle and body temperatures (Fletcher & Jones, 2004).

To conclude, in light of the small sample size and significant pairwise comparisons it seems reasonable to suggest dynamic stretching over other forms of pre competition/practice
stretching to enhance the performance of a split jump. Coaches and athletes should take the results of this study into consideration in addition to previous research on the subject when deciding on a warm-up regimen. Additionally, it is possible that if the split jump trials were scored by judges in addition to the quantitative measures used the results may have been more definitive.
References


Table 1.
*Stretching Protocols*

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<thead>
<tr>
<th>Protocol</th>
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<tr>
<td>No Stretch</td>
<td>6.5 minutes of moving around the lab to stay warm</td>
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| Static Stretch    | 1. Left knee on the floor, Right leg out straight in front with foot flexed, reach forward and lay chest onto front leg to stretch the quadriceps and plantarflexors. (45 seconds)  
2. With chest up, bend front leg 90˚, with right hand grab left foot and pull towards the buttocks to stretch the hamstrings (45 seconds)  
3. Move forward into deep knee lunge with chest up to stretch the hip flexors (45 seconds)  
4. Slide into splits (1 minute)  
*Repeat sets 1-4 on other leg* |
| Dynamic Stretch   | 1. Forcefully lift right leg forward to maximum range of motion (10 times slowly, 2 sets of 10 times quick)  
2. Forcefully lift right leg backward to maximum range of motion (10 times slowly, 2 sets of 10 times quick)  
3. Rapidly swing right leg forward and backward through full range of motion (3 sets of 10)  
4. Repeat steps 1-3 on other leg  
5. With legs together and hands on the floor stretch the plantarflexors by alternating one leg bent, one straight (10 each) |
Table 2.

Preliminary Analysis of Variance

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<td></td>
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<td>Trial * Day</td>
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<td>Δ COM Height</td>
<td>( F(1,6) = .016, p = .903, )</td>
<td>( F(1,6) = 1.656, p = .246, )</td>
<td>( F(1,6) = .262, p = .627, )</td>
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<td>partial ( \eta^2 = .003 )</td>
<td>partial ( \eta^2 = .216 )</td>
<td>partial ( \eta^2 = .042 )</td>
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<td>Δ SACR Height</td>
<td>( F(1,9) = 1.979, p = .193, )</td>
<td>( F(1,9) = 2.998, p = .117, )</td>
<td>( F(1,9) = 2.794, p = .129 )</td>
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<td>partial ( \eta^2 = .180 )</td>
<td>partial ( \eta^2 = .250 )</td>
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<td>Max Split</td>
<td>( F(1,6) = 1.071, p = .341, )</td>
<td>( F(1,6) = .027, p = .876, )</td>
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<td>Flight Time</td>
<td>( F(1,11) = 2.741, p = .126, )</td>
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<td></td>
<td>partial ( \eta^2 = .199 )</td>
<td>partial ( \eta^2 = .086 )</td>
<td>partial ( \eta^2 = .018 )</td>
</tr>
</tbody>
</table>
Table 3. 
Means and Standard Deviations for Change in COM Height, Change in SACR Height, Maximal Split Angle, and Flight Time

<table>
<thead>
<tr>
<th></th>
<th>Static Stretching</th>
<th>Dynamic Stretching</th>
<th>No Stretching</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Δ COM Height (mm)</td>
<td>252.3</td>
<td>59.2</td>
<td>260.1</td>
</tr>
<tr>
<td>Δ SACR Height (mm)</td>
<td>168.0</td>
<td>56.1</td>
<td>168.7</td>
</tr>
<tr>
<td>Max Split (°)</td>
<td>127.7</td>
<td>21.4</td>
<td>130.7</td>
</tr>
<tr>
<td>Flight Time (ms)</td>
<td>45.1</td>
<td>4.8</td>
<td>45.8</td>
</tr>
</tbody>
</table>
Table 4.

Results of Repeated Measures ANOVA

<table>
<thead>
<tr>
<th>Measure</th>
<th>F(1,12)</th>
<th>p</th>
<th>partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ COM Height</td>
<td>3.321</td>
<td>.096</td>
<td>.232</td>
</tr>
<tr>
<td>Δ SACR Height</td>
<td>2.026</td>
<td>.182</td>
<td>.182</td>
</tr>
<tr>
<td>Max Split</td>
<td>1.477</td>
<td>.250</td>
<td>.118</td>
</tr>
<tr>
<td>Flight Time</td>
<td>.647</td>
<td>.438</td>
<td>.056</td>
</tr>
</tbody>
</table>