Stretching Scientifically Part II: the Pros and Cons to Modern Methods

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Commentary Article

Stretching Scientifically Part II: Stretching methods, the pros and cons to each method

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ABSTRACT

Flexibility training in sport is recognized as a major fitness component for the improvement in performance and in the prevention of injury. There are 3 components to flexibility: passive, dynamic and active. Passive flexibility facilitates the development of the other two, however each method needs to be trained and developed separately. In gymnastics this should be periodized over the long term development of the athlete. In the early developmental stages of the athlete passive flexibility should be the dominant form of training. As the gymnast advances and the passive flexibility is developed, dynamic training should beginning to take focus. This is usually in line with the introduction of advanced leaps and jumps in WAG and the training of flairs and certain high bar skill in MAG. Once passive and dynamic flexibility has been developed, active flexibility can realistically be achieved, and should become the focused of the flexibility program. There are many stretching methods to develop each flexibility component, but the PNF CRAC method is the one most often cited as being the most effective method for developing ROM in a join. The advantage of the CRAC method is that it develops active flexility, passive flexibility, and strengthens the muscles and thus aiding with dynamic as well. The trade off is that the method cannot be applied to large groups especially at young ages. In this article the most common stretching methods used in sports training are discussed and analyzed against the physiological adaptations covered in part I of this series (published in Vol1 of Gym Coach, December 20007).

Key Words: passive flexibility, dynamic flexibility, active flexibility, conditioning, physical preparation

INTRODUCTION

What is the best way to develop flexibility? This is a question most coaches would like the answer too. Currently there are 5 popular stretching methods: static stretching, ballistic stretching, dynamic stretching, static-active stretching, proprioceptive neuromuscular facilitation (PNF). In recent years vibration training has also begun to gain recognition as an effective method for developing flexibility. Each method has its inherent advantages and disadvantages with training adaptations which develop different facets of a joint's flexibility. Majority of literature suggests that PNF is the best method.

Flexibility can be divided into three different components: passive, dynamic and active. These components are mutually beneficial to one another but can and need to be considerate separately in any flexibility training program. The knowledgeable coach should be able to recognize between these different forms of flexibility and thus know how to best develop each kind to best meet his or her athletes demands. Coaches need to also know which stretching method is best suited for the development of each type of flexibility.

In part I of the stretching scientifically series, published in Vol.1 of Gym Coach (December 2007), the long and short term physiological adaptations from flexibility training were discussed. Following on from that discussion this issue will examine the different stretching methods from a scientific and physiological approach, and try to highlight the pros and cons to each method, as well their practical application.

DISCUSSION and REVIEW


Figure 1 - *Example of passive flexibility.*

Flexibility can be divided into 3 components, passive (aka static flexibility) active flexibility and dynamic flexibility (31,36). *Passive flexibility* is the maximum range of motion a joint can achieve with the aid of an external force such as gravity or manual assistance, without consideration of speed of movement, or muscular effort (31,33). An example of passive flexibility is a gymnast in a split position on the floor (Figure 1). *Dynamic flexibility* is the maximum range of motion an athlete can move a joint through, using his/her own muscular effort with the aid of momentum (31,33). An example being the degree of split achieved in a straddle jumps by acrobats (Figure 2). *Active flexibility* is the maximal range of motion an athlete can move a joint through, using solely his/her own muscular effort (36). A good example is the leg control demonstrated by martial artists (Figure 3). These components are to some degree dependant of one another, but need to be trained separately and specifically to be improved to any considerable level. There are 5 conventional stretching methods to training these flexibility components, each with its own advantages and disadvantages: static stretching, ballistic stretching, dynamic stretching, static-active stretching, proprioceptive neuromuscular facilitation (PNF).

Figure 2 - *Austria's aerobics talent Lubi Gazov demonstrates a great deal of dynamic flexibility in a straddle jump.* Source: GYMmedia.com

Figure 3 - *An impressive dyslplay of active flexibility by a martial artist during a kata.* Play Video

Passive Flexibility

Static Stretching

Static stretching is probably the most popular method of stretching to develop ones passive flexibility (31). The benefits to static stretching are that it is easy to administer, its effective, relatively safe to be done by anyone, time efficient, and there are is a variety of stretches in progressive intensity. Static stretching is highly correlated with increasing passive flexibility, but it is not very effective in improving dynamics or active flexibility to any great deal. The author's belief is that static stretching is highly overdone in gymnastics practice, and usually with the wrong intentions in mind. The author acknowledges that static stretching has a very important role in the early developmental preparation of the young gymnast (first 2-4 years of training), however more advanced athletes need should be concentrating on maintaining or improving passive flexibility secondary to dynamic and active.

The necessary passive flexibility for a gymnast should be developed between the ages of 5-8. At this age kids are in their prime age bracket to improve for passive flexibility. At this age their natural elasticity and stretch-ability of the collage is at its peak (collage is the main building block of connective tissues in the body. It is the main molecular structure affected by stretching of these connective tissues (32)). Even though after 8yrs of age passive flexibility can still be effectively trained and improved, there are diminishing return with age, and training status (32). This means that the older you get and the longer you have been doing static stretching for the harder it is to achieve improvements. This is because the collagen crosslink's increase with age and elasticity is lost.

A common sight in the gym is to see coaches frustrated with their older gymnasts or not so flexible ones, and turning to pushing down on them in order to somehow get faster results. This 'push' method was commonly used by the Russians and Chinese in 80's and it has since spread in popularity, with it being still widely used in western and Chinese gyms today. However the Russians at least have realized that actually it doesn't work that well with older gymnasts at least, as it can easily result in injuries (32). All that is actually happening is that they are hurting the gymnast with minimal added benefit, because the tissue is just increasing in stiffness in order to prevent a potential injury, which is the natural reaction of all biological tissue. The faster and the more you load it, the stiffer it becomes (32).

One universal recommendation by all flexibility trainers and researcher authors is that passive stretches be should performed at or just below the subject's pain threshold (14,32). However, from personal observations of coaches who use the 'push' method, most tend to ignore the gymnast's pain threshold, and usually go overboard, usually ending up with the gymnast in tears, and sometimes injury.

Unfortunately there is no good way of determining from day to day where the gymnast is on their pain threshold scale (30) (the results eventually do tell). The 'push' method does help to ensure the gymnast is at the necessary point of stretch intensity. There are no set guideline recommendations about the use of the 'push' method aside from common sense, so the following have guidelines are advised.

1. The coach MUST listen to the gymnast. Stop means stop.
2. The coach should apply pressure slowly and at a constant rate. No faster than 5 deg/s (this is quite slow)

3. The coach should push the gymnasts to the point of 'just tolerateable stretching pain'. This will most likely be beyond what the gymnast does normally themselves.
4. Use the push method to teach the gymnast where they should be holding their stretches too. Cycle though periods where you push the gymnasts for a couple of weeks then allow them to take the initiative. Periodized the use of this technique.

The downfall to this method is that the coach can only be assisting one kid at a time per stretch.

So what is the best way to develop passive flexibility, how should it be trained? Several studies have tried to determine the appropriate parameters for static stretching; however due to all the inconsistencies between studies, true comparison is impossible (2). Depending on the study and author, the recommended lengths of time to hold a stretch ranges between 5-60 sec (2,32). From discussion in part I of this series it was highlighted that the most efficient duration of stretch hold to benefit ratio is in the first 20-30 sec (32,12,17,18,19). Stretching frequency recommendations range between 1-3 times a day, up to 5 times a week (2). According to Brandy et al. there is no added benefit to stretching more then once a day, (18), but others suggest more is better (32). Its also important to consider that most research is done on the average recreational male and female athlete, and thus even though 1 time a day 5 days a week is considered adequate for that population group, elite athletes are know to train flexibility 2-3 times a day for 6 to 7 days a week (36).

Some have suggested that intensity and duration of stretching is more important then volume, but there is limited data to support this claim. One thing that is for sure is that the effectiveness of any flexibility program depends on its length, consistency, and progressive overload (31). Dr. Bill Sands, who is the Director of Research and Development for USA Gymnastics, and who is one of the few gymnastics researches in the world recommends holding stretches for 30sec, and repeating each stretch 3 times with 20sec rests in-between (32).

It is now widely accepted that flexibility training should be done at the end of the training (7), with as much time between conditioning and flexibility training. It is important to separate conditioning training and flexibility training as much as possible, in order to give the muscles an *unambiguous* stimulus for adaptation (32). If the gymnast does 2 training sessions a day, it is good to have one session which focuses on flexibility and the other on conditioning. If the sessions are long enough to separate conditioning and flexibility by 2hrs at least then you can safely and effectively do flexibility training twice day, but with periodization in mind (in order to prevent plateau/overtraining). If you have one training session leave the bulk of static stretching (aka passive flexibility training) for end to be done at warm-down (32,36).

Vibration stretching

Vibration training is a flexibility training aid that is relatively unknown to most, but the Russians and Chinese have known and used it since the 80's (39). Vibration training to enhance flexibility was first used by Dr. Vladimir Nazarov on Russian gymnasts as a method to improve their ankle flexibility. Dr. Nasarov's results showed that stretching while the muscle is vibrated produced greater results then stretching alone (15). Unfortunately since then there have been only a few other studies examining the benefits of vibration training on flexibility development (14,15), the predominant form of research on the technology and methods has been in whole body training, and rehabilitation particularly with its relevance to with resistance training. It has not popular practice.

There are several proposed mechanisms to explain the benefits of vibration training on flexibility:
1- Increases pain threshold (14,15)
2- Increased muscle temperature by stimulating blood-flow (14)
3- Induced relaxation of stretched muscle (autogenic inhibition) (14,15)

Unfortunately the benefits of vibration training to flexibility, rehabilitation, and recovery have been largely untouched (14). Probably the most recent and interesting study done on vibration training to enhance flexibility is by Sands et al (2005). The purpose of his study was "to examine the acute and long-term (4 weeks) influence of vibratory stimulation on forward split flexibility in young highly trained male gymnasts" (14). In the study gymnast performed front splits by placing their front leg and then their back leg on top of a vibrating device for 10s followed by 5sec rest 4 times (Figure 4), resulting in 1min of total stretching in each position. The vibrating device is

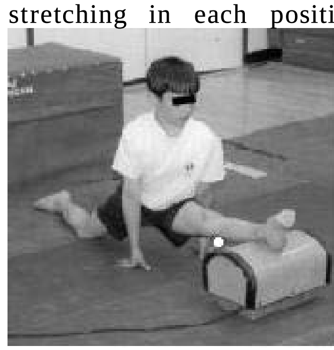

Figure 4 - *Forward split stretching positions on the vibration device used by Sands et al (2005).*

described to have a sinusoidal vibrating frequency of 30Hz and an approximate displacement of 2mm. A vibrating frequency of 30Hz is said to be part of a range of frequencies that cause inhibitory effects on monosynaptic reflex (the stretch reflex) (14). The acute effects of the vibration training are described as "immediate and startling" resulting in immediate increases in range of motion; however the long term study showed that only 1 leg reached statistical significance and the other didn't (14). Even though the research results were relatively inconclusive, they did show that though vibration training (or it may have been just due to variety in method) even elite athletes who have apparently reach their genetic peak in passive flexibility can still achieve improvements. Interestingly enough following the study the US Olympic Training Center adopted the technology for the training of its international team gymnasts (14).

It is common assumption that passive flexibility is essential to developing active flexibility, but this is a fairly debatable topic. The two type of flexibility are definitely complimentary, but also impendent of each other. A joint's maximal passive range of motion, only demonstrates its potential, but it does not mean the muscles are strong enough to take the joint trough this range of motion actively. We often see evidence of this with gymnasts who have achieved 180deg+ splits, and yet, struggle to hit 180deg split in jumps and or leaps, or do a full turn with their leg held at 90 or above. On the other hand (from personal observation) there are martial artists who can elevate and hold their leg in front above 90deg, but cannot do a front split. Even though technique can be a limiting factor, it is usually just the secondary reason for the lack active and dynamic flexibility/strength. There is a large lack of research comparing active and passive flexibility, and training protocols, however the relationship between active and passive flexibility demonstrates the relationship between flexibility and strength, which coaches should try to understand.

Passive flexibly could play a crucial role in injury prevention, particularly in younger gymnast during fast and dynamic movements (7). This may seem like common knowledge but scientifically speaking passive flexibility as injury preventative mechanism is controversial at best (6). It is however safe to say that its better be safe (in this case passively flexible) then sorry.

Dynamic Flexibility

As the gymnast becomes more experienced and achieves the necessary level of passive flexibility (determined by skill/routine requirements, and coach assessment), focus should shift on developing the gymnast dynamic flexibility, as at this stage the gymnast should be sufficiently conditioned, and mentally ready for the more demanding training. Research shows that dynamic flexibility (which also includes active is much more critical to sports performance compared to static flexibility (36,10, 31, 12). This is not to say that passive flexibility is not important, it just means that dynamic flexibility is more critical to skill performance compared to passive flexibility. We often see examples of this in gymnasts with great passive flexibility, and yet inadequate performance in skills that require dynamic flexibility like leaps, flairs, scissors etc.

The 2 common stretching protocols for dynamic flexibility training are often confused or used synonymously: Ballistic stretching and dynamic stretching. However it is important to distinguish between the two as they have distinct roles in the development of flexibility.

Ballistic Stretching

Ballistic stretching uses the momentum of a moving body or a limb in an attempt to force it beyond its normal range of motion, which usually involves rhythmic bobbing, bouncing, rebounding types of movements (35,36). Dynamic stretching involves the rhythmic and controlled movements of joints in progressively increasing ranges of motion and velocity of movement (35). In gymnastics both methods play specific roles and should be done/trained appropriately

Ballistic stretching was originally condemned by the physical therapist community as a dangerous and ineffective method to improving ROM, because it is believed that out of all the stretching methods to be most likely to lead to injury and soreness (32,36). The use of ballistic stretching is still a very controversial, with several reported disadvantages:

- It creates somewhat uncontrolled forces within the muscle that can exceed the muscles extensibility (31)
- It facilitates the stretch reflex which causes the muscle to reflexively contract, this could lead to damage to the muscle fiber and or connective tissue, as well as muscle soreness (6)
- It fails to provide adequate time for tissues to adapt to the stretch, which increases muscular tension, making it more difficult to stretch the connective tissue (31,32,36).

It is now known that ballistic stretching does improve flexibility, contrary to popular knowledge, with similar results to passive stretching, as well as being an essential training component for many sports (6,31,36). However because of the disadvantages already outlined, it is usually not the technique of choice for most athletes, in particular with young athletes. In gymnastics skills ballistic stretching has ironically an important role in injury prevention. During the execution of many high level skills (eg, stalders, endos, re-catching of release skills, ring swings etc) the gymnast adopts or falls into certain body positions that require maximal ROM in certain joints. Because of the high forces generated during many of these skills, especially during the learning process, and in the occasional poor execution, the joints can be jerked, or bounced beyond their already available or trained ROM at very high velocities. If this happens and joints, connective tissues, and or muscle fibers are not conditioned appropriately, injuries are likely to result (36).

It would be advantageous that gymnasts training at such a high level undergo progressive velocity ballistic flexibility training programs specific to the skill/s that expose the athlete to such possibilities. Over time, the gymnast can go through a series of stretch/es were the velocities and ranges of motion are combined and controlled on a progressive basis (36). The gradual program will permit the gymnast's muscles and musculotendinous junctions to adapt to these potentially ballistic movements, hence reducing the risk of injury (36). Zachazewski (1990, p.228) recommends the basis for such a program to be: "After static stretching, slow short end range (SSER) ballistic stretching is initiated. The athlete then progresses to slow full range stretching (SFR), fast short end range (FSER) and fast full range (FFR) stretching. Control and range are the responsibility of the athlete." There should be no interference by the coach. It could be beneficial to do such stretching prior to training or performing particular skills.

Unfortunately there is no research to the author's knowledge that examines any particular recommendation with regard to frequency, or duration of ballistic stretches. In most studies ballistic stretching is usually compared with static stretching, involving similar protocols. Based on this, It is recommend to adopt the same durations, and frequencies for ballistic stretching as you would for passive stretching, with each stretch lasting about 30sec with 10-15 bounces per set (depending on the velocity of movements, and experience of athlete), for 3-4 sets (36). Bouncing movements should be rhythmical, with velocities progressing in the manner described by Zachazewski.

Dynamic Stretching

Dynamic stretching techniques are very effective with several benefits:

- Highly correlated with improved sports performance (36,10, 31, 12)
- Effective in reducing stiffness (12,13,6)
- Effective at improving joint flexibility (36,31,32,35,12,6)
- Skill specific

Dynamic stretching is velocity specific (36,31,32). Generally in gymnastics, movements are fast and powerful and thus dynamic stretching movements should mimic the velocities of dynamic skills as closely as possible (36). Unfortunately to my knowledge there are no specific/scientific based recommendations for frequency, or duration for dynamic stretches. Alter (1998), recommends 8-12 repetitions for 2-3 sets for most athletes, but mentions that other authors recommend ranges of 40 repetitions with full amplitude for experts. Alter also cites that some experts recommend three for six sets of 10-15 repetitions per set. An essential point that is made by Alter is that fatigue and the consequent reduction in amplitude that includes range of motion and velocity of movement, is a sign to stop. This is a good guideline to follow with any exercise done for power training. If the athlete experiences their muscles quivering, persistent pain, or decrease in range of motion, then they have over stretched (36), and it's important to educate the athlete of how to know their limits. This is particularly important when doing weighted dynamic stretches.

Another benefit shared by all dynamic flexibility stretching methods, is that it can reduces muscle stiffness and thus tensile stress (12,13). This is particularly important for muscle/tendon compliance, which is important for injury prevention. In one particular study comparing continuous passive motion (such as for example bouncing up and down in a calf stretch position) and passive hold stretches in the ankle, it was shown that stiffness was significantly decreased with continuous passive motion but not with passive holds (12). They showed that following continuous passive motion there was an overall decrease in tension of 10.54% over 60sec, with the largest changes observed in the first 2 repetitions (approximately 15sec) (12). These findings are similar to other studies. Because stiffness is 59% greater in the last 10% of ROM (12), there are serious benefits in reducing stiffness in those end ranges of motion for injury prevention (7). This also supports the use of ballistic stretching in gymnastics.

ACTIVE FLEXIBILITY

Active flexibility is considered by the author as the ultimate measure of a joints range of motion. Not coincidentally, active flexibility like dynamic flexibility is highly correlated with sporting performance, and thus it's essential for gymnasts to not only develop their passive and dynamic flexibility but their active as well. Active flexibility is however the hardest form of flexibility to develop because it is dependent to some degree on passive ROM and muscle strength to be able to hold and maintain each position. Active flexibility can be developed with resisted dynamic stretching, static-active stretching, and Proprioceptive neuromuscular facilitation (PNF)

Static-Active Stretching

Static-active stretching involves the stretching of an antagonist muscle group/s by moving a joint though an active ROM using the strength of the agonist (prime mover) muscle group/s. This works on the basis of reciprocal innervation/inhibition, which means that when one muscle group is contracting the other is inhibited allowing it to lengthen (31). An example of static-active stretching is a traditional front leg hold. While the agonist (in this case the quadriceps and hip flexors) is contracting to elevate the leg, the antagonist muscle groups (hamstrings and hip extensors) are being stretched (36).
However, if you have ever done this stretch, or have your gymnasts doing it, you will know that no one ever complains of how painful the actual 'stretch' to the hamstrings is, but rather the cramping in the quads. This is explained by the fact that most gymnasts have passive flexibility far superior to their active flexibility. They simply lack the strength to move the joint to a position where the hamstring is stretched to a point beyond or testing of the passive ROM available. This difference

between passive and active flexibility is the known as the 'active-passive inadequacy gap'. This is where in dance training and martial artists training can be is superior to gymnastics training.

The true benefit to static-active stretching is that it strengthens the agonist muscle group/s while also potentially working the passive flexibility of the antagonist (10). When the agonist contracts it performs an isometric contraction. An isometric contraction is when the muscle is contracting while remaining at a constant length (31). Unfortunately this type of contraction has a downfall, and that is that strength gains are relatively specific to with only about 20% overflow to the joint angle at which training is performed (31). This means is that if you hold your leg at 90deg, the muscle is training to be strongest at 90deg, with diminishing benefits above and below 90deg by 20%. At other angles the strength curve drops of dramatically because of a lack of motor activity at that angle (31). This makes it quite hard to overload the muscles, and thus its quite a hard and slow process to develop active flexibility. The key is to progressively work up the strength, working at various angles.

Like most other flexibility components, active flexibility has received relatively little scientific attention, and there is only a limited amount of specific recommendations for developing active flexibility. The expert recommendations are:

1- Adding resistance to dynamic movements can strengthen the agonist muscles and thus improve active range of motion (5), especially working with the negative control (the lowering down slowly)

2- Holding an active stretch for 15sec results in greater improvements in active ROM compared to 5sec (10). Thus it can and should be progressively trained.

3- Active stretches should be held for 10-30 seconds for 1-2 sets per muscle group (29).

When static-active stretching is used to strengthen the active range of motion, it should be treated as a strengthening exercise and thus strength training protocols should be used for greatest effects. This means that rather then doing endless kicks, add resistance to the movements so that only 3-4 reps can be performed at full range of motion, and ideally at full or near skill specific velocities. However from an endurance point of view, and a progressive development, you can start with greater volume (more reps) and lower intensity. I have heard of martial artists do 100+ kicks per style of kick (at relatively constant speeds and power) each session, not including the actual skill practice, just as general conditioning. At this point the coach should be asking him/her self how many kicks, active shoulder extensions, or shape changes do your gymnasts do per session?

Proprioceptive neuromuscular facilitation (PNF)

Probably the most researched stretching method (probably even more so than static stretching) is proprioceptive neuromuscular facilitation (PNF). There are 3 common protocols of administering PNF stretching (protocols adopted from www.sport-fitness-advisor.com). These protocols can be done for any muscle group. 1 repetition is all that is recommended, but for an advanced athlete with sufficient strength and flexibility and maturity, more repetitions are acceptable.

Hold-Relax

1. A partner moves the athlete's joint to a point of mild discomfort in the stretch. This passive stretch is held for 10 seconds.
2. On instruction, the athlete isometrically contracts the muscle being stretched by pushing their limb against their partner. The partner should apply just enough force so that the limb remains static. This is the 'hold' phase and lasts for 6 seconds.
3. The athlete is then instructed to 'relax' and the partner completes a second passive stretch held for 30 seconds. The athlete's limb should move further than before (a bigger stretch) due to autogenic inhibition activated in the hamstrings.
4. Repeat from this new position Steps 1-3, and continue until no more apparent ROM gains. This constitutes 1 whole repetition.

Contract-relax (CR)

1. A partner moves the athlete's limb to a point of mild discomfort. This passive stretch is held for 10 seconds.
2. On instruction, the athlete concentrically contracts the muscle being stretched. The partner should apply enough force so that there is resistance while allowing the athlete to move their limb through maximal ROM to the anatomical position (i.e. through the full range of motion). This is the 'contract' phase.
3. The athlete is then instructed to 'relax' and the partner move the limb back to complete a second passive stretch held for 30 seconds. The athlete's limb should move further than before (greater stretch) due to autogenic inhibition
4. Repeat from this new position Steps 1-3, and continue until no more apparent flexibility gains. This constitutes 1 whole repetition.

Hold-Relax Agonist Contract (aka CRAC)

1. A partner moves the athlete's limb to a point of mild discomfort. This passive stretch is held for 10 seconds.
2. On instruction, the athlete isometricaly contracts the stretched muscle by pushing their limb against their partner. The partner should apply just enough force so that the limb remains static. This is the 'hold' phase and lasts for 6 seconds. This initiates autogenic inhibition.
3. The partner completes a second passive stretch held for 30 seconds; however the athlete is instructed to pull the limb in the same direction as it is being pushed. This

initiates reciprocal inhibition allowing the final stretch to be greater.
4. Repeat from this new position Steps 1-3, and continue until no more apparent flexibility gains. This constitutes 1 whole repetition.

PNF stretching methods use autogenic and reciprocal inhibition to relax the muscle before stretching the target muscle group, enhancing the effectiveness of the passive stretch (1,2). PNF has a few advantages:
1. Research has consistently reported that the CRAC method is the most effective method of developing passive flexibility, and its superior to other forms of PNF stretching (1,36,33,30,7).
2. PNF techniques (especially CRAC) also develops active flexibility (1)
3. Can develop strength in agonist muscle, making it an effective rehabilitative tool (3)
4. It can be done for every muscle group, making it very versatile form of stretching.

Unfortunately there are also several disadvantages:
1. It is recommended that PNF techniques be done only by experienced and qualified coaches, therapists, strength and conditioning trainers etc. Unfortunately this disqualifies most coaches who have no formal training (36).
2. It can be very time consuming (30,36)
3. Many of the stretches require a partner (36)
4. Its been shown to develop passive muscle stiffness, possibly due to the higher mechanical stress (This is a disadvantage if the sole purpose of stretching is to develop passive flexibility) (3)
5. Not recommended for pre-adolescents (38) (this is because it could cause/aggravate some child Osteo-chondritis dissecans conditions such as Severs disease, Osgood-Schlatter, Patellar tendonitis (jumpers knee) etc. However this is a safety guideline, and an experienced, knowledgeable coach should know when and when not to administer PNF.

PNF stretching has been highly researched and there are several recommendations to the application of PNF stretches, in order to maximize its effects.
1- ROM improvements seem to be independent of contraction/isometric intensities, with 20% of subject's maximal voluntary contraction having been show to be very effective, this is contrary to common belief that the harder you push against your partner the better (1). This is important as it means that properly instructed gymnasts could administer PNF to each other, without risking injury. Some evidence suggests that it's more effective to progressively increase the contraction intensities compared with consistent intensity, so that could be something that can be varied through the year (1).
2- PNF should be done between 2-3 times a week with 1 repetition per stretch (1), and not on consecutive days. 1 repetition is all that is recommended for most, but for an advanced well conditioned athlete who no longer sees benefits from regular stretching methods more repetitions are acceptable to educe overload.
3- Static holds and contractions should range between 3sec and 15sec (1). In one study comparing isometric concentric length between 0, 3, and 6sec supported the hypothesis superiority of longer isometric contractions (36). The typical 6sec recommendation of isometric holds is due to the allow time for autogenic inhibition to take place. Logic would suggest that it could be more efficient to apply specific passive flexibility recommendation, and hold the static stretch for up to 30sec, but there is no data on this.

Resisted Dynamic Stretching
Finally the last method to develop active flexibility is through resisted dynamic stretching. This is probably the most common method used by gymnastics coaches.

It usually involves the addition of ankle weights or therabands attached to the limbs to provide resistance and overload. Simply said the method does work, but what works best? Well yet again the available literature is inadequate in this field. The two methods have never been directly compared. To the authors knowledge there is only one study that has explored the used of therabands to improve already highly trained gymnasts' split leap leg positions over a 4 week period (41). The study found an improved range of motion in both strong side and weak side split leaps. The amount of improvement was similar regardless of side. The average difference pre and post study was approximately 6 degrees. Even though 6 degrees might not seem like much, as illustrated in figure 5, 5 degrees makes a considerable visual difference. The theraband used in the study was black (color is indicative of the resistance with black being near highest resistance) which can be bought from any medical supply store. Aside from this study there is little research into this method of training. One recommendation based on this study is to progressively increase the intensity in order to prevent injury (41).

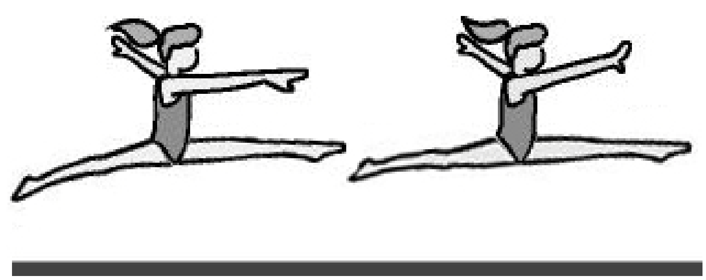

Figure 5 – *Illustration of a split leap at 165 degrees on the left and 170 degrees on the right. The visual and aesthetic difference is quite significant even at 5deg of difference. Source: Enhancing Flexibility in Gymnastics*

CONCLUSIONS

Majority of coaches would agree that flexibility training should be a key component to any successful gymnastics program particularly in the early developmental stages. However how much do we really know about training flexibility? The science behind flexibility is still relatively uncharted and there many unanswered questions, but there is plenty to think about. There three major flexibility training outcomes desired for gymnastics. At an early developmental level passive flexibility is the focus, developed using static stretching techniques including vibration, PNF, and static-active training. As the athlete progressed in training experience and passive flexibility dynamic flexibility should begin to take focus. This is best achieved using ballistic stretches for skill specific training and dynamic stretches. Lack of research leaves the ideal volume, intensity, duration, and frequency of these methods to be determined. The recommended protocols are based on recommendation similar to passive stretching. This has shown to be effective in studies. The final goal of flexibility training is to have the absolute control of the ROM available at the joint, which is best achieved through active flexibility training. The probably best method to develop active flexibility is through static-active stretching, but this form of stretching is usually not suitable for gymnasts who have a large passive-active gap. PNF and resisted dynamic stretching are also alternative methods that can be used, and most often used by gymnasts to develop their active flexibility.

Scientific literature proposes that the PNF CRAC method is the most effective stretching technique; however its disadvantages make it hard to apply regularly and to large groups. For gymnastic training its important to periodize it and understand that each kind of flexibility requires its own training focus.

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