Training the hamstrings for high speed running

Part 2

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Part one of this discussion into training the hamstrings, examined the research and theory behind hamstring muscle function during running and the mechanisms of hamstring strain injury. The aim of part two, is to describe a training system which includes specific exercises that will develop both the characteristics of hamstring function and reduce the injury risks that were explained in part one.

The key findings from the research into hamstring function are:

1. The hamstring is most active during late swing phase, through early to the mid-stance phase of the gait cycle.[9,13,14,16]
2. The hamstring muscle tendon unit acts to reverse rapid hip flexion into rapid hip extension and decelerate knee extension prior to initial ground contact. This is a classic stretch-shortening cycle (SSC) muscle action.[13,14]
3. The hamstring muscle tendon unit is lengthened beyond resting length during late swing (i.e. it is stretched).[13,14]
4. Having been pre-activated during the SSC action of late swing (after initial ground contact), the hamstring remains highly active and acts to both stabilise the knee joint and extend the hip joint during early to mid-stance.[9,16]
5. The hamstrings are bi-articular in structure (i.e. attach across two joints, the hip and knee). By being active at both joints, they help transfer energy between the ground and the hip and knee.[11]
6. The co-ordination and control of hamstring muscle forces are dependent on the opposite leg hip flexion forces and control of the pelvis during the gait cycle.[2,13,14]

The key findings from the research into the mechanisms behind hamstring injury are:

1. Both the strength of the hamstring muscle, and crucially, its length-tension relationship (i.e. at what joint angle does peak force occur) are important for preventing strains. Athletes will benefit from reaching peak muscle force at longer muscle lengths.[3,6]
2. The compliance of the muscle tendon unit (i.e. the ability of the hamstring to lengthen under loading), as well as the basic flexibility of the muscle are important for preventing strains. Athletes may benefit from having flexible hamstrings and hamstring tendons and also benefit from being able to stretch them with less force.[6,14]
3. The biceps femoris goes through a greater stretch during the late swing phase.[8,13,14] and acts as the sole lateral rotator of the knee and so is especially at risk of strain injury.[5]

All of these key findings influence the following training selection of specific exercises, as well as coaching experience teaching various hamstring strength exercises and designing injury prevention programmes over a number of annual training cycles.

Dynamic Correspondence

Dynamic correspondence is a term applied to strength exercises by Russian authors[15,17] and is an important concept when considering

exercise specificity. It suggests that a mechanical or physiological aspect of the strength exercise should correspond to a key mechanical or physiological component of the sporting movement. This is the key to exercise specificity.

For an exercise to demonstrate dynamic correspondence, it must match the sporting movement in one or more of the following ways:

- the joint or combination of joint movements
- the specific range of joint movement where force is applied
- the type of contraction (e.g. SSC, isometric, concentric, or eccentric)
- the energy systems

Note, that strength exercises do not have to look like sporting movements to be specific. They simply need to share a component movement and/or contraction characteristics.

Using these principles, we can define what kind of hamstring strength exercises will have dynamic correspondence to muscle function during running and we can suggest hamstring strength exercises that will be related to the prevention of injury with regards the specific mechanics of injury.

Firstly, the hamstrings need to be trained as hip extensors, with a closed chain movement, as this corresponds to the action during the stance phase in running. Secondly, the hamstrings need to be trained with exercises that stress the eccentric muscle action. This is related to the swing phase in running, as the muscle must generate eccentric force at both hip and knee joints. In addition, eccentric hamstring exercises have been shown to positively influence the length-tension relationship, and are therefore specific to injury prevention mechanisms.

The hamstrings also need to be trained with SSC type exercises, with an open chain. These types of movements correspond to the muscle action during the late swing phase in running. The SSC contraction of the hamstrings has been suggested to be critical in injury prevention, as research discussed in part one showed that the strain is likely to occur when the muscle tendon unit is being stretched. These SSC exercises should involve full range of motion and ensure the hamstring muscle-tendon unit is placed upon sufficient stretch for full benefit and specificity. Exercises which target strengthening the tendon component will also be specific to the injury mechanics. In general, we assume that exercises are purely for the muscle, when in fact the ability of the tendon - non contractile tissue - to absorb strain energy is highly important for avoiding hamstring strain. Taking the dynamic correspondence ideas one step further, SSC type exercises can also combine hip flexion movements of the opposite leg. This makes them specific to the co-ordination and control of the pelvis during running.

Finally, the hamstrings should be trained with exercises that have a rotational movement element which will make the biceps femoris muscle more active[12] and stresses its role as a lateral rotator.[5]

The following are three categories of exercises which target each of the hamstring dynamic correspondence principles outlined above. The aim and general principles of each exercise category is provided as well as the coaching points required to ensure correct benefit is attained through quality execution of the movements.

High Load Closed Chain Hip Extension Exercise

These exercises aim to develop the strength of the hamstring muscles, specific to hip extension. The closed chain movement means that the hamstrings are working with the gluteal and erector spinae muscles to achieve the task. Sometimes these are referred to as posterior chain exercises. The training aim is to increase the load (weight) lifted with perfect form.

The high loading used in this category of exercises is to ensure positive neuromuscular adaptation. (Particularly in terms of eccentric muscle activation and force capability of the hamstring muscle group).[1]

Multiple sets of 8-10 repetitions would be used, until robust technique is established and sufficient strength in the back muscles has been developed to tolerate higher loadings. At the appropriate time, the intensity can be increased to the 5-6 repetition range and maximum strength can be developed. Some athletes who have achieved good strength levels at these exercises may wish to use the 2-4 repetition range at even higher loads to further increase strength. However, whether this choice is made, is individual to the athlete.

A frequency of 2-3 times per week is recommended to develop strength.

It is recommended that these exercises are trained during off-season and pre-competition phases for speed and power athletes. High intensity training of these movements may be incompatible with high intensity and high velocity sprint training (where the quality and timing of the hamstring muscle contraction is vital).[16] A frequency of once per week, in the 5-8 rep range, will be sufficient to maintain strength during high intensity training and competition phases.

1. Romanian Dead Lift (RDL, also called Straight legged dead lift)

This exercise is performed using barbells to provide the load. It is particularly effective as the movement requires taking the hamstring into a lengthened position during the eccentric phase of the lift, providing a high load eccentric training

stimulus, as well as a hip extension concentric strength stimulus.

The key technique that needs to be perfected for this exercise to be both safe and optimally effective, is that the athlete is able to maintain the correct extended position of the spine as they flex forward at the hip. To do this correctly, athletes need to learn to rotate their pelvis as they flex forward, so that all the flexion is from the hip, (as if the hip acts as a hinge joint) and absolutely no flexion occurs in the spine.

Start position: Standing upright holding the barbell across the front of the hip, with a shoulder width grip and hip to shoulder stance width.

Eccentric movement: Lean forward from the hips only (see above), tilting your pelvis up to the back (tail bone up), and using your back muscles to actively maintain an extended spine. Allow the bar to run down your thighs, making sure the bar stays close to your body. Your hips will go back slightly as you lean forward.

Mid point position: If you keep your spine extended and tilt you pelvis correctly, you will lengthen your hamstring, placing them under eccentric load. Stop leaning forward when you feel a strong stretch in the hamstring. Do not try to go down lower by bending your spine. (Most people can get the bar to around their knees – some athletes with either longer arms or flexible hamstrings can get to their shins).

Concentric movement: Stand back upright, sliding the bar back up your thighs.

2. Single Leg Good Morning

This exercise is traditionally used to strengthen the back when performed on two legs. The single leg variation ensures the hamstring is the limiting factor in terms of strength. The spine and pelvic mechanics discussed above for the RDL are also essential for the safe and effective execution of the Single Leg Good Morning. This exercise also provides an excellent high eccentric stimulus by taking the hamstring into a lengthened position under load.

Start position: Standing upright holding the barbell on the back, across the top of the shoulders.

Eccentric movement: Lean forward from the hips only (see above), and using your back muscles to actively maintain an extended spine. Your hips will go back slightly as you lean forward.

Mid point position: If you keep your spine extended and tilt your pelvis correctly, you will lengthen your hamstring, placing it under eccentric loading. Stop leaning forward when you feel a strong stretch in the hamstring. Do not try to go down lower by bending your spine.

Concentric movement: Stand back upright.

3. Glute-ham Raise

This exercise requires a specific frame known as a glute-ham raise machine. If you have access to this equipment it allows you to perform an excellent posterior chain strengthening exercises. This exercise works the hamstring as a knee flexor and hip extensor and also involves eccentric loading into a lengthened position.

Start position: Place your lower leg in the frame and lie over the thigh support with your hip bone just off the edge, so you are free to flex forward. Start with your hips and back fully extended with your knees slightly bent.

Eccentric movement: Lower your trunk and head down, flexing at the hip to about 90 degrees. This will stretch your hamstrings a little.

Concentric movement: From the bottom perform a dynamic hip extension. (It will look like a back hyperextension in the roman chair), and once your trunk is raised above the horizontal, also actively pull with the hamstrings, flexing your knees and pulling yourself upright. Finish with your knees bent to 90 degrees and trunk upright. Slowly extend your knees, keeping your hips extended back to the start position.

The loading of this exercise can be increased by holding a plate across your chest or behind your head.

Moderate Load Eccentric Exercises (including rotational movements)

These exercises aim to load the hamstring muscle tendon unit eccentrically, placing force through the muscle group whilst the hamstring muscle is lengthening. The training goal is to increase the volume, not necessarily the load of these exercises. This is to orientate the exercises to developing the tendon (non-contractile tissue) loading capacity, as relatively high volume and high frequency eccentric exercise has been shown to be very beneficial to tendon strength and quality.[10] The ability of the muscle tendon unit to absorb eccentric load efficiently and repetitively is the key physical quality these exercises are aiming to improve to reduce the risk of injury.

It has also been shown that the response to relatively high volumes of eccentric hamstring exercises, designed to purposefully cause muscle soreness, is an increase in the length tension relationship.[4] It was suggested that the muscle adapted to the repetitive eccentric strain damage by adding sarcomeres, and thereby increasing the muscle length at which peak force can be produced. In subsequent research, an increased peak force muscle length relationship was shown to reduce hamstring strain injury risks.[3] This does not exclude the possibility that the high load strength emphasis exercises detailed above do not also result in the same length tension relationship benefits. It is just the research looked, at high volume, eccentric only, nordic curls to produce this effect. Logically, any exercise regime that results in eccentric action

muscle damage will produce this training adaptation. However, high volume schemes seem most likely to produce this result.

There is a sound rationale for the injury prevention benefits of eccentric exercise for the hamstring muscle tendon unit. In terms of tendon health, the benefit seems to come more from the adaptation to repetitive eccentric loading and the loading seems less important. This makes these exercises distinct from the first category, where loading was essential to change to the neuromuscular recruitment of the hamstring muscle and increase the hip extension force production. Both categories of exercises should be implemented in training programmes as they will achieve different physiological adaptations.

The eccentric exercises are best performed with multiple sets of 8-12 repetitions. A frequency of 3-5 times per week can be utilised to build up tendon strength during the off-season and pre-competition phases. Regular doses of eccentric exercise can be safely given during the high intensity training and competition phases with these moderate loading exercises, as they will not induce as much hamstring muscle fatigue as the high load category of exercises.

1. Single leg RDL

This is exactly the same movement as the RDL described above, but performed on one leg. We particularly recommend this exercise as during the eccentric phase of the movement the hamstring can be lengthened to its fully stretched position, as the muscle is fixed at the knee (tibial insertion) and lengthened due to hip flexion at the pelvic insertion. The technical points in terms of pelvis and spine position described above, are essential to ensure the hamstring is fully stretched.

The athlete usually holds a heavy medicine ball or dumbbell in two hands held in front of the body. The weight is kept close to the legs as the athlete leans forward and the hips go backwards (exactly the same as in the RDL above). Athletes may find it easier to perform the movement by lifting the leg back and up as the trunk leans forward, as this helps with balance and rotating the pelvis up towards the back. Alternatively, if they are able to keep their legs close together and flex correctly at the hips, then this is also good technique. The important thing is that the hamstrings are taken under eccentric loading to a fully stretched position.

Anecdotally, we can report that athletes who perform this exercise regularly, following the high volume, high frequency, moderate loading recommendation can actually increase hamstring range of motion as measured by a straight leg raise test conducted by a physiotherapist. Thus, the RDL can promote flexibility as well as provide the injury prevention benefits discussed above.

2. Single leg RDL with Rotation

The exercise is very similar to the previous exercise, except as the athlete leans forward from the hips stretching the hamstring, they should direct the weight and their shoulders towards the inside. This places greater emphasis upon the lateral hamstring muscle, the biceps femoris, which as discussed in part one and above, is at most risk of hamstring strain and the rotational action of this muscle needs to be trained. Research has shown that this movement preferentially recruits the bicep femoris much more than the semitendonosis and semimembranosis muscles.[12]

3. Nordic Curl (aka Russian Hamstrings)

This is the exercise used in the research cited above[3] that showed the positive adaptation to hamstring eccentric training. It involves using body weight and is similar to the glute-ham raise exercise in category one. It has been placed in this category for its specific eccentric loading benefits and the technique described below has been used for a number of years with athletes in the 8-10 repetition range. The exercise can be quite difficult to begin with, as bodyweight provides quite high eccentric loads initially, until some muscle strength has built up. The following describes a safe and effective method of progressing the movement.

Before describing the exercise, it is worth noting that in this movement the hamstring is acting as an eccentric knee flexor and the hip joint is fixed. The start position is with the hip extended and knee flexed and so the hamstring is shorter than resting length at the start. The knee is extended, controlled by eccentric knee flexion force, and lengthened to around its resting length. This is different to the RDL, which starts with the hamstring at resting length and stretches it to a fully lengthened position, which is arguably a disadvantage of the exercise, as it only involves the inner range.[7] However, the Nordic Curl is certainly effectively for providing eccentric loading of the muscle tendon unit. The fact that the RDL eccentrically loads the hip extension function of the hamstring and the Nordic curl eccentrically loads the knee flexion function of the hamstring, suggests that both exercises can be included in the training programmes for optimal benefits and injury prevention, especially if one considers the dynamic correspondence principle and that the hamstring must act eccentrically at both joints during the running gait cycle.

Learning the Nordic Curl:

Athlete begins in a kneeling position, trunk upright and feet/lower legs fixed firmly. Hands are kept beside the body and hips are fixed in an extended position. The athlete starts to fall forward from the knees, maybe 10-20 degrees, until they feel some tension in the hamstring. They hold that position for a few seconds and

then are assisted back to the start position.

The athlete would begin by performing 2 sets of 5 reps of this. Then they would build up to 3 sets of 10 repetitions. Once they had mastered this movement, learning to keep the hips fully extended with the trunk upright and are comfortable with the hamstring muscle tension, they can progress to the full movement.

Training the Nordic Curl:

Athlete starts kneeling, trunk upright and feet/lower legs fixed firmly. The hands are beside the body. The athlete slowly, and using the hamstring muscles to control the movement, falls forward from the knees. The aim is to take the body out to 45 degrees, keeping the hips fully extended as you do so, using the hamstring muscles to control the movement. Once the hamstrings cannot hold the position, the athlete simply relaxes and falls to the floor, using their hands to catch the fall. The athlete pushes themselves back up with their arms and kneels back upright to start again. Note, the athlete only performs the eccentric contraction with this technique. Some people do perform the concentric movement as well, but we would argue that this makes the exercise high load hamstring strength training. To ensure the eccentric muscle tendon unit benefits argued above, performing the eccentric movement only means this exercise is reasonable moderate in loading, once the athlete has built up some strength, and can be trained in the 8-12 repetition range.

Stretch-Shortening Cycle Exercises

Part one explained how the hamstring has a SSC action during the swing phase of running. Therefore, following dynamic correspondence principles, training the hamstrings with repetitive SSC movements, sometimes called reactive or plyometric movements, will be highly relevant to both hamstring performance and injury prevention.

The aim of this category of exercises is to optimise the timing and control of the eccentric forces generated in late swing phase. Specifically, these exercises can place the hamstring in a lengthened position at the hip and eccentrically control knee flexion forces and then rapidly produce concentric hip extension movement. These exercises also have the advantage of being more functional by including the opposite leg in reciprocal hip extension/flexion movements, which trains the control of the pelvis and co-ordination of contralateral hip flexion and extension forces, which has also been shown to be important for efficient running and injury prevention.

Reactive Running Drills (e.g. B Skips, straight legged run, straight leg hurdle skips)

Some of the popular and commonly performed running drills provide an ideal hamstring SSC training stimulus. These movements involve fast cycling of the unloaded limb to activate the hamstring muscle into controlling knee extension and re-coiling with hip extension. Probably the most well known and effective of these drills are the B-skips, straight leg runs and straight leg hurdle skips. The techniques of how to perform these movements are well documented elsewhere.

Reactive hamstring running drills can be varied in nature and performed as part of extended warm ups prior to training sessions. This high frequency, low load but high speed, method of hamstring training may provide a positive tendon stimulus that will promote non-contractile tissue loading. The repetitive full range of motion nature of the movements means that these drills are also seen to promote dynamic flexibility of the hamstrings and may help promote compliance of the muscle-tendon unit, which as discussed above has been shown to be important for avoiding muscle strain. Thus, running drills are arguably another important component of hamstring conditioning that can provide a SSC training stimulus and promote muscle tendon unit compliance.

We recommend the regular performance of running drills, particularly B-Skips or straight leg runs and skips, all year round as part of a hamstring conditioning strategy. A frequency of 2-4 times per week, with drills performed 2-3 times over a 20m distance is appropriate.

Plyometric Exercises

Plyometric exercises are generally thought of as performance orientated exercises for jumping and sprinting. However, certain plyometric exercises that require very fast scissoring type movement of each leg whilst in the air borne phase of the exercises will be specific to dynamic correspondence principles of the hamstring muscle action during running. Specifically, the very fast opposing hip flexion and hip extension that occurs during the air borne phase (often referred to as the double float phase), requires a great deal of pelvic co-ordination and the research has shown that generation of force in the opposite hip flexor is related to the force generation in the hamstring.[2] The fast scissor action of reciprocal hip extension and flexion also creates an SSC action in the hamstring as there is a fast hip flexion which stretches the hamstring followed by immediate hip extension prior to ground contact. The high power hip extension movement of these plyometric exercises will also train the hip extension power capacity of the hamstring muscle group.

Speed bounding is particularly useful for training the hamstrings due to the fast opposing hip flexion and extension and active hip extension prior to ground contact. Details of the technique

of speed bounding have been written extensively elsewhere. To optimally stress the hamstring, athletes should focus on keeping the trunk upright and stable whilst the legs move very quickly especially in the double float phase. Emphasis on the speed of the hip flexion extension rather than the push force into the floor will ensure the hamstring is trained effectively.

In terms of organisation, speed bounding is often incorporated into traditional plyometric workouts, in which case the hamstring training benefit will be developed. If this type of training is not in the programme, then specifically including speed bounds, along with the running drills, may be a practical way of including this type of training. A few sets of 10 to 20 bounds performed twice a week would be an appropriate level of training. We would recommend developing strength with the hip extension and eccentric exercises and developing dynamic flexibility and SSC co-ordination with the drills, such as B Skips, prior to introducing speed bounding as a hamstring training exercise.

Open Chain Leg Cycles

Another option for training the SSC quality of the hamstring which we have used with some well conditioned athletes, involves using a band or a pulley machine attached to the ankle to provide resistance. The training goal of this movement is for the hamstring to quickly create tension to control the accelerating movement as the weight pulls the legs forward and return the leg backwards quickly. This trains the hamstring to activate quickly through a full range of motion. Load is not important for the benefit. Instead, the speed of movement, provides the benefit with a quick stretch and then contraction of the hamstring muscle. We recommend sets of 8-12 repetitions of this movement, performed 2-3 times per week will develop SSC hamstring performance. Care should be taken with these exercise, as they are not 'tried and tested' in the same way as the others, and given the variety of hamstring stimuli suggested in this article, they may not be necessary. However, to use them effectively we recommend the athlete first achieves good levels of strength and condition on the eccentric exercises and can perform the running drill type movement very well.

Summary

The above discussion attempts to relate both the function of the hamstrings during running and the mechanism and risk factors of hamstring strains with specific exercises. A system of three distinct types of strength and conditioning exercises are proposed — all three with different aims and training guidelines. This multifaceted approach to hamstring conditioning and injury prevention is strongly recommended, given the background theory and evidence of effectiveness. Eccentric training has the greatest body of evidence to support its usage.

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