

STRETCHING TO AVOID INJURY

A SPECIAL REPORT FROM



**PEAK
PERFORMANCE**

The research newsletter on
stamina, strength and fitness

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From the editor

No matter what type of sport you play or at what level, you always remind yourself, or are reminded by others, to stretch beforehand. Yet how often are these warm-ups productive, both for performance and injury avoidance? I myself have blamed injuries on under-stretching and poor performance on over-stretching. Having read these articles though, it appears I didn't know the half of my problems!

Whether it's choosing between static or dynamic stretching, getting your head round PNF or knowing which time of day is best to do which type of stretches, there are plenty of right and wrong ways to go about it.

This mini-report opens with a beginner's guide to stretching and warming up. The middle two chapters are interesting articles based on recent research. The first takes a look at periodisation, a popular training concept, and how it can be applied to stretching routines. The second looks at pre-exercise stretching, and how old techniques can do more harm than good. Finally there is a practical guide to dynamic stretching with fifteen exercises to keep you warm!

A handwritten signature in black ink, appearing to read 'SB', with a long, sweeping horizontal line extending to the right.

Sam Bordiss

Editor

A beginner's guide

Introduction: What's the point?

Sports practitioners, trainers, coaches and therapists have for decades routinely prescribed stretching in pursuit of various fitness goals for recreational and elite athletes alike. But what are the evidence-based benefits of stretching? Do we advise and practise it out of habit, outdated beliefs or current best practice? This overview of the research on stretching should help therapists to update their understanding of what works and why – as well as what doesn't.

The basics

There are three commonly used stretch techniques:

- **Static:** sustained pressure is applied to a muscle or muscle group in a lengthened position;
- **Dynamic or ballistic:** repeated bouncing movements are made at the end of range of the muscle length, stimulating the stretch reflex;
- **PNF (proprioceptive neuromuscular facilitation):** combines a series of isometric muscle contractions and static stretches performed according to several specific protocols.

Stretching is normally done to achieve one or more of five aims:

1. To increase muscle length
2. To reduce the risk of injury
3. To enhance prospects of healing for injured tissues
4. To enhance performance
5. To reduce pain associated with muscle and joint stiffness.

The many permutations of goals and techniques for stretching make it hard to draw overall conclusions from the research

about what works in which circumstances. Below we draw out some of the main themes and conclusions – but it is clear that more research is needed in many areas (the role of stretch in hamstring flexibility/rehab, for instance, is relatively well covered, whereas other muscle groups and other objectives are far less well researched).

Stretching for flexibility

i. Static stretching works

The research seems pretty clear in its support for the efficacy of the single most common use of stretch: static stretching to achieve an increase in range of movement^{†(7,8)}.

Increases in muscle length are thought to be achieved through two mechanisms⁽²⁶⁾:

- a. Increased muscle-tendon viscoelasticity results in a direct decrease in muscle stiffness (less force is needed to produce a change in muscle length).
- b. Inhibition (overcoming) of the stretch reflex reduces the active resistance of the muscle to the force applied.

So in principle stretching is effective in increasing muscle flexibility. What is the appropriate exercise prescription? This depends on whether you are seeking short-term or long-term flexibility gains.

Short-term gains are what we all expect when we undertake conventional ‘preparatory’ stretching prior to activity, with the hope of enhancing performance or decreasing the risk of injury. Long-term changes might be the goal during the management of a chronic injury, rehabilitation from an acute injury or to achieve a change in range of movement which will facilitate an improved sporting technique that was previously inhibited by muscle inflexibility.

Magnusson⁽¹⁹⁾ demonstrated in his 1998 study of passive properties of human skeletal muscle during stretch manoeuvres that long-term increases in joint range of motion resulted from a change in stretch tolerance rather than increased viscoelasticity. To complicate the picture further, different muscles have been

How stretching works

Muscles (and their tendinous attachments) have properties of elasticity (resilience), plasticity (pliability) and viscosity (internal friction). Strength training over time generally bulks up and shortens the muscle; stretching lengthens it. The 'stiffness' of a muscle-tendon complex describes how readily it stretches when a given force is applied: a stiff muscle moves less far than a compliant one, which means it is less flexible, but on the other hand has greater potential elastic recoil and therefore stored power. The speed of movement also matters: the slower the loading, the more pliable and less resistant the quality of movement.

The muscle's spindle cells govern the nervous system response to maintain contractile properties, most notably the 'stretch reflex' – the automatic contraction of a muscle which has relaxed and lengthened to the edge of its safe range of movement. Stretching for flexibility uses various slow, static and end-of-range movement techniques to overcome the stretch reflex and encourage a gradual lengthening of the muscle and tendon fibres and/or greater nervous system tolerance of the stretch at the end of range.

shown to adapt differently to stretching and some muscle stretches may need to be held for longer than others.

In a 2004 literature review, Shrier and Gossal⁽²⁵⁾ suggested the following for static stretch flexibility protocols.

- Static stretches should be held for 15 to 30 seconds.
- For short-term changes there is no benefit in holding a stretch for longer than 15 seconds⁽¹⁸⁾.
- There is no added benefit in repeating a stretch more than 4 to 5 times on one particular muscle^(3,10).

In a highly practical 1994 study, Bandy and Irion⁽²⁾ looked at long-term flexibility changes. They found that muscles stretched for 30 seconds a day continued to yield gains in their range of movement for up to six weeks before the ROM reached a plateau. If the daily stretches were held for 15 seconds, it took 10 weeks to achieve the same degree of flexibility change.

Stretching for greater ROM is more effective after a jogging warm-up^(21,29) – and it is reasonable to suggest this would be true of other modalities of warm-up, too. Stretching is also more

effective when heat or ice is applied⁽¹³⁾, with heat having much the same effect as a warm-up and ice having an inhibitory effect or decreasing pain so as to enable greater stretch tolerance.

Putting all these findings together, then, we can say that long-term isometric stretching programmes should produce changes in less than six weeks if stretches are done daily after a five-minute warm-up, held for 30 seconds and performed four to five times.

ii. PNF is even better

Research comparing the effectiveness of PNF stretching versus static stretching produces varied results. However, there seems to be consensus on the superior effectiveness of PNF stretching for increased flexibility, particularly with hamstring muscles.

Sady *et al* (1982) compared flexibility training using ballistic, static and PNF on shoulder, trunk and hamstring muscles and found PNF the most effective⁽²⁴⁾. Etnyre and Abraham (1986) studied PNF versus static stretching on one-joint muscles using the plantarflexors of the ankle and reached the same conclusion⁽⁹⁾. They also studied the two most common forms of PNF – contract-relax (CR) and contract-relax-antagonist-contract (CRAC) – and found the latter to be more effective. As submaximal contractions during PNF are just as effective as maximal⁽¹¹⁾, it is advisable to use these, because of the lower risk involved. PNF stretching is equally effective whether contractions are held for three, six or ten seconds⁽⁴⁾.

Stretching to reduce injury risk

The research evidence here is contradictory. It is also even harder to make valid comparisons between studies on this topic, as it splits between acute and chronic injury, as well as between the efficacy of stretching as part of an activity regime versus stretching regimes performed separately from any other workout.

Stretch linked to activity

Two literature reviews shed some light on stretching in the

context of activity, both pre-exercise and afterwards. In their 2004 review, Thacker *et al*⁽²⁷⁾, reported: ‘There is not sufficient evidence to endorse or discontinue routine stretching before or after exercise to prevent injury among competitive or recreational athletes’ and called for more well-conducted randomised controlled trials. In 2002 Herbert and Gabriel⁽¹⁴⁾ examined the hypothesis that ‘stretching before exercise does not seem to confer a practically useful reduction in the risk of injury’ but also found little evidence to support that contention.

A study of military recruits between 1996 and 1998 who practised a series of 18 static stretches before and after training, compared to a control group who performed no stretches, demonstrated a significantly lower rate of muscle-related injuries, but no difference in the rate of bone or joint injuries⁽¹⁾. The way this study differentiates between different types of injury makes it exceptional among the research. There is certainly scope here for further inquiry.

Stretch in isolation

In the context of overall stretching programmes, a 2004 survey of flexibility training protocols and hamstring strains in professional football clubs in England conducted by Dadebo *et al*⁽⁷⁾ found that ‘hamstring stretching was the most important training factor associated with HSR [hamstring strain rate]’. The most common technique used was static stretching and the authors concluded that HSR went down in inverse relation to the amount of stretching incorporated into training.

But the results of another hamstring flexibility study apparently show the opposite effect. ‘Does the toe-touch test predict hamstring injury in Australian Rules footballers?’ investigated in 1999 how far flexibility was a factor in hamstring strains. The authors⁽³⁾ concluded that it wasn’t.

Turl and George (1998) reported something similar⁽²⁸⁾. They assessed rugby players with a history of repeated grade I hamstring strains versus a control group and found no variation in hamstring flexibility between the two groups. They also, however, found adverse neural tension in 57% of the

hamstring injury group, against 0% for the controls. It is common to find a confused understanding of the difference between hamstring flexibility and adverse neural tension (restricted movement of a nerve as it passes along its tract) when stretching for increased flexibility is prescribed as part of a hamstring injury rehab programme.

We can summarise the knowledge on stretching to reduce injury risk thus:

- It is proven that static stretches have a short-term beneficial effect on muscle stiffness and that muscle tone and flexibility can affect the movement of a joint.
- An overall static stretching regime can help prevent muscle-related injuries, but not necessarily because it promotes increased muscle flexibility.
- It is not necessary to perform static stretching before or after exercise to prevent injury.

From these conclusions, it is reasonable to extrapolate that a chronic joint injury may benefit from injury-specific static stretches prior to activity; for example, stretching the shoulder's external rotators before swimming or a throwing activity. On the flip side, there are chronic injuries where excessive flexibility is an underlying cause of pain and in these cases stretching will often be detrimental. The role of stretching in chronic injury management is certainly an area needing more research.

Stretching for injury rehab

The aim of stretching during rehabilitation is to aid extensibility of the healing site and return normal muscle length as early as possible. Malliaropoulos *et al* (2004) assessed the role of stretching during rehabilitation from grade II hamstring strains and concluded that the group 'which carried out a more intensive stretching programme, was found to have a statistically significant shorter time of regaining normal ROM and rehabilitation period'⁽²⁰⁾.

The importance of a controlled progression of stretching during rehabilitation from muscle strain is widely accepted and

backed by the research. What is less clear is whether we should stretch injured muscle tissue in the same way as non-injured tissue. We also need more investigation into what role, if any, there is for ballistic stretching during rehabilitation.

Stretching for performance gains

To maximise power, don't stretch

Plenty of research data is available on this question. Most of it relates to the effect of preparatory static stretching on the performance of activities involving the stretch reflex or maximal voluntary contraction (MVC) – in other words, sports demanding explosive power such as sprint, high jump or basketball.

While the evidence varies, the balance of data finds that static stretching has a negative effect on the subsequent performance of activities involving the stretch reflex. Power *et al*⁽²³⁾ found that a preparatory bout of static stretching decreased the isometric force output of the quadriceps muscles for the next two hours. This would certainly suggest that for optimum performance in explosive sports, pre-activity stretch is not a good idea.

In a separate 2005 study, Cramer *et al*⁽⁶⁾ also demonstrated a decrease in force production and muscle activation in the rectus femoris and vastus lateralis muscles after static stretching.

But even here, the issue is not clear-cut, because Power *et al*'s study also recorded no similar adverse effect on the plantarflexors or on overall jump height.

To put this decrease in force output into functional terms, we can refer to a 2004 study that assessed the effect of different static and dynamic stretch protocols on the 20m sprint performance of rugby union players⁽¹²⁾.

The static stretching warm-ups resulted in a decrease in performance; whereas dynamic warm-ups improved performance. A dynamic stretch programme features *eg* swinging movements of the arms and legs that take activity-specific muscles through a range of movement, imparting a stretch at the end of range which is not held (also known as 'elastic stretching').

The authors speculate that the static stretching increases compliance within the muscle-tendon unit, which in turn

reduces the unit's capacity to store elastic energy. The beneficial response to a dynamic warm-up is thought to relate to the rehearsal of specific movement patterns, which may help increase the coordination of subsequent movement.

In a study of the effect of static prep stretching on performance of vertical jump, Knudson *et al*⁽¹⁶⁾ found no changes in the kinematics of the vertical jump, despite a decrease in vertical velocity in 55% of the subjects. They concluded that it is neuromuscular inhibition rather than reduced muscle stiffness after stretching that is responsible for the changes in performance.

But a 2003 study measuring the effect of static preparatory stretching on concentric isokinetic muscle action of biceps brachii, revealed the opposite⁽¹⁰⁾, with no measurable change in EMG amplitude. The researchers suggested that deficits in force production after stretching were related to muscle stiffness changes rather than neuromuscular control.

So while it is reasonable to conclude that static stretching can have a negative impact on performance of activities involving the stretch reflex or maximal contractions, we cannot confidently say why.

Stretching isn't always best

What can we conclude about how static stretching influences other aspects of performance? Nelson *et al*⁽²²⁾ demonstrated a significant reduction in muscle strength endurance after static muscle stretching.

Many sports, such as the tennis serve or golf swing, combine complex movement patterns with a need for maximum force and accuracy. Very little data seems to exist on how stretching might affect these activities – so this is another area ripe for further investigation. The best advice in practical terms is likely to be based on an extrapolation from tests involving simple movement tasks. Beyond this there seems to be just one study, Knudson *et al*⁽¹⁷⁾, on the performance of a tennis serve after static stretching, which used speed of serve and accuracy as outcome measures. It demonstrated no change in performance.

Stretching to reduce pain

It doesn't work on DOMS

It is a common belief that recreational athletes suffer with DOMS (delayed muscle onset soreness) because they fail to stretch sufficiently before activity; it is also said that DOMS can be alleviated with subsequent bouts of stretching. In reality DOMS is linked to an athlete's physical ability to tolerate the eccentric loading of a particular activity and preparatory stretching cannot relieve this soreness⁽¹⁵⁾. Neither stretch, cryotherapy nor electrotherapy has any effect in relieving DOMS⁽⁵⁾. DOMS can only be relieved by NSAIDs, exercise and possibly massage.

More generally it is very hard to undertake objective assessment of the benefits of stretching in reducing injury-related pain. If an injury is associated with a restriction in muscle flexibility, then stretching is a viable treatment option. However, if muscle inflexibility is not considered an influencing factor, for example in an instability problem, then clinical reasoning should rule out stretching as a treatment tool. Thus the use of stretch is going to be determined by the specific individual's injury profile.

Summary

Sports therapists lack a harmonised 'best practice' approach to stretch based on the available research. Here's what we know:

- Static stretches with the aim of achieving short-term range-of-movement gains should be held for 15 to 30 seconds and for maximum effect should be repeated four to five times. These short term changes will last between 60 and 120 minutes.
- For long-term changes, stretches should be held for 30 seconds and also repeated four to five times. Long-term results should take six to seven weeks at most before the changes start to plateau.
- PNF can achieve range of movement changes, and is often more effective than static stretching, but is also more difficult for athletes to perform on their own.

- It is reasonable to assume that PNF techniques will achieve the same results as those produced by the various research studies into static stretching.
- Stretching is a vital part of recovery from muscle strains and a progressive stretching programme can decrease rehabilitation time.
- Preparatory stretching is not necessary to prevent injury. However, from practical experience, it is the author's belief that specific static prep stretches can be beneficial in the management of chronic injuries.
- A regular stretching routine as part of an overall training programme can help prevent injuries and this should be individualised and sport specific.
- Static stretching should not be included in warm-ups, as it seems to decrease performance of explosive actions and activities demanding muscle strength endurance.

We are still some way from having a clear picture of the pros and cons of stretching. However, there is still solid evidence from which we can draw conclusions and base our management and training programmes. In many cases, the research challenges traditional approaches, which underlines the importance of sports practitioners keeping up to date with the science, so they can adjust their practice and programming in line with the best available evidence.

Sean Fyfe

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Stretching your horizons – why timing counts

Introduction

Recent research has shown that some types of pre-exercise stretching may not only fail to enhance performance, but can also be counter-productive. However that doesn't mean that you shouldn't be stretching – you just have to stretch appropriately.

Practice and research shows that the components of stretching are as varied as other training principles such as speed or strength. But all too often, stretching is either just tagged on to other forms of training, or overlooked completely. And repeating the same stretching routine day in, day out inevitably gets you the same results. However, adding a variety of stretches and altering the types of stretching that you do at different times of day, time of season, or time of year should enable you to improve your flexibility and your performance.

Is stretching bad for you?

I've recently had this comment thrown at me by coaches and athletes alike. As is often the case, information can be misinterpreted or applied in the wrong context (with the best of intentions) and then becomes dogma – for example 'weight training makes you slow'. There has been a lot of research in recent years that has shown that static stretching as part of a warm-up may not improve performance, and may actually inhibit speed and power activities⁽¹⁾. But some athletes and coaches have extrapolated these findings to conclude that all stretching is bad for you at any time. In fact, there may be a clue in the phrase 'warm-up' as to what you are supposed to do! We will examine this later.

In the 1960s, martial artists from the East who came to Britain did warm-ups with little no static stretching, but lots of movements. At the same time, Eastern European coaches were getting their athletes to do lots of movements in their warm-ups. Anecdotally, having worked in the fitness industry for eight years in the 1990s, I suspect the fad for doing a warm-up then stretches, and then the workout, came from gym-based exercise courses. I was always asking my fitness staff why they prescribed warming up on an exercise bike for 5 minutes, and then 5 minutes of static stretches, then run on a treadmill for 20 minutes, rather than simply walk, jog and then run on a treadmill!

Now the wheel has turned full circle and researchers are confirming what experienced coaches from different countries have been practicing for years. So, if static stretching is not best performed in the warm-up, does that mean that it's bad for you? If acute stretching in the warm-up does not prevent injury and can lead to an immediate performance decrement, does chronic stretching and improved flexibility prevent injury in the long term and improve performance⁽²⁾?

Studies looking at the benefits of regular stretching have found the opposite effects to that of acute stretching before an activity. These benefits include:

- A possible decrease in the likelihood of injury⁽³⁾;
- An increase in muscular force and power;
- A possible increase in sprinting speed⁽⁴⁾.

The improvements may only be mild (approximately 2-5%) but in athletic performance terms, very significant. All three areas are obviously very important to most athletes, so developing flexibility should assume a corresponding importance in an athlete's training programme. However, the question may arise of how can you fit it all in? Time constraints may hamper your efforts, and flexibility training should not necessarily replace your strength or endurance and especially not your skills training. But training smarter and looking at the time of day and type of stretching may allow you to reap benefits without additional training.

Time of day

The study of biorhythms considers circadian rhythms and the best times to perform strength and power workouts. The body's ability to stretch also changes throughout the day, and so the type of stretching you do should change too.

One recent study of healthy 24-year-old males measured patella tendon stiffness in the morning and in the evening⁽⁵⁾. Tendon stiffness was found to decrease by 20% at 6pm compared to 8am. This should mean that the evening is a better time of day to work on developmental flexibility, as the tendons are more compliant. However, no mention was made in the study of the subject's current level of flexibility or exercise status, including stretching routines. The results may have been different in another population who had more or less exposure to flexibility routines.

Why are tendons less stiff in the evening? It could be down to an increase in body temperature, increased movement patterns during the day, or increased testosterone and cortisol levels that tend to peak later in the day and can influence tendon compliance⁽⁶⁾.

Studies looking at the muscle force contraction or tendon compliance at different times of day have measured the skin temperature changes that occur naturally, and compared them with artificially induced temperature changes by external means.

In a study looking at peak power contractions at 7am and 6pm, naturally occurring skin temperature changes were low (2.6C) compared to studies looking at externally induced temperature changes (around 10C), but the evening power contractions were still as high⁽⁷⁾. This led the authors to surmise that skin temperature changes were not responsible for the evening muscle power being higher because the results appeared to be similar whether the temperature change was 2.6C or 10C. Another study tried looking at external methods of temperature change – ice packs and hot packs – but found no change in tendon stiffness as a result⁽⁸⁾.

While temperature changes in the muscle and tendon may influence compliance slightly, it is more likely that movement

and hormonal changes lie behind the greater evening tendon compliance. The reasons why increased hormones affect tendon compliance are not yet clear, but there does seem to be a link. However, although the increased movement explanation may not seem ground breaking, just try touching your toes when you have just got out of bed in the morning, or have been sat in a car for a couple of hours, compared to when you have been moving around all afternoon.

Type of stretching

If tendons are more compliant in the evening, then this is when your developmental stretching should take place. But what about first thing in the morning? You get out of bed, you're stiff, and ignoring all circadian rhythm advice (because you have to work) you are intending to train before 8am. We have seen that movement is likely to increase tendon compliance, so movement type or ballistic stretches are best performed in the morning or immediately before training. These ballistic stretches may seem like heresy, but performed in a controlled manner, are a way of increasing range of movement (ROM) effectively, without an acute detriment to performance.

A study on male and female college basketball players compared the effects of static stretching versus ballistic stretching versus no stretching in the warm-up on vertical jump (VJ) performance after 20 minutes of playing⁽⁹⁾. The authors delayed the VJ test for 20 minutes, because that is when improvements in power are most needed – in the middle of the game, rather than before the start.

The static stretches were held for 30 seconds, whereas the ballistic stretches were in the same position but consisted of small bounces at the end of the ROM in time to a metronome set at 60 beats per minute. Many athletes will have been told not to bounce when stretching, but there is a difference between small controlled movements and flinging your limbs around wildly beyond your normal ROM! The authors of this study could find no evidence that ballistic stretching was harmful.

An example of ballistic stretching for the quadriceps would

be to lie on your front and pull one foot towards your buttocks with both hands then pull your heel into your bum about another 1cm and release, repeating the pull/release sequence for 30 seconds. This is assuming that you can comfortably perform this stretch in a static position and that you never try and go beyond your normal ROM, especially first thing in the morning.

Dynamic stretching can take place first thing in the morning too and consists of more circular or action-orientated movements, which mobilise joints. A 10-minute routine (*see box 1*) before breakfast that replicates movements found in your sport or in your fitness training sessions will 'kick start' your mobility for the day. Rather than wait for your body to become mobile throughout the day, a structured session can fast track this progress. Box 2 shows a sample routine for a footballer.

Box 1: Dynamic stretching routine using circles

Perform each movement in two directions, either forwards and backwards, or clockwise/anticlockwise 10 times, and for both left and right sides of your body.

- 1. Wrist circles** – clasp hands together and rotate wrists around.
- 2. Neck semi-circles** – start with your chin on your left shoulder, roll chin down and forward across your chest to your right shoulder, and come back the other way.
- 3. Shoulder circles** – hands by your side, roll your shoulders forward.
- 4. Small arm circles** – hands out to side, make small circles about the size of a tennis ball.
- 5. Large arm circles** – try and get your arms brushing your ears and your hips.
- 6. Waist twists** – bend both knees slightly, keep your hips facing forward, bend both arms so that fingertips are touching each other level with your chest and twist to the right and then to the left.
- 7. Hip circles** – hands on your hips, circle your hips around like you are hoola-hooping!
- 8. Full body circle** – bend forward from the waist, let your fingertips sweep across the floor from right to left (keep your knees bent slightly), carrying on up to the left to bring your arms behind your head and down to outside your right foot.
- 9. Ankle circle** – keep your big toe on the floor in a fixed position and then rotate your ankle around it.

Box 2: Dynamic stretching routine for a footballer

This can be done first thing in the morning before breakfast.

Try each exercise five times to start, left and right side. You can then progress up to 10 times, the object is to mobilise you, not tire you out. Do all exercises in a controlled manner so that you can stop your body at any time in the movement, don't use momentum.

- 1. Knee raises** – lift knee to chest.
- 2. Bum kicks** – kick your bum with your heel.
- 3. Knee circles out to in** – bring knee out to the side, thigh parallel with the floor and then into the middle of your body and down.
- 4. Knee circles in to out** – bring knee up to the middle of your chest, then out to the side of your body and back down.
- 5. Leg swings forward** – stand with left leg slightly in front of the right, swing your right leg forward and off the floor so foot is level with hip (or higher if you are more flexible) and back down.
- 6. Leg swings backward** – swing right leg back behind you to about a 45-degree angle and back down.
- 7. Leg swings out to in** – same idea as for the knees, but with leg straight (it is a bit harder) so keep your leg straight and bring it out to the side, foot level with your hip and around to the front of your body and down.
- 8. Leg swings in to out** – bring your foot level with your hip to the front and then around to the side of your body and down.
- 9. Chest hugs** – cross both your arms across your body and hug then straighten the arms out and back to the side.
- 10. Chest hug diagonals** – same as above, but release your arms diagonally, so one hand is pointing to the floor and the other to the ceiling, squeeze in and then reverse.

Evening stretching

If ballistic and dynamic stretching are useful first thing in the morning and pre-workouts, what about post-workouts and during the evening? Two main types of stretching are useful here. The first is commonly known now as proprioceptive neuromuscular facilitation stretching (PNF) but is also known as isometric stretching⁽¹⁰⁾. The second is static stretching and is most commonly used for developmental stretching.

Two interesting studies have compared the two different methods of stretching on hamstring flexibility. The first compared static stretching, self-stretching, PNF and a control

group (who did no stretching)⁽¹¹⁾. After four weeks of a 30-second stretch three times a week for four weeks, only the static stretching group showed an increase in hamstring ROM compared to the control group.

The second study compared 5-minute stretching protocols from rest and after 60 minutes of exercise⁽¹²⁾. This study showed that PNF stretching was effective in improving acute hamstring flexibility after exercise, whereas static stretching was not effective.

PNF stretching

PNF stretching can be used post-workout or as a separate flexibility session, but it is probably more effective immediately after exercise. However, any method that requires isometric contraction can also cause fatigue as the muscle is working, so care should be taken when considering how much PNF stretching to do. One stretch per muscle group would be enough. PNF stretching could be done after any strength training session, or on the same day, but not on alternate days between strength training sessions otherwise those muscles will not be allowed sufficient time to recover before the next strength training session.

To start with, try holding the isometric contraction for 2-3 seconds then relax and stretch for 10-15 seconds and repeat two to five times. Try to perform the stretch as soon as you have finished the muscle contraction, preferably within one second. Make progress by holding the contraction for up to 10 seconds and the stretch for up to 30 seconds. You can repeat this up to five times, but this is quite a lot of work for your muscles, which then becomes very time consuming. If time is a limiting factor, you can stretch two or three muscle groups at each workout, and then rotate to different ones throughout the week.

Static stretching

This is perhaps the safest and least fatiguing of all stretching methods. As such, it is ideal for use on rest days or after fatiguing workouts, or as part of a relaxation routine. It is best done in the

later part of the day when tendon compliance is at its greatest. It shouldn't be done immediately before performance or competition, unless there are specific tight areas that you wish to release. Static stretching should be performed in a warm, comfortable, preferably quiet, environment, to allow full relaxation of the muscles. Thursday night at 9pm sat in a puddle on a rugby training pitch in December, is possibly not the optimal environment for developing flexibility!

Perform each stretch slowly until you cannot reach any further. Breathe in and out slowly, and try to stretch a little bit further, hold this position for another 25 seconds, relax and then repeat again. Concentrate on releasing all tension within the muscle that you are stretching to allow a greater ROM. Because you have to relax your muscles, you may find that you are mentally relaxing too. This is another benefit of performing static stretching at the end of the day for many athletes. Try to match stretches for the left and right side of your body and also the front and back. For example, if you perform two stretches for the hamstrings, then do two for the quadriceps. Variety within stretching is as important as for any other training method, so think about two to four stretches for each muscle group that you can rotate between stretching sessions.

Summary

Doing the same stretching routines all the time and at the wrong time will lead at best to maintenance of your current levels, but at worst to a short-term performance decline and possibly staleness. An awareness that increased flexibility can lead to long-term performance improvements, and less likelihood of injury, is a good incentive to put time aside to stretch. By matching the type of stretching you do to the time of day you do it, you can improve your performance by working with your body and not against it. If you don't have time to do additional stretching routines in the day, simply performing the right type of stretching within your workout will help you improve performance.

James Marshall

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Pre-exercise stretching – is it time to tear up the old rule book?

Introduction

In accordance with traditional guidelines⁽¹⁾, many individuals stretch before exercise^(2,3). But, there's increasing evidence that pre-exercise stretching fails to prevent injury and is detrimental to sports performance. Let's review the literature...

What are the current guidelines on stretching before exercise?

The American College of Sports Medicine (ACSM) has traditionally recommended that exercise sessions contain a warm-up of around ten minutes' duration, during which light activities precede static stretches of the major muscle groups^(4,5). However, the ACSM now recognises that there is increasing evidence that stretching is detrimental to performance. Indeed, its latest guidelines suggest that the pre-exercise warm-up need only consist of cardiovascular exercise⁽⁶⁾.

Does pre-exercise stretching reduce the risk of injury?

In order to investigate cause-and-effect relationships, scientists have conducted randomised, controlled trials. In one such study, researchers investigated the effect of pre-exercise stretching on the risk of exercise-related injury in 1,538 male army recruits⁽⁷⁾.

Nineteen platoons were randomly allocated to the stretch group and 20 platoons to the control group. Throughout the

12 weeks of training, both groups warmed up for approximately five minutes before marching, running, swimming or wrestling. The stretch group also followed a typical stretching routine during every warm-up (one 20-second stretch of the gastrocnemius, soleus, hamstring, quadriceps, hip adductor and hip flexor muscle groups). The control group did not stretch before exercise. The lower-limb injury rate among 735 men who stretched (158 injuries, or 21.5%) was not significantly different to that of the control group (175 injuries, or 21.8%). In an earlier study of 1,093 servicemen, the same group also found that pre-exercise stretching did not protect from injury⁽⁸⁾.

In another randomised, controlled trial, Dutch scientists found that warming up and stretching did not reduce the risk of injury in 421 recreational runners⁽⁹⁾. During the 16-week study, there were 5.5 injuries per 1,000 hours of running in those who stretched before exercise, and 4.9 injuries per 1,000 hours of running in those who did not stretch before exercise.

Bucking the trend, a study carried out three years ago reported that injury rates were lower among 518 army recruits who performed static stretching before exercise than among 383 army recruits who did not perform static stretching before exercise⁽¹⁰⁾. However, a closer look at this study reveals that the so-called 'control group' performed five to ten minutes of ballistic stretching before each physical training session.

The results of another randomised controlled trial must also be interpreted with caution. In this study, researchers reported 75% fewer injuries among soccer players who took part in an injury-prevention programme⁽¹¹⁾. However, it is impossible to distinguish the effect of pre-exercise stretching from the co-interventions, which included leg guards, ankle taping, corrective training and the support of doctors and physiotherapists.

Collectively, these randomised, controlled trials suggest that pre-exercise stretching does not reduce the risk of injury.

It has been suggested that stretching might prevent injuries in sports involving jumping and bouncing, such as soccer and basketball⁽¹²⁾. This would seem to be the case if 'stretchy' muscle

were better able to absorb energy. However, it has in fact shown that less force is required to rupture ‘stretchy’ muscle than a ‘stiff’ muscle⁽¹³⁾.

Does pre-exercise stretching improve performance?

To investigate the effect of static stretching on subsequent leg strength, a team of researchers from the University of Hawaii tested the one-repetition maximum (1RM) lift of 30 physical education students following stretching of the hip, thigh and calf muscles⁽¹⁴⁾.

Each volunteer performed a 1RM prone (lying face-down) knee flexion and a 1RM seated knee extension on two successive days following either ten minutes of quiet rest or 20 minutes of stretching. The stretching protocol consisted of three 15-second conventional stretches of five muscle groups involved in knee flexion and knee extension followed by three 15-second assisted stretches of the same groups. Nautilus machines were used to measure knee-flexion strength and knee-extension strength. Each subject performed one progressively heavier lift

Fig 1: effect of static stretching on knee strength

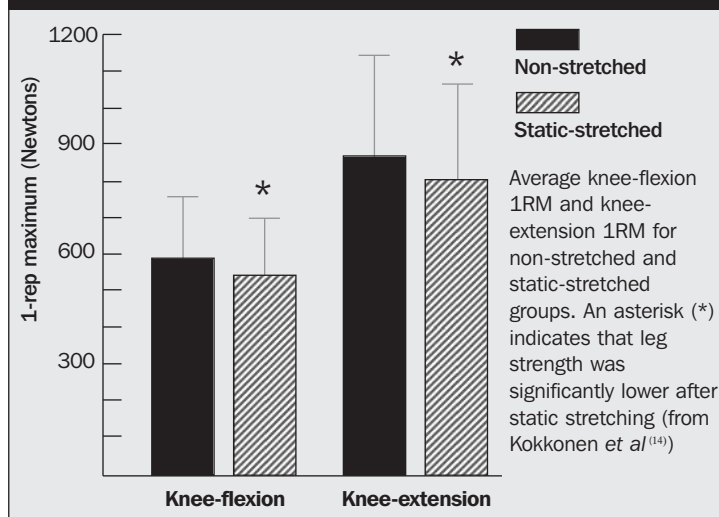
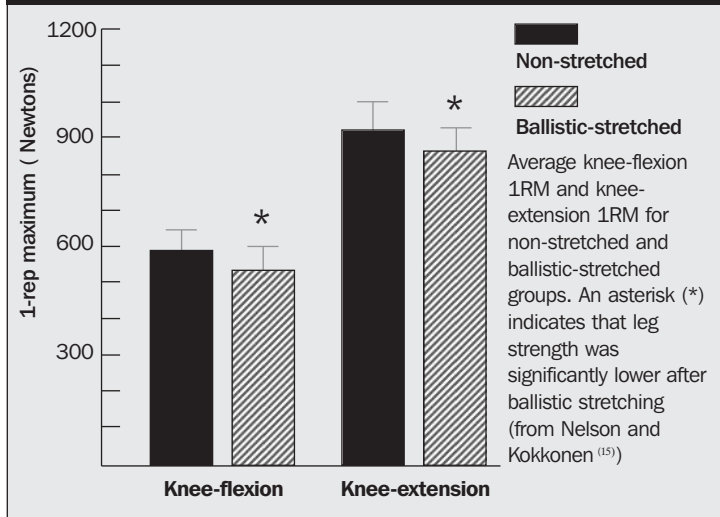


Fig 2: effect of ballistic stretching on knee strength

every 60 seconds until failure. As shown in Figure 1 on page 35, static stretching reduced knee-flexion strength by 7.3% and knee-extension strength by 8.1%.

In a later study, scientists at the University of Louisiana used an identical protocol to determine the effects of ballistic stretching on leg strength in 22 physical education students⁽¹⁵⁾. This time, the stretching procedure included three 15-second unassisted ballistic stretches and three 15-second assisted ballistic stretches of five muscle groups involved in knee flexion and knee extension. Unassisted ballistic stretching required the subjects to bob up and down about once per second after feeling the stretch. During assisted ballistic stretching, an experimenter moved the participant's joint back and forth through approximately two to five degrees after feeling the stretch. As shown in Figure 2, above, ballistic stretching reduced knee-flexion 1RM by 7.5% and knee-extension 1RM by 5.6%.

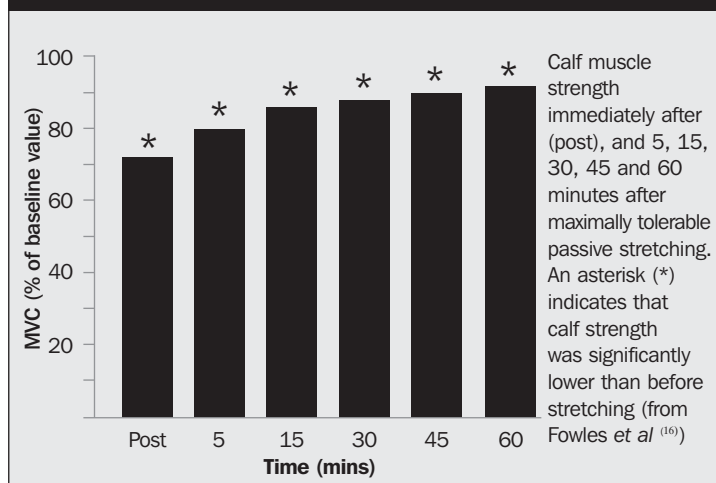
In 2000, Canadian researchers published a study showing that calf muscle strength is reduced for an hour after static stretching⁽¹⁶⁾. To measure maximal calf-muscle strength, ten

subjects were each secured in a leg-holding device designed to position the knee and hip angles at 90 degrees whilst a foot was strapped to a metal plate that rotated about the same axis of rotation as the individual's ankle. Force applied to the footplate was measured by strain gauges. The footplate could also push against the foot in order to passively stretch the soleus muscle. The experimental procedure for each subject was:

1. Baseline maximum voluntary contraction;
2. Ten-minute rest;
3. Thirteen 135-second maximal passive stretches over 33 minutes or, on a separate occasion, non-stretch control;
4. Maximum voluntary contractions immediately after (post) and at 5-, 15-, 30-, 45- and 60-minute intervals.

As shown in Figure 3, below, muscle strength was 28% lower immediately after stretching. Compared with the baseline value, maximum voluntary contractions (MVC) were also lower 5, 15, 30, 45 and 60 minutes after stretching. Another study, carried out in 2004, has shown that quadriceps strength is reduced for 120 minutes after static stretching⁽¹⁷⁾.

Fig 3: effect of passive stretching on calf strength



After finding that quadriceps strength was reduced by 12% after static stretching, Canadian scientists concluded that ‘it would be difficult to imagine that overall athletic performance would be consistently enhanced if, following acute bouts of prolonged stretching, force output was diminished’⁽¹⁸⁾. Indeed, the same group later demonstrated that running and practice jumps had a positive influence on jumping performance, whilst static stretching of the knee extensors had a negative influence on jumping performance⁽¹⁹⁾.

More recently, the Louisiana group (*see page 36*) reported that stretching decreases subsequent muscle strength-endurance⁽²⁰⁾. On average, 22 physical education students were able to perform 14.5 knee-flexion lifts at 60% of body weight without prior stretching, and only 11 knee-flexion lifts at 60% of body weight after passive stretching of the hip, thigh and calf muscle groups. Successful strength training requires progressive overload. For example, a lifter might add five kilos to his or her next training session once he or she has successfully pressed 100 kilos for four reps. These results suggest that stretching prior to lifting could induce a ‘false negative’ experience that would delay the progression to a higher load.

Stretching is not just detrimental to performance in the contrived setting of the laboratory; it’s also detrimental on the track. A study carried out last year found that 20-metre sprint times were significantly increased in collegiate athletes following four 30-second static stretches of the hamstring, quadriceps and calf muscles⁽²¹⁾. Twenty-metre sprint times were also increased in rugby union players following 20-second static stretches of the gluteals, hamstrings, quadriceps, adductors, hip flexors, gastrocnemii, and solei⁽²²⁾.

Does flexibility training improve performance?

No large studies have investigated the effect of flexibility training on performance. However, cross-sectional data suggest that runners are less flexible than their sedentary counterparts, demonstrating tight hamstring and soleus muscles⁽²³⁾. Given the elastic properties of muscles and tendons, such tightness is likely

to improve performance. Indeed, it has been shown that the least flexible runners are also the most economical⁽²⁴⁾.

Why is pre-exercise stretching detrimental to performance?

Two mechanisms may explain why pre-exercise stretching is detrimental to performance. Firstly, stretching damages the contractile proteins in skeletal muscle. Secondly, stretching reduces one's ability to recruit skeletal muscle.

Skeletal muscle contains thick filaments and thin filaments that are connected by cross-bridges. When a nerve signal reaches the muscles, the thin filaments slide over the thick filaments. However, movement cannot occur if the cross-bridges between the filaments are broken. Indeed, animal studies have shown that force production is reduced when muscle filaments are stretched beyond overlap⁽²⁵⁾. Animal studies have also shown that cross-bridges are broken when muscle is stretched only 20% beyond its resting length⁽²⁶⁾. In humans, there is evidence of muscle damage 24 hours after a bout of stretching, which has led scientists to conclude that stretching causes delayed onset muscle soreness⁽²⁷⁾.

The nerve signals that initiate muscle contraction are electrical in nature. Thus, electrodes can be used to monitor muscle activity. In humans, such studies have shown that muscle activity and force production are reduced after stretching^(16,18,28,29). These findings suggest that stretching produces some kind of neural inhibition that is detrimental to performance. This hypothesis is supported by a study showing that balance and reaction time are also impaired after static stretching⁽³⁰⁾.

Conclusion

What does this mean for sportsmen and women? These large, well-conducted, randomised, controlled trials provide compelling evidence that pre-exercise stretching does not reduce the risk of injury. The available evidence also suggests that pre-exercise stretching is detrimental to maximal strength,

strength-endurance, jumping height and sprinting time. Given this evidence, it seems only reasonable to conclude that stretching should not be performed before exercise. Instead, warm-ups should consist of aerobic activities that are likely to prevent injury and improve performance^(31,32).

Dr Gary O'Donovan

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The dynamic alternative to static stretching

Strength and conditioning coaches and trainers are engaged in a constant search for the best ways to improve sport performance. All things being equal, a bigger, faster, stronger, more conditioned athlete will rule supreme on the playing court or field. While there is constant debate over techniques for boosting sport specific speed, power and strength, I believe we tend to overlook the importance of a comprehensive warm-up, and the role it plays in optimising performance in each and every workout, practice and game.

This leads to the obvious question: what is the best way to prepare an athlete for performance – mentally as well as physically? For many years the accepted norm has been to perform a light warm-up followed by some static stretching. In fact, almost anywhere in the world you will see athletes – from schoolchildren to elite competitors – starting their practice sessions with ‘a couple of laps’ and some light stretching. So ingrained is this type of routine in almost every coach’s head that it tends to go unquestioned.

But is this approach really beneficial? Does it adequately prepare an athlete for the workout ahead? Is there a better way? I believe there is. In my view, an active or ‘dynamic’ warm-up is an infinitely superior way to prepare for physical activity.

Although this type of warm-up has been used by track and field athletes for years, it is not widely practised within other sports – *eg* football, basketball and baseball – at junior, senior or professional levels.

The great thing about a comprehensive dynamic warm-up is that it doesn’t take any more time than the more traditional stretching method, but is much more focused, effective and

productive. Since your warm-up sets the tone for the entire workout, these are just the qualities you should be looking for.

The specific advantages of a dynamic warm-up, by comparison with the more traditional ‘sit and stretch’ routine, are as follows:

1. Because it involves continuous movement, it maintains warmth in your body and muscles. I have found that many athletes drop their core temperature by 2-3° after sitting and stretching for 10-15 minutes;
2. It prepares the muscles and joints in a more sport specific manner than static stretching;
3. It enhances coordination and motor ability as well as revving up the nervous system – benefits which are particularly important for younger athletes who are still ‘learning their bodies’;
4. Finally, and possibly most importantly, it prepares the mind for the workout ahead. Proper mental preparation for any sport is vital and, in my considerable experience with teams and groups, I have found that while many sit-and-stretch routines are an excuse for daydreaming, the dynamic warm-up forces athletes to focus and concentrate on the task at hand.

Your starting point should be a general cardiovascular warm-up lasting 5-10 minutes (or until you have broken a light sweat). This raises the body’s core temperature enough to enhance the elasticity of muscles, tendons, ligaments and overall joint structures and prepare you for the workout ahead.

This portion of the warm-up can be accomplished in several ways, including light jogging, skipping (jump rope) or even performing different footwork patterns in a speed ladder. My personal preference is for skipping because it also warms up the upper body, doesn’t take much space and uses several different footwork drills and patterns to keep you psychologically stimulated.

Another purpose of this initial warm-up is to prepare the mind for the workout ahead. It is a time to focus and concentrate, leaving all outside distractions and stressors (school work,

relationship problems etc) at the door. It is vital to make sure your initial cardiovascular warm-up is serious and not a time for ‘goofing around’.

After this initial preparation of body and mind, it is time to move to the next phase of preparation and begin the dynamic part of the warm-up.

When designing the day’s dynamic warm-up for the athletes I work with, I try to include exercises that address all the major muscle groups (hamstrings, quadriceps, calves/Achilles and hip flexors) on a fairly equal basis. I also try to vary the routine to keep the athletes interested and make sure they don’t become complacent.

With a menu of 25-plus dynamic warm-up exercises in my toolbox, I choose a different 8-10 each time. Below is a list of my top 15. From these you should select 8-10 each day to perform over a distance of 15-20 yards (half a basketball court), followed by a light jog back to the starting point to maintain the warm-up effect.

As with any drill, it is important to start out conservatively and slowly until an athlete has mastered the movement with perfect technique. For drills such as ‘high knees’, athletes can certainly increase speed as they become more proficient at performing the movement. For drills such as ‘pointers’, speed should be kept slow and controlled, with improving range of motion as the primary focus. The entire dynamic warm-up can be done in as little as five minutes or as long as 20 minutes, depending on the goals, age, and fitness level of the group.

Ankle pops: Lightly bounce off both toes while keeping the knees very slightly bent. This is very similar to a skipping motion, except that it is performed while moving forward. The idea is to introduce progressively more range of motion as you move through the prescribed distance.

High knees: This is basic running form while bringing the knees up higher than normal – ideally beyond your waistline. Aim to

keep your feet moving as fast as possible and your ankles, knees, hips and shoulders facing forwards.

Butt kicks: Similar to high knees except you keep your thighs perpendicular to the ground while kicking your heels up towards your backside. Again, move fast and keep ankles, knees, hips and shoulders in alignment.

Carioca: Moving laterally to your left, cross your right foot in front of your left, then step with your left, then cross your right foot behind the left and repeat. Aim for as much hip rotation as possible and keep those feet moving fast! If performed correctly, this looks like a new dance move!

Step slide: Assume a low athletic position with your feet slightly wider than shoulder-width apart, your ankles, knees, hips and shoulders facing forwards and your knees slightly bent. Pushing off your right leg, slowly step laterally to the left with your left leg, then slide your right leg back to its original position, making sure your feet don't touch or cross. This is similar to a 'defensive slide' in basketball and the coaching cue when performing it is 'step – slide'.

Glute walk: In the process of your walk, put your left hand on your left knee and right hand on your left ankle, then pull both in towards your chest. Take a step and repeat on the other leg.

Back pedal: Run backwards maintaining a little bit of a forward lean (shoulders over your toes) to prevent falling. Really 'reach back' as far as you can with each step to help stretch the hip flexor muscles.

Frankenstein march: Keeping your left leg straight, kick it up in front of you as high as you can, trying to touch the fingertips of the opposite arm – basically a straight leg march – then repeat with the right leg. This is an excellent way to increase hamstring flexibility.

Knee hug: While walking forward, hug your left knee into your chest, then step and repeat on the right leg, continuing with alternate legs. This is an excellent way to loosen up the glutes and hips.

Pointers: Keeping your left leg straight (and right leg bent) and left foot pointed upwards, reach down with your right hand to try to touch your left toe. Then take a step and repeat on the other side. This is another excellent movement for enhancing hamstring and low back flexibility.

Quad walk: While walking forwards, pull your left heel in to your buttocks, then step and repeat with the right leg, continuing with alternate legs. This is ideal for loosening up the quadriceps and hip flexors.

Low lunge: Step forward with your left leg into a lunge position (ankles, knees, hips and shoulders facing forward, torso upright) trying to place your left elbow on the ground as close to your left heel as possible.

Over the fence: Facing in the opposite direction to the way you want to travel, raise your left knee as high as possible and rotate it behind you as if you were trying to walk backwards and step over an imaginary fence. Repeat on the right leg and continue with alternate legs.

Inchworm: Assume a push-up position on the ground, and walk your feet close to your hands while keeping the legs as straight as possible. Then return to the start position. Repeat over the prescribed distance, making sure your hands and feet never leave the ground.

Scorpion: Lie face down on the ground with arms extended out to the sides, palms facing down, so your body forms a 'T' shape. Maintaining this face-down position and keeping your shoulders flat on the ground, bring your left heel and swing it

back towards your right hand in a reverse twisting motion. Repeat on the other leg.

I want to challenge the traditional thinking that suggests 'warming up and stretching out' as the ideal way to maximise performance for every workout, practice or game. I believe a dynamic approach will do a better, more sport specific job of preparing an athlete's mind and body for the task ahead and play an important role in boosting athletic performance.

Alan Stein

Further reading

Speed & Agility Revolution by Jim Kielbaso (Crew Press, 2004, US\$19.95)