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What is the Impact of Stretching on Injury Prevention During Physical Activity?

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What is the Impact of Stretching on Injury Prevention During Physical Activity?

A Synthesis of the Research Literature

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Abstract

The purpose of this synthesis was to examine the impact that stretching has on injury prevention during physical activity. The studies reviewed in the critical mass reviewed the different types of stretching methods: static, dynamic, and proprioceptive neuromuscular facilitation. The studies in the articles provided showed that neither stretching method had any huge impact on the prevention of injury. Some findings did show conflicts between stretching and muscle strength as well as stretching and muscle performance. More research is needed to study the impact that stretching has on injury prevention during physical activity as well as the impact it has on muscle strength and muscle performance.

Keywords: [Stretching, Injury prevention, Static stretching, Dynamic stretching, PNF]

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Chapter 1 Introduction

Society has grown to recognize that physical activity is an important part of a healthy lifestyle (Thacker, Gilchrist, Stroup, & Kimsey, 2004). According to International Health, Racquet, and Sports Club Association, within the last ten years the fitness industry in the U.S. has grown by at least 3-4% annually and isn't showing any signs of slowing down (Midgley, 2018). Midgley (2018) explains that some of the reasons why the fitness industry is booming are because there is a new demand for healthy foods, there are devices such as Fit bit and Apple watch to increase awareness, there are exercise classes that can be streamed, there are more budget friendly gyms, and the outdoor obstacle races are growing in popularity. With this recognition, the participation in physical activity has grown immensely; therefore the potential risk of injury is high.

There may be many factors to specific injuries such as age, strength, flexibility, stretching, warm-up, etc. (McHugh & Cosgrave, 2009). When an athlete enters an athletic training room because of an injury, it is automatically assumed that the reasoning is inflexibility. When an active individual shows up at the orthopedists office with back pains, they are instantly put on a back stretching program (Ingraham, 2003). What has not been looked at is the evidence that the lack of flexibility is the root of these injuries.

Common Injuries

Some of the most common injuries in physical activity are anterior cruciate ligament (ACL), shin splints, and hamstring strains (McEvoy, 2019). ACL injuries are one of the most common knee injuries in physical activity (Kiefer, et. al., 2015). An ACL injury commonly occurs in sports involving a lot of jumping, accelerations, and decelerations (Welling, Benjaminse, Gokeler, & Otten, 2017). There are approximately 150,000 ACL injuries that occur in the United States every year (OrthoInfo, 2014). There are current ACL intervention programmes, however, athletes that have high compliance have significantly reduced injury rates compared to athletes with low compliance (Benjaminse, Otten, Gokeler, Diercks, & Lemmink, 2017). Many of these training programs have included injury education as well as multicomponent training (Dai, Herman, Liu, Garrett, & Yu, 2012). Coach's feel as though implementing such program is not of primary interest, therefore there is a need for improvement on ACL injury prevention strategies (Benjaminse, et. al., 2017).

Another common injury is shin splints. Studies have shown that shin splints are one of the most common lower leg injuries accounting for 50% of lower leg injuries in select populations (Craig, 2008). Shin splints, also known as medial tibial stress syndrome (MTSS), cause pain on the lower inside part of the shin and are most common among runners (Hussain, Shehzad, & Waqas, 2018). A few recommendations to prevent shin splints are to increase mileage, mix training surfaces, and strengthen mobility ("Medial Tibial Stress Syndrome in Runners," 2017).

Hamstring strains are another common sports injury. There are three tiers to a hamstring strain: a pull, a partial tear, or a complete tear (OrthoInfo, 2015). Hamstring strains typically occur when high speed sprinting and kicking are frequently performed (Liu, William, Garrett, Moorman, & Bing, 2012). It is recommended that in order to prevent and improve the treatment of hamstring strains, it is important to understand the injury rate, mechanisms, and risk factors (Liu, et. al., 2012).

Stretching

Stretching is an overlooked practice of participation in any type of physical activity. Individuals who stretch are typically doing it because they believe it will prevent injury and improve performance (Thacker, et. al., 2004). It is said that stretching also helps increase flexibility, or in other words range of motion (ROM) (Jamtvedt, et. al., 2010). When ROM is improved then physical performance is improved and the risk of injury is reduced as well as muscle soreness (Costa, Herda, Herda, & Cramer, 2014). Individuals that stretch before or after physical activity have reported that they do so to enhance their sense of looseness, well being, or preparedness to exercise (Jamtvedt et. al., 2010). When performing a warm-up, individuals are preparing their body to undertake physical activity, and by doing this their body temperature rises. Because of this, the blood will reach the muscles much faster and increase their excitability, which leads to higher competence during physical effort (Boguszewski, Białoszewski, Radomska, & Kerbaum-Visser, 2018). When the body is fully warmed-up, it is recommended to perform stretching. The practice of stretching has been passed down from generation to generation and has become accepted by many professionals (Ingraham, 2003). There are numerous journals, articles, and textbooks that are devoted to different approaches individuals can use to stretch and different parts of the body for specific sports (Thacker, et. al., 2004). There are many different methods of stretching, however the most common are static, dynamic, and more recently proprioceptive neuromuscular facilitation (PNF) (Thacker, et. al., 2004). Stretching is a standard practice for participation in physical activity. Professionals such as coaches, athletes, trainers and therapists recommend that stretching be done to reduce injury and enhance performance (Thacker, et. al., 2004). However, some investigators have begun to question the practice of stretching because there is little to no evidence that it prevents injury (Jamtvedt, et. al., 2010). It is important to identify the impact that stretching has on individuals to reduce the risk of injury.

Statement of the Problem

The purpose of this synthesis is to explore the impact that stretching has on injury prevention during physical activity. Stretching is an extremely overlooked practice, and with the rise of participation in physical activity, this synthesis seeks to identify the impact that stretching has on injury prevention.

Operational Definitions

The following operational definitions are used in this paper:

1. Static Stretching- "Static stretching is best described as moving a limb into a tolerated, stretch position and maintaining that position for a period of time" (Vardiman, Carrand, & Gallagher, 2010, p. 32).
2. Dynamic Stretching- "Dynamic stretching is described as moving the limbs through range of motion in an organized pattern to increase range of motion" (Vardiman, Carrand, & Gallagher, 2010, p. 33).
3. Proprioceptive neuromuscular facilitation (PNF)- "This technique requires the subject to stretch the target muscle to its end-point, then contract the muscle against a partner for a set duration, and then relax the target muscle" (Vardiman, Carrand, & Gallagher, 2010, p. 33).

Scope of Synthesis

This synthesis will examine three different types of stretching, static, dynamic, and proprioceptive neuromuscular facilitation. Other areas of consideration include stretching before or after physical activity, as well as related common injuries. This synthesis will draw conclusions as to whether or not stretching is impacting injury prevention positively or negatively. Finally, recommendations will be constructed for use to determine which type of stretching is better and if it reduces injury. Factors that will also be looked at are whether stretching has a different impact before physical activity or after.

Chapter 2 Methods

In order to find a critical mass of articles for my topic, I used the Brockport Drake Library Online database. I started off searching through Academic Search Complete, SportDISCUS, and ProQuest, which are all a part of EBSCOhost. When searching through these electronic databases, key words such as "stretching," "injury prevention," "college athletes," "static stretching," "dynamic stretching," and "proprioceptive neuromuscular facilitation" was utilized to obtain information. Unfortunately, when using college athletes as a population, I received roughly 21 articles as a result. From those 21 results, only two contained suitable information regarding stretching and injury prevention in college athletes. From this I decided to broaden my topic to healthy active individuals. I also decided through EBSCOhost I would use all of the databases available because many of the databases were medicine related and my topic is in relation to that. Once the results were narrowed down I was able to find articles, which were more specifically directed to my topic of study and the population of focus. I was able to use the ancestry method to locate additional articles. By doing this I found systematic reviews that were similar to my topic, giving me the opportunity to review reference lists of several key articles

Inclusion Criteria

The next step in my research was to choose the articles to include in my synthesis. First, I selected studies having to do with static stretching, second was dynamic stretching, and third was PNF stretching. I then chose studies that compared the different types of stretching. Most articles contained information on static stretching and dynamic stretching and very few had to do with proprioceptive neuromuscular facilitation. All of the articles chosen were peer reviewed and contained information on how stretching impacted injury rates or how stretching impacted range of motion. The Articles were then grouped on whether the stretching was done before participating in physical activity or after. Unfortunately, there was not enough information or articles to determine the impact that stretching had before or after physical activity. Articles were chosen for inclusion based on the different types of stretching. The requirements allowed me to narrow down the pool of articles and I was able to find a mass of 10 research studies on the topic for inclusion in this synthesis.

Data Analysis

I had to group my articles based on the purpose of their study. The themes that came out were the different types of stretching methods, static, dynamic, and PNF. Once the articles meeting the criteria were chosen for inclusion in this synthesis, a thematic coding chart was created to organize the criteria (See Appendix A). This chart provides the author and the year as well as whether the article contained static, dynamic or PNF stretching. The information from each article was then put into an article grid (See Appendix B). The findings associated with the themes are discussed in the next section.

Chapter 3 Results

The following section will provide an overview of the results found in the critical mass of literature, consisting of a total of 10 research articles on the impact of stretching on injury prevention. The themes that emerged were based on the different stretching techniques, static stretching, dynamic stretching, and proprioceptive neuromuscular facilitation. As previously mentioned, thematic coding chart was created to track the themes within each study (see Appendix A). In this section, the discussion of the results is organized based around the themes.

Static Stretching

"Static stretching can best be defined as moving a limb into a tolerated, stretch position and maintaining that position for a period of time" (Vardiman, Carrand, & Gallagher, 2010, p.32). Static stretching is the most common type of stretching performed because it is easier and safer to perform than others (Bacurau, et. al., 2009). In a study conducted by Pope, Herbert, Kirwan, and Graham (2000), 901 healthy male military recruit subjects were split into control and experimental groups. The recruits in the experimental group performed a static stretching routine consisting of 18 exercises focusing on different parts of the body. Each stretch was held for 30 seconds resulting in a 20-minute routine before and after physical training was done for 3 hours. The recruits in the control group did dynamic stretching but only spent 5 to 10 minutes. The study period for the intervention was 2 years. The results showed that the injury rate for the stretching group was 11.2% and the injury rate for the non-stretching group was slightly higher at 14.1%. The study shows that static stretching did not have a significant difference in injury rate from the non-stretching group.

In a similar study conducted by Jamtvedt et. al. (2010) a comparable intervention was taken. In this intervention the sample size was slightly larger at 2,125 participants but was conducted over a 12-week period. The participants were split into a control and experimental group. The participants in the experimental group stretched seven muscle groups, using static stretching. They were told to hold each stretch for 30 seconds resulting in a 14 minute stretch routine. The participants in the control group were asked not to stretch at all. All participants were asked to complete weekly reports of injury and bothersome soreness. The results showed that the overall injury rate for the stretching group was 339 while the injury rate for the non-stretching group was 348. Overall, there is no significant difference.

Another study, similar to the two mentioned above, conducted by Mechelen, et. al. (1993), was done in hopes to find the effect of a health education intervention on running injuries. The intervention consisted of a warm-up of running exercises, loosening exercises and 10 minutes of static stretching, and took 16 weeks to complete. There were two separate groups, a control group and an intervention group. Of the 463 total participants, the results showed that there were 23 injuries in the control group and 26 in the intervention group. Unlike the studies mentioned earlier, this study actually had more injuries in the experimental group. However, the numbers are not comparable enough to conclude that there was an impact on injury prevention. The findings in these studies are similar in that static stretching did not have a significant difference on reducing injury.

Although these studies have shown that stretching has no statistical impact on injury prevention, a more recent study was done by Boguszewski et. al. (2018) to determine the effectiveness of static and dynamic stretching in minimizing the functional limitations of the locomotor system. The participants in the study were students of the Medical University of Warsaw, consisting of 70 women and 18 men. The participants were split into two groups, a static stretching group, and a dynamic stretching group. Both groups performed two tests, the Functional Movement Screen test and the Core Muscle Strength and Stability Test. The study showed that there were positive impacts on minimizing the functional limitations of the musculoskeletal system for both the static and dynamic stretching groups. With the positive impact on the limitations of the musculoskeletal system, the likelihood of being injured would be rare, which counters the findings mentioned earlier.

Dynamic Stretching

Although static stretching is the most common stretch to perform before physical activity, it has recently been challenged with arguments that static stretching may cause a force deficit, whereas dynamic may not (Costa, et. al., 2014). It is hypothesized that if there is a forced deficit then the capabilities of the muscles may be limited, if the capabilities of the muscles are limited, then there is a higher risk for injury (Herda, et. al., 2008). In a study conducted by Zakaria, Kiningham, and Sen (2015), they challenged this argument. By doing so they conducted a trial with 465 student athletes in 12 different soccer teams. Two different stretching groups were created to perform stretches before all practices and games throughout the season. The first stretching group performed both dynamic and static stretches while the second stretching group only performed the same dynamic stretches as the static and dynamic stretching protocol. Zakaria et. al. (2015) believes that the most effective stretching mimics the activity that is going to be performed, which is the type of dynamic stretching used in the trial. The trial was held during their entire season and the athletic trainer was contacted every 2 weeks to ensure the teams were properly performing the protocols. Over the entire season there were 20 injuries for the teams that performed the dynamic and static stretching protocol and there were 17 injuries for the teams that performed the dynamic stretching protocol. There is no statistical difference between the two stretching protocols. Although the dynamic stretching group had slightly less injuries, it is not enough to determine whether the argument mentioned is valid.

In a similar study conducted by Costa et. al. (2014), 21 women volunteered to be tested on the effects of dynamic stretching. Their protocol consisted of four sets of different dynamic stretching exercises lasting 30 seconds each. Two exercises focused on the posterior muscles of the thigh and the last two focused on the anterior muscle of the thigh. The women were tested 3 different times with at least 48 hours between the days. The study focused on concentric leg extensor and flexor peak torque, eccentric leg flexor peak torque, and the conventional and functional hamstring quadriceps. The stretching was assessed in a random order using a calibrated Lido Multi-Joint II isokinetic dynamometer at random ordered velocities of 60° s-1 and 180° s-1. The results for leg flexion peak torque decreased for the control at 60° as well as the stretching at 60°. When done at 180° there is also a decrease for the control as well as the stretching. The eccentric peak torque decreased only after stretching at 60° and at 180°. Overall, the results of the study show that dynamic stretching decreased both concentric and eccentric hamstring. With this decrease, the likelihood of injury prevention is slim and may even have in increase for risk of injury. Both studies have shown that incorporating dynamic stretching into a warm-up will likely have either no effect in prevention of injury or may possibly increase the risk, which counters the argument that dynamic stretching may not cause a force deficit.

A study conducted by Herda et. al. (2008) was done to examine whether dynamic stretching produces the same muscle force production as static stretching. The study consisted of 14 healthy men. Each participant either performed a static stretch or a dynamic stretch before conducting the assessment. The study was completed on three separate days. The study examined pre and post stretching for peak torque, EMG amplitude, as well as MMG amplitude for the knee joint angle. The results showed the peak torque values decreased for static stretching and the EMG amplitude and the MMG amplitude showed no differences from pre to post stretching for dynamic or static stretching. The results have shown that static stretching decreased peak torque of the hamstring muscles and dynamic stretching had no impact.

A similar study conducted by Bacurau et. al. (2009) was done as well to compare the effects of static and dynamic stretching on lower-limb maximal strength. Fourteen healthy women volunteered and performed three experimental sessions: control, dynamic, and static. The subjects reported to a lab a total of 4 times with at least 5 days in between. The subjects would perform a warm-up upon arrival then either perform a static or dynamic stretch, and then were immediately tested on flexibility and maximum strength. The results showed a significantly greater improvement in ROM for static stretching than dynamic stretching. The maximum strength test decreased significantly after the static condition compared to the dynamic and control. The results have shown that static stretching has produced a force deficit whereas dynamic had no affect, however ROM was increased with static when compared to dynamic. These two studies coincide with the argument that static stretching may cause a force deficit and dynamic may not.

Proprioceptive Neuromuscular Facilitation

Proprioceptive neuromuscular facilitation (PNF) is a type of stretch that incorporates both static stretching and isometric contractions in a pattern to help increase range of motion (Behm, Blazevich, Kay, & McHugh, 2016). This practice is not something that is commonly used because it requires the use of another individual. There have been arguments that PNF techniques might increase the risk of injury because of the tolerance in stretching being performed (Thacker, et. al., 2004). A study was conducted by Barroso, et. al. (2012) to compare the effects of static stretching, ballistic stretching, and PNF on ROM. The subjects in the trial were 12 men ranging from 16 years to 24 years of age. The men were split intro four different groups, a static stretching group, dynamic group, PNF group, and a no stretching group. The men were tested on 3 separate days, at least 72 hours apart from each other. They would perform a warm-up that consisted of a 5 minute run followed by their stretching protocol. They were tested in three different areas, maximum strength, that was assessed using a conventional inclined leg press machine, number of repetitions, which consisted of 3 sets on the leg press until failure, and lastly sit-and-reach, which they were given three attempts. The results showed that for the sit-and-reach, which tested ROM, the PNF significantly improved

ROM when being compared to the static or dynamic groups. As recommended by Costa (2014), when ROM is increased then there is a higher chance of preventing injury.

In another study conducted by Konrad, Stafilidis, and Tilp (2017), he investigates the influence of static, dynamic, and PNF stretching exercises on various muscle-tendon parameters of the lower leg, and to detect possible differences between the methods. The subjects used in this trial were 79 males and 43 females. The subjects were split into 4 different groups: static, dynamic, PNF, and control. The stretching intervention was undertaken with a dynamometer. The dynamometer was moved to the participants max dorsiflexion ROM in all stretching techniques. Each group performed their stretching routine 4 times for 30 seconds with a 20 second rest in-between. The results for the stretching intervention from all the stretching groups showed a significant increase in dorsiflexion ROM. Overall, the results of the study showed that static, dynamic, and PNF stretching all increased the participants dorsiflexion ROM, which through recommendation, should help with the prevention of injury.

Summary

Studies have shown that stretching presents a wide range of impacts when it comes to injury prevention. When looking directly at static stretching, there is no significant impact on injury prevention when it comes to stretching. The statistics mentioned showed that static stretching had a slightly less rate of injury than control groups, however, the difference is not enough to conclude that static stretching has an impact. When looking directly at dynamic stretching, the studies mentioned showed either no impact on the prevention of injury or even a partial increase to the risk of injury. When looking directly at PNF, both studies showed an increase in ROM. When there is an increase of ROM then the chances of injury are reduced (Costa, et. al., 2014). Overall, the results have shown that none of the stretching methods mentioned have shown any worthwhile statistical reduction in the rates of injuries concluding that there is no impact.

Chapter 4 Discussion

This synthesis examined the impact that stretching has on injury prevention during physical activity. After collectively gathering results from the critical mass, the evidence shows that stretching has no direct impact on preventing injury during physical activity. However, the research has shown that there may be a possible correlation between stretching and performance, as well as stretching and muscle strength. The following sections provide insight on different types of methods to prevent injury, the correlation between stretching and muscle strength, the correlation between stretching and performance, as well as limitations and recommendations for possible research in the future.

Methods on Injury Prevention

Currently the literature shows that stretching does not have any statistical impacts on the prevention of injury, therefore should not be recommended to reduce injury rates. However, some studies have shown that some ways we can help prevent injury are neuromuscular training (NMT), providing feedback, and visuals. NMT, which is strength training that promotes correct movement and techniques, has been proven to reduce the risk of injury (Kiefer, et. al., 2015). A study by Foss, et. al. (2018) was conducted to determine the effects of a NMT program on sport related injury incidence in high school and middle school athletes. Foss et. al. (2018) concluded that participation in a NMT program resulted in a reduced injury incidence. Specifically, this study looked at injuries of the knee and ankle because they are the two most injured body parts in children between the ages of five to fourteen (Foss, et. al., 2018).

NMT is also a method to reduce the risk of injury in hamstring strains. A common cause for a hamstring strain is a muscle overload (OrthoInfo, 2015). Some possible risk factors for hamstring strains are muscle tightness, muscle imbalance, and weak muscles (OtrhoInfo, 2015). If the muscles are weak then they are less likely to handle the exercise that is being done and are more likely to be injured (OrthoInfo, 2015). When performing NMT, the muscles are becoming strength trained, therefore creating a stronger muscle to reduce the risk of injury (Kiefer, et. al., 2015).

With ACL injuries being one of the most common injuries in physical activity, there are current interventions that will help with the prevention of injury (Kiefer, et. al., 2015). A recent study conducted by Welling et. al. (2017) compared verbal EF, verbal IF, and video instructions on landing techniques. The results showed that males and females in the EF and IF instruction groups improved immensely during and after the training session. Adding in EF and VI may lead to efficient movement patterns (Welling, et. al., 2017). When an individual is shown video instructions on how to perform a movement, they are then encouraged to imitate the movements (Welling, et. al., 2017). The findings in this study have the potential to be an ACL injury prevention program (Welling, et. al., 2017). When reducing the risk of injury for ACL, there is a possibility for reducing the risk of secondary injuries (Kiefer, et. al., 2015).

Muscle Strength

There is a conflict between the effects of stretching and muscle force capacity (Bacurau et al., 2009). There are doubts as to whether stretching before physical activity is effective. Researchers, Balle, Magnusson, McHugh (2015) and Torres, Conceicao, de Oliveira Sampaio, Dantas (2009), have concluded in their studies that there was a major decrease in muscle strength directly after performing stretches. Barroso et. al. (2012) suggests that stretching before physical activity decreases muscle mass and muscle strength. However, when looking at specific types of stretching, each one has a different effect. When looking at dynamic stretching, there is no adverse affect on isometric strength of leg flexors, when looking at static and PNF there is a huge decrease on the isometric strength of leg flexors (Herda, et. al., 2008). Some possible reasoning's why dynamic stretching has no impact on muscle force production and static stretching does is because when using static stretching there is an increase in stress relaxation impairing the muscle force creating changes in the force-velocity and length-tension relationships. Whereas in dynamic stretching reflex activity may be enhanced creating an increase in force production (Bacurau et al., 2009). With this possible reasoning it is suggested that a warm-up may want to include dynamic stretching over static stretching before physical activity to maintain muscle strength (Herda, et. al., 2008). The findings mentioned concluded that static stretching and PNF have a negative impact on muscle force, whereas dynamic does not. However, there is more research needed to make the statement valid.

Muscle Performance

Many findings have shown that stretching may have an impact on physical performance. Much like the effects of stretching on muscle force capacity, there is also a conflict between stretching and performance. Barroso et. al. (2012) concluded through his study involving the effects of stretching on performance of 1 rep max that both static and dynamic stretching had no effect while PNF had a significant decrease. However, Boguszewski et. al. (2018) incorporated static and dynamic stretching into a warm-up stage and observed a statistically significant improvement in movement patterns. Boguszewski et. al. (2018) observed that women basketball players gained better Functional Movement Screen and Core Muscle Strength and Stability through the use of a stability training program that improved core stability, strength, and proprioception. It is suggested, through evidence, that dynamic stretching may be more appropriate because it is less likely to have an effect on performance whereas static stretching may want to be used for sports that rely more on ROM (Bacurau, et. al., 2009). A study, conducted by Nelson, et. al. (2005), has also shown that pre-performance stretching may negatively impact skills that require multiple high power outputs over a single output of peak force. In this study the participants performed three 20m sprints and the results showed the three stretching conditions performed were all significantly lower than the no stretching condition (Nelson, et. al., 2005).

Limitations

There is a very limited amount of research done in regards to the impact of stretching on injury preventing during physical activity. Much of the research that has been done on stretching and injury prevention has been done with many factors that may have created weaknesses to the critical mass. First and foremost, there is no correct universal way to perform static, dynamic, or PNF stretching. Therefore, each study has performed different types of the same technique of stretching for different time lengths. Gender distribution was not taken into account in any of the studies. This is important for the obvious reasoning that there are well-known structural and functional differences between the sexes. Another reasoning there may be some weakness in the critical mass is that along with gender, age was also not taken into consideration.

Recommendations for Future Research

The existing data has shown that stretching has no direct impact on prevention of injury during physical activity. With the popularity of being physically active rising, additional research must be done to effectively examine this topic. A further look could be made at the impact of different types of stretching on different muscle groups, which may possibly support further research on injury prevention or possibly help draw conclusions on prevention of muscle soreness or muscle strains. Even though there is a rise of being physically active, another possible research question could be done on humans that are inactive and whether stretching impacts injury prevention. Additional research could be done on different age groups, different sexes, and different sports. The stretching protocols in the critical mass ranged from 1 day to 18 months. Research needs to be done to determine the most effective length of stretching necessary to possibly reduce injury. Much like the topics briefly discussed in this synthesis, further research could be done as to whether stretching has an impact on muscle strength or physical performance.

Conclusion

The research examined in this synthesis indicates that stretching has no statistical impact on injury prevention. Because of the wide range of limitations in each study and the conflict between each study we are still left with many unanswered questions. There is conflict that static stretching and PNF may have a negative impact on muscle strength and dynamic stretching may have no adverse impact. When looking at physical performance, there is also controversy that dynamic stretching may have a positive impact, whereas static stretching may decrease performance. Because this synthesis was in relation to injury prevention, some possible methods were recommended to reduce injury rates. The methods recommended were NMT, providing feedback, as well as providing visuals. However, when it comes to the role that stretching has on injury prevention, more research is needed.

References

*Bacurau, R. F. P., Monteiro, G. A., Ugrinowitsch, C., Tricoli, V., Cabral, L. F., & Aoki, M. S. (2009). Acute effect of a ballistic and a static stretching exercise bout on flexibility and maximal strength: *Journal of Strength and Conditioning Research*, *23*(1), 304–308.

Balle, S. S., Magnusson, S. P., & McHugh, M. P. (2015). Effects of contract-relax vs static stretching on stretch-induced strength loss and length-tension relationship: Stretching and length-tension relationship. *Scandinavian Journal of Medicine & Science in Sports*, *25*(6), 764–769.

*Barroso, R., Tricoli, V., Santos Gil, S. dos, Ugrinowitsch, C., & Roschel, H. (2012). Maximal strength, number of repetitions, and total volume are differently affected by static-, ballistic-, and proprioceptive neuromuscular facilitation stretching: *Journal of Strength and Conditioning Research*, *26*(9), 2432–2437.

Behm, D. G., Blazevich, A. J., Kay, A. D., & McHugh, M. (2016). Acute effects of muscle stretching on physical performance, range of motion, and injury incidence in healthy active individuals: A systematic review. *Applied Physiology, Nutrition, and Metabolism*, *41*(1), 1–11.

Benjaminse, A., Otten, B., Gokeler, A., Diercks, R. L., & Lemmink, K. A. P. M. (2017). Motor learning strategies in basketball players and its implications for ACL injury prevention: A randomized controlled trial. *Knee Surgery, Sports Traumatology, Arthroscopy*, *25*(8), 2365–2376.

*Boguszewski, D., Białoszewski, D., Radomska, A., & Kerbaum-Visser, K.

(2018). The influence of static and progressive stretching exercises on the functional limitations of the musculoskeletal system. *TRENDS in Sport Sciences*, *25*(1), 13–19.

*Costa, P. B., Herda, T. J., Herda, A. A., & Cramer, J. T. (2014). Effects of dynamic stretching on strength, muscle imbalance, and muscle Activation: *Medicine & Science in Sports & Exercise*, *46*(3), 586–593.

Craig, D. I. (2008). Medial tibial stress syndrome: Evidence-Based prevention. *Journal of Athletic Training*, *43*(3), 316–318.

Dai, B., Herman, D., Liu, H., Garrett, W. E., & Yu, B. (2012). Prevention of ACL injury, part II: Effects of ACL injury prevention programs on neuromuscular risk factors and injury rate. *Research in Sports Medicine*, *20*(3–4), 198–222.

Foss, K. D. B., Thomas, S., Khoury, J. C., Myer, G. D., & Hewett, T. E. (2018). A school-based neuromuscular training program and sport-related injury incidence: A prospective randomized controlled clinical trial. *Journal of Athletic Training*, *53*(1), 20–28.

*Herda, T. J., Cramer, J. T., Ryan, E. D., McHugh, M. P., & Stout, J. R. (2008). Acute effects of static versus dynamic stretching on isometric peak torque, electromyography, and mechanomyography of the biceps femoris muscle: *Journal of Strength and Conditioning Research*, *22*(3), 809–817.

Hussain, A., Shehzad, A., Waqas, M., & Ayub, T., (2018). Prevalence of shin splint amongst rugby players of Pakistan. *Ophthalmology*. *16*(3) 734-736.

Ingraham, S. J. (2003). The role of flexibility in injury prevention and athletic performance: Have we stretched the truth? *Minnesota Medicine*. *86*(5) 58-61.

*Jamtvedt, G., Herbert, R. D., Flottorp, S., Odgaard-Jensen, J., Havelsrud, K., Barratt, A., … Oxman, A. D. (2010). A pragmatic randomised trial of stretching before and after physical activity to prevent injury and soreness. *British Journal of Sports Medicine*, *44*(14), 1002–1009.

Kiefer, A. W., Kushner, A. M., Groene, J., Williams, C., Riley, M. A., & Myer, G. D. (2015). *A Commentary on Real-Time Biofeedback to Augment Neuromuscular Train- ing for ACL Injury Prevention in Adolescent Athletes*. 9.

*Konrad, A., Stafilidis, S., & Tilp, M. (2017). Effects of acute static, ballistic, and PNF stretching exercise on the muscle and tendon tissue properties. *Scandinavian Journal of Medicine & Science in Sports*, *27*(10), 1070–1080.

Lui, H., Garrett, W.E., Moorman, C.T., Yu, B. (2012). Injury rate, mechanism, and risk factors of hamstring strain injuries in sports: A review of the literature. *Journal of Sports and Health Science, 1*(2), 92-101.

McEvoy, B. (2019). Top 10 most common sports injuries. *2019 UnityPoint Health.* Retrieved from https://www.unitypoint.org/livewell/article.aspx?id=591d8cf1-1ee5-4cb3-b662-a5f21f6f13bc.

McHugh, M. P., & Cosgrave, C. H. (2009). To stretch or not to stretch: The role of stretching in injury prevention and performance. *Scandinavian Journal of Medicine & Science in Sports*.

*Mechelen, W.V., Hlobil, H., Kemper, H.C., Voorn, J.W., de Jongk, R. (1993). Prevention of running injuries by warm-up, cool-down, and stretching exercises. *The American Journal of Sports Medicine. 21*(5), 711-719.

Medial tibial stress syndrome (shin splints) in runners. (2017). *Co-Kinetic*.

Midgley, B. (2018). The Six Reasons The Fitness Industry Is Booming. Retrieved from website: https://www.forbes.com/sites/benmidgley/2018/09/26/the-six-reasons-the-fitness-industry-is-booming/.

Nelson, A. G., Driscoll, N. M., Landin, D. K., Young, M. A., & Schexnayder, I. C. (2005). Acute effects of passive muscle stretching on sprint performance. *Journal of Sports Sciences*, *23*(5), 449–454.

OrthoInfo. (2014). Anterior cruciate ligament (ACL) injuries. Retrieved from https://orthoinfo.aaos.org/en/diseases--conditions/anterior-cruciate-ligament-acl-injuries/

OrthoInfo. (2015). Hamstring muscle injuries. Retrieved from https://www.orthoinfo.org/en/diseases--conditions/hamstring-muscle-injuries

*Pope, R. P., Herbert, R. D., Kirwan, J. D., & Graham, B. J. (2000). A randomized trial of preexercise stretching for prevention of lower-limb injury: *Medicine & Science in Sports & Exercise*, *32*(2), 271.

Thacker, S. B., Gilchrist, J., Stroup, D. F., & Kimsey, C. D. (2004). The impact of stretching on sports injury risk: A systematic review of the literature: *Medicine & Science in Sports & Exercise*, *36*(3), 371–378.

Torres, J., Conceição, M., de Oliveira Sampaio, A., & Dantas, E. (2009). Acute effects of static stretching on muscle strength. *Biomedical Human Kinetics*, *1*, 52-55.

Vardiman, P., Carrand, D., & Gallagher, P. M. (2010). *Theory* into *Practice* : Stretching: Does it help? *Strategies*, *23*(4), 32–34.

Welling, W., Benjaminse, A., Gokeler, A., & Otten, B. (2017). Retention of movement technique: implications for primary prevention of ACL injurieds. *International Journal of Sports Physical Therapy*, *12*(6), 908–920.

*Zakaria, A. A., Kiningham, R. B., & Sen, A. (2015). Effects of Static and Dynamic Stretching on Injury Prevention in High School Soccer Athletes: A Randomized Trial. *Journal of Sport Rehabilitation*, *24*(3), 229–235.

Appendix A

Author	**Static**	**Dynamic**	**PNF**	**Before**	**After**
Boguszewski, David (2018) * Static	X	X		X	
Barroso,Renato (2012) *PNF	X	X	X	X	
Zakaria, Alan (2015) * Dynamic	BOTH	JUST D		X	
Costa Pablo (2014) *Dynamic		X		X	
Konrad, A (2017) *PNF	X	X	X	X	
Herda, Trent (2008) *Dynamic	X	X			
Bacurau, Reury (2009) *Dynamic	X	X			X
Pope, Rodney (2000) * Static	X	X		X	X
Jamtvedt, G (2010) *Static	X			X	X
Mechelen (1993) *Static	X	X		X	X

Appendix B

Author	**Title**	**Source**	**Purpose**	**Methods & Procedures**	**Analysis**	**Findings**	**Recommendations**
Dariusz Boguszewski, Agnieszka Radomska, Katarzyna Kerbaum-Visser, Dariusz Bialoszewski (2018)	The influence of static and progressive stretching exercise on the functional limitations of the musculoskeletal system	Trends in Sports Sciences	The main objective of the study was to assess the effectiveness of a warm-up programme that incorporated static and progressive stretching exercises in minimizing the functional limitations of the locomotor system	Two groups: Group I performed a warm-up and static exercise. Group II performed a warm-up consisting of progressive stretching exercises.	Data was analyzed using standard methods of statistical analysis and arithmetic means, including standard deviations. The FMS test as well as the CMSS test	Static and progressive stretching has a positive impact on minimizing the functional limitations of the musculoskeletal system	It is very important to take care of safety when performing movements, and to introduce measures preventing bodily injuries. For this purpose, supplementary exercises, such as stretching, should be a part of trainings.
Willem Van Mechelen, Hynek Hlobil, Han Kempe	Prevention of running injuries by warm-up, cool-down, and stretching exercises	The American Journal of Sports Medicine	The purpose of this study was to evaluate the effect of	Two groups of subjects, a control and an	Incidence was calculated taking exposure into accoun	Forty-nine injuries, 23 in the control group and 26 in the	The study was not successful due to there being no significance on the

r, Wim Voorn, Rob de Jongh (1993)			a health education interventio n on running injuries. The interventio n consisted of informatio n on, and the subsequent performan ce of, standardize d warm-up, cooldown, and stretching exercises.	interv ention group, are comp ared with differ ences in runnin g injury	t and express ed as the numbe r of newly sustain ed runnin g injuries per 1000 hours of runnin g. If applica ble, overall differe nces betwee n the interve ntion	interven tion group,	effect of incidence of injuries
Gro Jamtve dt, Robert D Herbert , Signe Flottor p, Jan Odgaar d-Jensen, Kari Håvelsr ud, Alex Barratt, Erin Mathie	A pragmatic randomise d trial of stretching before and after physical activity to prevent injury and soreness	British Journal of Sports Medici ne	To determine the effects of stretching before and after physical activity on risks of injury and soreness in a community population.	12 week trial of two separa te group s. Group I stretc hed seven muscl es using static stretc hing.	The effects of stretchi ng on muscle sorenes s were analyz ed using partici pant's weekly ratings of the severit y of muscle	The results showed that the overall injury rate for the stretchin g group was 339 while the injury rate for the non-stretchin g group was 348	Stretching does not reduce the risk of all lower-limb injuries combined, but might reduce the risk of injuries to muscles, ligaments, and tendons.

u, Amanda Burls, Andrew D Oxman (2010)				Group II were asked to not stretch at all	soreness.		
Rodney Peter Pope, Robert Dale Herbert, John Dennis Kirwan, Bruce James Graham (2000)	Effect of Static Stretching on Prevention of Injuries for Military Recruits	Military Medicine	Evaluate whether static stretching can prevent training-related injuries in Japan Ground Self-Defense Force military recruits.	Recruits in one group performed static stretching before and after physical activity and the recruits in another group spent 5-10 minutes on dynamic stretching	Chi-square analysis was performed on the injury data	Injury rate for the stretching group was 11.2% and injury rate for the non-stretching group was 14.1%	Static stretching may prevent low-energy injuries including muscle strains, low back pain, and minor tendonitis.
Reury Frank Periera Bacurau, Gizele Assis Monrei	Acute Effect of a Ballistic and a Static Stretching Exercise Bout on	Journal of Strength and Conditioning Research	The purpose of this study was to compare the acute effect of a ballistic	Three groups. Group I performed static	Flexibility test and Maximum strength test. Analyz	Flexibility improved significantly after ballistic	Static stretching may not be recommended before athletic events or

ro, Carlos Ugrinowitsch, Valmor Tricoli, Leonardo Ferreira Cabral, Marcelo Saldanha Aoki (2009)	Flexibility and Maximal Strength		and a static stretching protocol on lower-limb maximal strength	stretching while group II performed ballistic stretching and group III was a control group	ed with mixed models.	and static stretching. However static stretching ROM improved greater than ballistic. Leg press decreased after static.	physical activity that require high levels of force.
Trent Herda, Joel Cramer, Eric Ryan, Malachy McHugh, Jeffrey Stout (2008)	Acute Effects of Static versus Dynamic Stretching on Isometric Peak Torque, Electromyography, and Mechanomyography of the Biceps Femoris Muscle:	Journal of Strength and Conditioning Research	The purpose of this study was to examine the acute effects of static versus dynamic stretching on peak torque (PT) and electromyographic (EMG), and mechanomyographic (MMG) amplitude of the biceps femoris muscle	The participants performed Pre and post exercising stretches that consisted of static and dynamic stretching.	A three-way repeated measures ANOVA was used to analyze the data	The results showed the peak torque values decreased for static stretching and the EMG amplitude and the MMG amplitude showed no differences from pre to post stretching for dynamic	The decreases in strength of the static stretching may negativelt affect the performance of athletes in sports that require high levels of force production

			(BF) during isometric maximal voluntary contractions of the leg flexors at four different knee joint angles.			or static stretching. The results have shown that static stretching decreased peak torque of the hamstring muscles and dynamic stretching had no impact.	
Konrad, A., Stafillidis, S., Tilp, M. (2017)	Effects of acute static, ballistic, and PNF stretching exercise on the muscle and tendon tissue properties	Scandinavian Journal of Medicine & Science in Sports	The purpose of this study was to investigate the influence of a single static, ballistic, or proprioceptive neuromuscular facilitation (PNF) stretching exercise on the various muscle-tendon parameters of the lower leg	The subjects were split into 4 different groups: static, dynamic, PNF, and control	SPSS (version 20.0, SPSS Inc., Chicago, Illinois, USA) was used for all the statistical analyses.	The results of the study showed that static, dynamic, and PNF stretching all increased the participants dorsiflexion ROM	A single stretching exercise for four times for 30 seconds is an appropriate tool to increase the ROM and to decrease muscle stiffness

			and to detect possible differences in the effects between the methods				
Pablo Costa, Trent Herda, Ashley Herda, Joel Cramer (2014)	Effects of Dynamic Stretching on Strength, Muscle Imbalance, and Muscle Activation:	Medicine & Science in Sports & Exercise	This study aimed to examine the acute effects of dynamic stretching on concentric leg extensor and flexor peak torque, eccentric leg flexor peak torque, and the conventional and functional hamstring-quadriceps ratios	21 women volunteered to be tested on the effects of dynamic stretching. Their protocol consisted of four sets of different dynamic stretching exercises lasting 30 seconds each. Two exercises	The stretching was assessed in a random order using a calibrated Lido Multi-Joint II isokinetic dynamometer at random ordered velocities of 60° s-1 and 180° s-1.	The results for leg flexion peak torque decreased for the control at 60° as well as the stretching at 60°. When done at 180° there is also a decrease for the control as well as the stretching. The eccentric peak torque decreased only after stretching at 60° and at 180°.	The results suggest that strength and conditioning coaches, athletic trainers, and physical therapists may want to avoid using static or dynamic stretching before physical activity to prevent injury

				focused on the posterior muscles of the thigh and the last two focused on the anterior muscle of the thigh			
Alan Zakaria, Robert Kiningham, Ananda Sen (2015)	Effects of Static and Dynamic Stretching on Injury Prevention in High School Soccer Athletes: A Randomized Trial	Journal of Sport Rehabilitation	To determine if there is any benefit to static stretching after performing a dynamic warm-up in the prevention of injury in high school soccer athletes	465 student athletes in 12 different soccer teams. Two different stretching groups were created to perform stretches before	Descriptive statistics for injuries per team in each protocol were calculated. The average numbers of injuries across the entire season were compar	20 injuries for the teams that performed the dynamic and static stretching protocol and there were 17 injuries for the teams that performed the dynamic stretchin	Static stretching does not provide any added benefit to dynamic stretching in injury prevention

				all practices and games throughout the season. The first stretching group performed both dynamic and static stretches while the second stretching group only performed the same dynamic stretches as the static and dynamic stretching	ed between the groups receiving the two different stretching types.	g protocol	

				protocol			
Renato Barroso, Valmor Tricoli, Saulo dos Santos Gil, Carlos Ugrinowitsch, Hamilton Roschel (2012)	Maximal Strength, Number of Repetitions, and Total Volume Are Differently Affected by Static-, Ballistic-, and Proprioceptive Neuromuscular Facilitation Stretching:	Journal of Strength and Conditioning Research	To compare the acute effects of SS, BS, and PNF stretching on maximal strength, number of repetitions, and total volume performed during a multiple-set resistance training bout	12 men ranging from 16 years to 24 years of age were split intro four different groups, a static stretching group, dynamic group, PNF group, and a no stretching group.	Normality was assured by a Shapiro-Wilk test. ROM was analyzed using a 1-way analysis of variance (ANOVA)	The results showed that for the sit-and-reach, which tested ROM, the PNF significantly improved ROM when being compared to the static or dynamic groups	To avoid a decrease in both the number of repetitions and total volume, stretching exercises should not be performed before a resistance training session