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Morgan Stefanoff

Wright State University - Main Campus, stefanoff.3@wright.edu

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# Dynamic and static stretching are equally effective techniques for female high school soccer players

Morgan Stefanoff

Undergraduate Honors Thesis

Department of Biological Sciences  
Wright State University  
3640 Colonel Glenn Hwy.  
Dayton, OH 45435-0001

Advised by: Lynn Hartzler, PhD

## Conflicts of Interest Notification

I did not receive any external funding for this study, and I do not have any conflicts of interest involving this study.

**Abstract:**

Female athletes are more likely than males to experience anterior cruciate ligament (ACL) tears. Common mechanisms for ACL injury include anterior tibial shears occurring between 20-30 degrees of knee flexion and knee valgus (adduction). Stretching prior to exercise reduces the likelihood of ACL tears. I tested the hypothesis that dynamic stretching would reduce the likelihood of ACL tears as indexed by a greater range of motion (ROM) and greater joint stability (knee valgus) than static stretching. Twenty-seven healthy female soccer athletes in high school (ages 15-18) participated. The athletes completed a sit-and-reach test for flexibility, squats to assess ROM, and countermovement jumps to assess knee valgus. They were split into static and dynamic stretching groups and then played an hour of soccer. The flexibility, ROM, and knee valgus measures were taken again after practice. Flexibility of right leg (RL) and left leg (LL) before and after both stretching conditions increased significantly ( $p \leq 0.05$ ). Dynamic stretching improved flexibility more than static stretching. Range of motion of RL and LL before and after both stretching conditions was not significantly different, nor was there a difference in ROM between the two stretching conditions. Knee valgus angle of RL and LL before and after both stretching conditions was not significantly different, nor was there a difference in knee valgus between the two stretching conditions. Since neither the ROM nor the knee valgus were dependent on the type of stretch, athletes should choose their stretching method to improve their performance rather than to reduce risk of ACL injury.

Keywords: dynamic stretch, static stretch, range of motion, knee valgus, flexibility, ACL tear

## **Introduction:**

Anterior cruciate ligament (ACL) tears are often considered “sports’ most devastating knee injury” requiring surgery and resulting in intense therapy and lengthy recovery time (18). On average, ACL repair surgery costs approximately \$17,000 and surgical and rehabilitative costs total approximately \$646 million annually in the United States (13). Additionally, an ACL tear can have long-term consequences like chronic pain or development of osteoarthritis (8). Such a devastating injury can also have profound effects on an athlete’s confidence, resulting in the loss of their athletic identity or evoking a sense of powerlessness (17). To combat this issue, ACL tears have been widely studied in attempt to understand how and why they occur.

Medical professionals categorize ACL tear injuries as either contact or noncontact. A contact ACL injury occurs when a player experiences a blow to the lower extremity, ultimately causing the ACL to tear (15). While contact ACL injuries are less preventable and less common for athletes playing contact sports (8). Noncontact ACL injuries occur more frequently: approximately 83% of the time (9). Therefore, noncontact ACL injuries, or ACL injury as a result of rapid changes of motion or improper jump landings, are more prevalently studied (8, 15). To help reduce the threat of a noncontact ACL tear, proactive measures for ACL tear prevention have been examined and put into practice. A common training method used by athletes to reduce their risk of ACL tears is completing ACL tear prevention programs. These programs focus on reducing risk of the two most common noncontact ACL tear injury mechanisms: anterior tibial shears mostly occurring between 20-30 degrees of knee flexion and also knee adduction (valgus) (4, 12). To target these areas, ACL prevention programs use techniques such as core training, agility, and balance tasks (4). Each of these exercises ultimately aims to strengthen different aspects the lower extremity in relation to the knee joint to allow the athletes to safely reap the health benefits of their chosen sport (12).

A big part of ACL prevention programs are the pre-exercise workout routines, including stretching. Two common stretching methods athletes use are static stretching and dynamic stretching; however, ACL prevention programs utilize dynamic stretching techniques preferentially, on the basis that moderate dynamic stretching improves factors like performance on plyometric tasks (2, 4, 6, 23, 27). Additionally, dynamic stretching improves lower extremity balance, which is linked to a decreased risk of injury (2). In contrast, static stretching improves flexibility (7, 17, 23). Therefore, athletes should select the pre-workout stretching method to best enhance their performance while also considering the potential risks of the stretching method employed (5). For a sport such as soccer, skills, agility, endurance, and strength are all needed. The pre-exercise routine chosen for these athletes should consequently reflect and act to boost these qualities, while making sure the athlete is using proper techniques to avoid common injuries.

While virtually everyone is susceptible to ACL tear injuries, females are at an increased risk. For example, high school to collegiate aged female athletes are much more likely to experience ACL tears than their male counterparts (1, 8, 27). Nearly 1 out of every 20 female high school athletes experiences an ACL injury in their career (12). The reason for this disparity between genders is not completely understood, but hypotheses for this inequality include differences in hormone levels, anatomy, and/or muscle strength (15, 24, 27). Also, soccer players of both genders have a greater risk than basketball players of tearing their ACL (1).

The purpose of this study is to determine how different methods of stretching affect range of motion, flexibility, and joint stability in the lower extremity for young female soccer players

who are susceptible to anterior cruciate ligament tears. While ACL prevention programs use dynamic stretching warm-ups on the basis that they increase overall performance, little is known about the direct effects of dynamic and static stretching in relation to ACL tear mechanisms. I will examine how dynamic and static stretching affects range of motion, flexibility, and joint stability in context to ACL tear mechanisms: anterior tibial shear (20-30 degrees of knee flexion) and knee adduction (valgus). Static stretching increases the range of motion in the knee joint (19). I will examine the implications of dynamic and static stretching techniques on the anterior tibial shear ACL tear mechanism, which could potentially increase range of motion in the knee to 20-30 degrees of flexion when going into a squatting position. Additionally, static stretching increases flexibility tasks such as touching the toes or doing the splits (7, 16, 23). An increase of lower limb flexibility can also be linked to an increased range of motion of the knee, and thus have an effect on the anterior tibial shear ACL tear mechanism. No studies have been conducted to assess the direct effects of stretching on knee adduction which is the other common ACL tear mechanism.

I hypothesize that my female subjects will benefit from dynamic stretching techniques with respect to range of motion and joint stability of the knee as compared to static stretching. When examining knee range of motion, I expect static stretching before a workout to result in more participants feeling strain in their knee within the dangerous 20-30 degree range when bending their joint. Therefore, static stretching would be a contributing factor to the common ACL tear mechanism of anterior tibial shear. In contrast, dynamic stretching stimulates the repetitive motions of workout activities, and will therefore enhance the range of motion needed for subsequent workout activities. I expect that dynamic stretching will reduce the amount of participants who feel strain in the knee within the dangerous 20-30 degree range when bending their joint. In this case, dynamic stretching would not be contributing to the common ACL tear mechanism of anterior tibial shear. When looking at flexibility of the knee, I expect that performing static stretches before sports participation will increase the flexibility of the lower extremity, allowing the muscles surrounding the knee joint to extend to a higher degree than dynamic stretching. Therefore, I expect that static stretching will lead to insufficient joint stability causing a greater degree of knee adduction (valgus). Dynamic stretching reflects common motions of the sport being engaged in and will allow for proper techniques of these activities to be established due to muscle memory and reduce risk of injury by only allowing the knee joint to become appropriately flexible instead of experiencing hyper-flexibility (14, 28). Therefore, dynamic stretching should not lead to insufficient joint stability. This means that the female athletes should experience little to no knee adduction (valgus).

## Methods:

### *Participants:*

Twenty-seven female high school soccer players (ages 15-18) participated in this experiment. The average age was 16 years  $\pm$  1, the average height was 136.1 cm  $\pm$  17.8, and the average weight was 61.9 kilograms  $\pm$  8.1. None of these athletes had experienced prior ACL tears. The participants attended a parent/player meeting led by myself where the details of the experiment were outlined, participation requirements were addressed, and questions were answered. The participating players and their parents/legal guardians signed a comprehensive informed consent document in order to participate. This study was approved by the Institutional Review Board (IRB) at Wright State University.

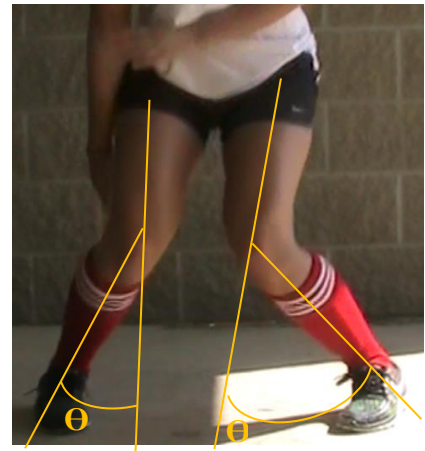
### *Protocol:*

Each participant was asked to bend at the knee while standing (going into a squat position). The angle at which the participant began to feel strain was the value recorded and the range of motion in their knee was recorded three times on each leg. The participants then performed a single-legged sit-and-reach test three times on each leg. Additionally, participants were recorded doing three repetitions of countermovement jumps, keeping their hands at their waist and the angle of knee valgus on each knee was calculated using vectors.

I recorded each trial in my notebook, but only the highest value was used for the analysis (10, 23). Then after random assignment of the conditions, static stretching (SS) and dynamic stretching (DS), the two groups conducted their assigned stretching method. The static stretching group performed right and left leg quadriceps, hamstring, calf, gluteus, and groin stretches. Each stretch on each leg was held for 20 seconds. The dynamic stretching group performed 10 yards of high knees, "butt-kicks", lunges, karaoke, walking knee lift, walking leg cradle, open-the-gate, close-the-gate, and right and left side lunges. The athletes then competed in an hour of a soccer scrimmage against one another (random assignment of teams). Following the soccer scrimmage, each athlete repeated the range of motion, flexibility, and knee joint stability tasks again. The following practice, I returned and repeated all of the same measures in the same manner, except that participants used the alternative assigned stretching method. This methodology is similar to that used in other experiments (5, 10, 23).

### *Statistical Analysis:*

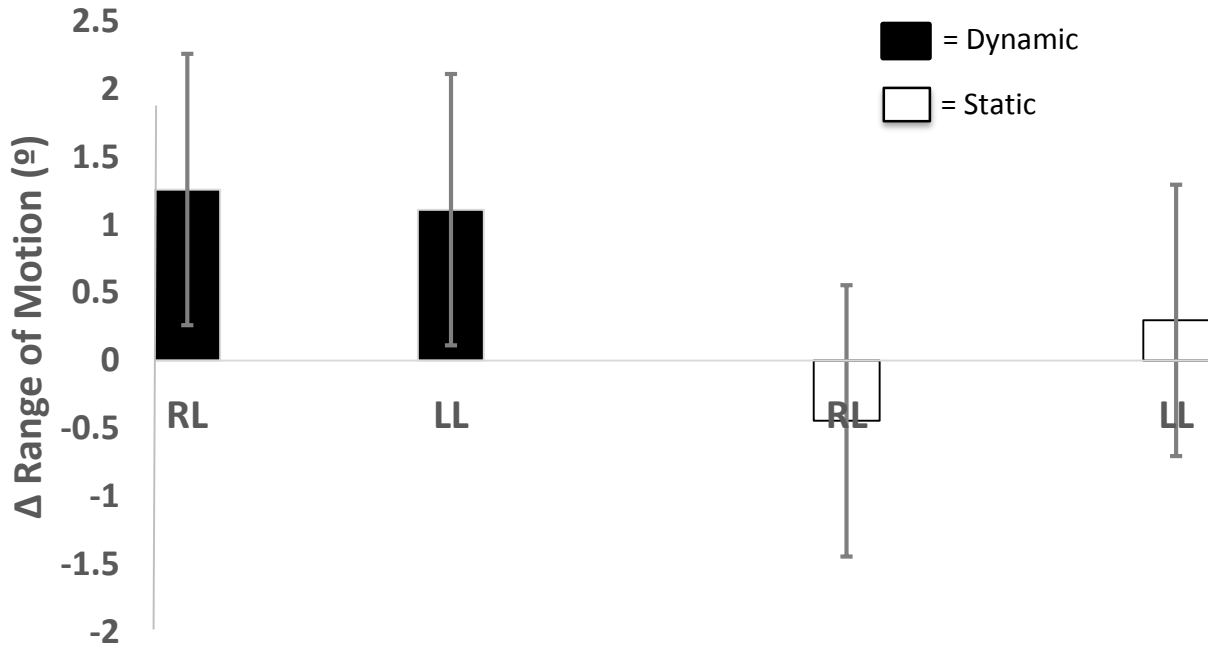
A paired t-test was used to compare the mean values of before and after each leg within the same stretching condition, and to compare the mean difference values between the two stretching conditions. Differences were considered significant if  $P < 0.05$ .



**Figure 1. Knee valgus after a countermovement jump is measured by the angle ( $\theta$ ) the knee moves medially upon landing.**

## Results:

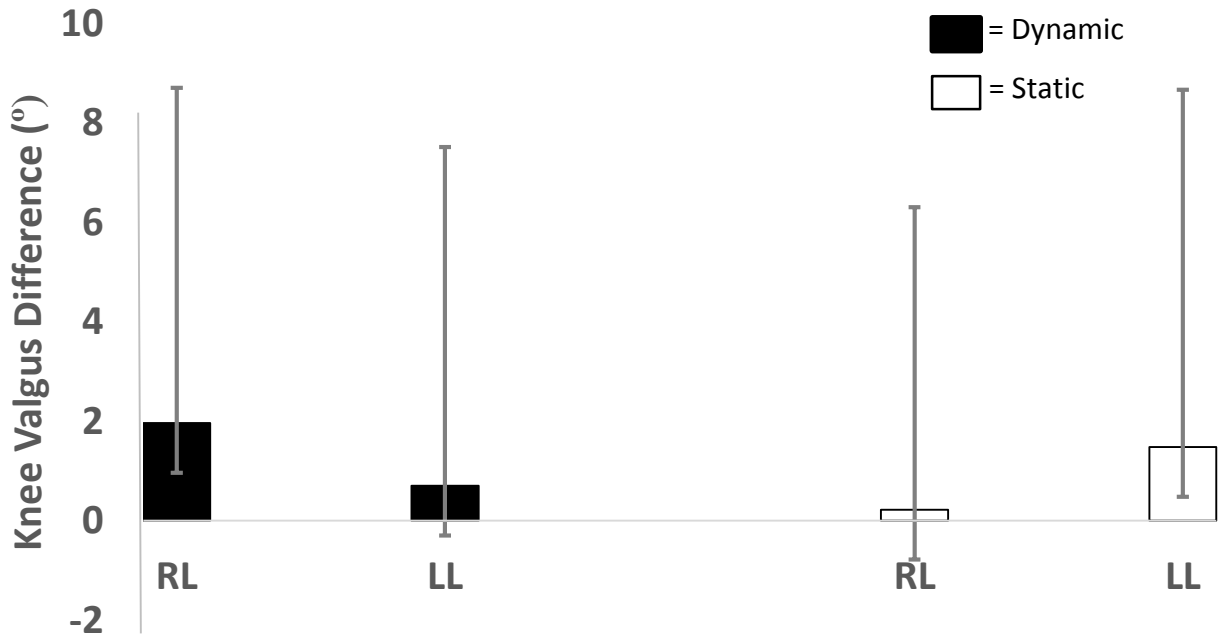
The average difference of ROM before and after each leg under static and dynamic conditions is not significant between the two stretching groups (Fig. 2). The average difference for the right leg under dynamic stretching conditions was  $(1.26^\circ \pm 5.49)$ , left leg under dynamic stretching conditions was  $(1.11^\circ \pm 5.03)$ , right leg under static stretching conditions was  $(-0.44^\circ \pm 6.44)$ , and left leg under static stretching conditions was  $(0.30^\circ \pm 5.80)$ . There were no significant differences between legs and between stretching conditions ( $P > 0.05$ ).



**Figure 2. ROM in both the left and right leg is not different between static and dynamic stretching conditions ( $P > 0.05$ ).**

The average difference of knee valgus before and after each leg under static and dynamic conditions is not significant between the two stretching groups (Fig. 3). The average difference for the right leg under dynamic stretching conditions was  $(1.96^\circ \pm 6.74)$ , left leg under dynamic stretching conditions was  $(0.70^\circ \pm 6.81)$ , right leg under static stretching conditions was  $(.22^\circ \pm 6.08)$ , and left leg under static stretching conditions was  $(1.48^\circ \pm 7.49)$ . There were no significant differences in knee valgus between legs and between stretching conditions ( $P > 0.05$ ).





**Figure 3. Knee valgus in both the right and left leg is not different between static and dynamic stretching conditions ( $P > 0.05$ ).**

Table 1 shows that the average difference of flexibility before and after each leg under static and dynamic conditions is significant between groups ( $P \leq 0.05$  for all conditions).

**Table 1. Static stretching and dynamic stretching both increase flexibility in the right and left legs. Note: Delta ( $\Delta$ ) values are the average difference between the before/after values.**

Flexibility								
	Right Leg				Left Leg			
	Before (cm.)	After (cm.)	P-value	$\Delta$	Before (cm.)	After (cm.)	P-value	$\Delta$
Static Stretching	50.2 ± 6.1	52.4 ± 5.3	$P \leq 0.05$	3.6 ± 4.0	49.2 ± 5.5	51.7 ± 5.1	$P \leq 0.05$	2.5 ± 2.3
Dynamic Stretching	49.0 ± 6.3	52.3 ± 6.3	$P \leq 0.05$	3.6 ± 4.0	50.5 ± 6.3	52.2 ± 4.9	$P \leq 0.05$	3.2 ± 3.5

## Discussion:

Currently ACL tear prevention programs use dynamic stretching on the basis that it increases performance without considering how it may contribute to the two most common ACL tear mechanisms: anterior tibial shear and knee valgus. The 27 female soccer players participating in this study completed dynamic stretching one practice and static stretching another practice. After each practice session, I measured their flexibility, knee range of motion, and knee valgus, and compared the differences between the two stretching conditions to determine which (if either) were contributors to these common ACL tear mechanisms.

Even though researchers have suggested that knee valgus is a contributor to ACL tears in women (4,12), I found no definite value or range for which other researchers deem "dangerous" or more likely to cause an ACL tear because virtually any level of knee valgus is dangerous. Therefore, I examined whether or not the degree of knee valgus was increased by either stretching condition. Nearly all of the athletes exhibited knee valgus upon landing from a countermovement jump both before and after they performed the static and dynamic stretching conditions. However, neither static nor dynamic stretching conditions increased the incidence of knee valgus in the female athletes (Fig. 3). The mean difference in degree of knee valgus under dynamic conditions was  $1.96^{\circ}$  for the right leg and  $0.70^{\circ}$  for the left leg, and the mean difference for the degree of knee valgus under static conditions was  $0.22^{\circ}$  for the right leg and  $1.48^{\circ}$  for the left leg. These differences are more variable than seen by Root et al., with 0.27 difference in knee valgus for dynamic stretching and 0.43 difference in knee valgus for static stretching (22). However, there was also no difference between the two stretching conditions with respect to preventing knee valgus in young athletes (22). The data in my study and the Root et al., study were highly variable overall, and this could be a reason no significance between the stretching conditions was detected. Additionally, the sample size for my study was only 27 participants, while Root et al. had a sample size of 89 (22). The length or tension of the muscles surrounding the knee joint must not be a contributing factor to knee joint stability otherwise, either of the stretching conditions should have increased the incidence of knee valgus, especially for athletes performing static stretching techniques before exercising. Since knee valgus is a common, known mechanism for ACL injury or sports injuries in general, I suggest that players engage in training programs which teach proper landing techniques to prevent this form of injury (26).

ACL tears often occur between  $20-30^{\circ}$  of knee flexion (19). The athletes participating in this study had knee flexion ROM consistently between  $60-80^{\circ}$ . This suggests that  $20-30^{\circ}$  knee flexion does not often occur in controlled movements. The dynamic and static stretching conditions had no effect on range of motion (Fig. 2). The mean difference of range of motion between dynamic and static stretching for the right leg was 1.69 and left leg .82. This difference is slightly greater than seen in other studies, such as Steele et al. (dynamic difference .3 and static difference static difference 0), but still yielded the same result that there is no difference in knee joint stability after static/dynamic warm-up protocols mean difference between stretching conditions (25, 28). The similarity between knee ROM values of static and dynamic stretching techniques disproves my hypothesis that static stretching would increase joint stability to a greater extent than dynamic stretching because of increased muscle length and reduced muscle tension (25). Therefore, range of motion for the knee joint must not rely on the length or tension in surrounding muscles.

Both of the stretching conditions caused an increase in lower limb flexibility as (Table 1). The static stretching method increased flexibility by an average of 2.5 cm for left leg and 3.6 cm

for right leg. This increase is slightly lower than seen in other studies, such as Obradovic et al. (increase of 5.43 cm) and Covert et al. (11.9 cm) (7, 19). Static stretching holds the muscles under a constant, above-average tension for a longer time which causes them to be lengthened in their resting state. The dynamic stretching condition increased flexibility by an average of 3.2 cm for the left leg and 3.6 cm for the left leg. This increase is slightly lower than seen in other studies, such as Obradovic et al. (increase of 6.13) and Covert et al. (increase of 3.8) (7, 19). Dynamic stretching does not hold the muscles under a constant, above-average tension; rather, the dynamic stretches are exaggerations of normal exercise motions for whatever sport will be played. While in the exaggerated state, the muscles experience a brief period of above-average tension, causing them to be lengthened in their resting state. The difference of constant vs. brief tension periods is a possible explanation for why static stretching is supposed to increase flexibility to a greater extent than dynamic stretching. This hyper-flexibility of the knee joint has also been linked to knee laxity related to ACL tears (3). However, the subjects in this study were anomalies with respect to most other studies because they did not produce data consistent with this rationale. However, this result was consistent with Obraovic et al., who also saw a greater increase in flexibility for the dynamic stretching group (19). These particular study subjects most often use dynamic stretching in their pre-exercise routine and are therefore more comfortable with it. Static stretching was still an effective means of increasing flexibility for these athletes, but they may not have not been well-adjusted to this method or felt as prepared for their subsequent activities, resulting in lesser performance on flexibility tasks in comparison with dynamic stretching.

### *Limitations*

This study used a fairly small sample size and therefore may not be an adequate representation of the entire female soccer player community. However, many other studies have sample sizes ranging between 24 and 48 (2, 3, 5, 7, 10, 15, 19, 28). Although measures were taken to reduce the possibility of confounding factors, athletes may have been affected by outside factors such as mental or emotional state, physical soreness, and nutrition/hydration on the days the data were recorded (11, 20, 21). The participants may have also experienced different levels of strain during the pre-exercise stretching protocol/data collection and the post-exercise data collection during the soccer match. Different players have different roles and levels of activity; therefore, I am unable to standardize their responses of knee valgus, range of motion, and flexibility. The differences in position could have affected the post-exercise data collection values. However, the final data was collected after the soccer scrimmage to establish a more real-life scenario, in line with another study (28). Pre-exercise stretching techniques benefit the athlete throughout the duration of the exercise (28). The results I obtained, or lack thereof,

While it is often common practice within this area of research to only consider the highest trial value of the three trials rather than the average (10, 23). I think this can potentially lead to errors when analyzing the data. Each of these limitations may have skewed the data in either direction meaning that caution should be taken when drawing definite conclusions from this data because it may not reflect the true results which could be obtained in the absence of these factors.

## *Summary*

I did not find significant differences in static and dynamic stretching methods; my findings agree with reports from other studies (22, 25, 28, 29). Neither static stretching nor dynamic stretching pre-exercise increases risk of the common ACL tear mechanisms of anterior tibial shear or increased risk of knee valgus as determined by the knee ROM evaluation or degree of knee valgus evaluation, respectively. Flexibility is increased with both static and dynamic stretching methods, but this is not a determining factor for the method of pre-exercise stretch for sports, like soccer, which do not greatly emphasize the importance of flexibility. Therefore, athletes should choose their stretching method to improve their performance rather than to reduce risk of ACL injury.

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