Hamstrings are fascinating

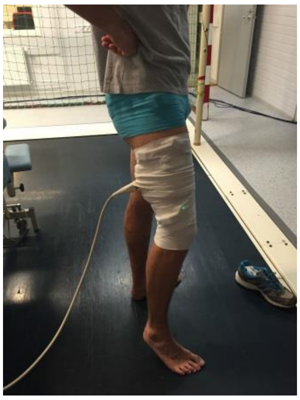
In recent years, scientific interest in hamstring muscle function has increased, in part because of the high (and largely unexplained) incidence of hamstring injuries, especially in fast movements like sprinting.

Broadly speaking, there are two main theories of how hamstring muscles function at the level of muscle fascicles during fast running:

1) The muscle fascicles lengthen during the late swing phase of running (e.g. Fiorentino & Blemker, J Biomech 2014), and such repeated strains of high magnitude and/or velocity could eventually lead to injury. According to this school of thought, eccentric-based training/rehabilitation should be favored because it conditions the muscles to work in a similar way to what is presumed to happen during sprinting.

2) The muscle fascicles are isometric during the late swing phase, and injury results when fatigue or some unexpected event occurs, whereby muscle stiffness is momentarily too small to resist length changes, and thus the muscle is strained and injured (e.g. Van Hooren & Bosch, J Sport Sci 2017). According to this second model, eccentric training would not necessarily be useful for injury prevention, and training/rehabilitation should focus instead on tasks that require high force isometric contractions of the hamstrings.

Clearly, which of these theories is correct (if indeed either are correct) has important implications for what coaches and athletes should do to prevent injuries. The problem is that the first theory relies completely on modelling data, and the other relies entirely on theory, much of which is in turn based on what happens in other muscles such as the triceps surae. Ideally, as noted by Ruan (J Sport Health Sci 2017), a method is required that allows fascicle behaviour to be studied in vivo during tasks such as sprinting, where injuries commonly occur.



In our lab, my PhD student Andras Hegyi and I recently spent approximately one year attempting to solve this problem. We accumulated a wealth of muscle fascicle data from various tasks, including running at a range of speeds, from jogging up to sprinting.

Compared to imaging the triceps surae muscles, this turned out to be quite an ordeal. My personal opinion has always been that ultrasound gives us ‘incorrect’ results, in the sense that the muscle is being imaged in 2D but the muscle (or tendon) actually function in 3D, meaning that we are always missing some information (see my review with Lichtwark, where we discuss this issue among others). However, this issue of ‘3-dimensionality’ seems to be particularly problematic in hamstrings.

Below are a few examples of ultrasound videos taken during dynamic conditions. These are of course not the best case scenarios that we observed, but I include them here to point out some of the difficulties of imaging this muscle group during fast human movement.

Click to see Video 1

The first video shows biceps femoris movement during sprinting in real-time. This video should help to highlight the difficulty of tracking the actual length changes of the muscle fascicles.

The second video (below), which has been slowed down for clarity, illustrates clear 3D rotation of the muscle, as certain structures are visible at some parts of the step cycle but then disappear. As mentioned above, this is a major limitation of all dynamic ultrasound studies based on B-mode imaging, since any length change that occurs out of the plane of the probe cannot be quantified. However, it is particularly pronounced here.

Click to see Video 2

Another important observation from the second video is the long length of the muscle fascicles, making it impossible to image an entire fascicle within the 60mm field of view of most probes. Moreover, most ultrasound systems cannot acquire data at frame rates higher than about 80Hz, so fast movements result in relatively large length changes between consecutive images, which in turn makes tracking of length changes more difficult. All of these issues collectively suggest that making inferences based on what happens in other muscles such as the triceps surae, where the muscle-tendon anatomy is quite different, is not necessarily valid.

Next steps

After struggling with this issue for too long, we decided that we could not place enough faith in most of the data to warrant publishing it. Instead we switched our plan of attack to examining muscle activity using multi-channel EMG arrays, again during a wide range of tasks including running.

With this method we use a single column of small electrodes to examine muscle activity from different sites along the length of a muscle. Of course, EMG is still prone to the same issue of ‘3-dimensionality’ mentioned above, since the electrodes are attached to the skin surface, whereas the muscle moves underneath the surface. However, this method does allow us to examine activity from a much larger area of the muscle, and provides much greater time resolution than ultrasound.

The first papers from our group have started to appear, and we also have mountains of other data that we plan to publish in the near future. It's been a long road to get to this point, but it's also been a great learning curve. We have had the opportunity to work with some outstanding groups, including Francois Hug, Antoine Nordez and JB Morin in France, and Toni Arndt in Sweden. We're looking forward to sharing more of this work with the hamstring community soon…

Paper 1: https://onlinelibrary.wiley.com/doi/abs/10.1111/sms.13016

ORIGINAL ARTICLE

WILEY

Region-dependent hamstrings activity in Nordic hamstring exercise and stiff-leg deadlift defined with high-density electromyography

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Recent studies suggest region-specific metabolic activity in hamstring muscles during injury prevention exercises, but the neural representation of this phenomenon is unknown. The aim of this study was to examine whether regional differences are evident in the activity of biceps femoris long head (BFlh) and semitendinosus (ST) muscles during two common injury prevention exercises. Twelve male participants without a history of hamstring injury performed the Nordic hamstring exercise (NHE) and stiff-leg deadlift (SDL) while BFlh and ST activities were recorded with

Paper 2: https://onlinelibrary.wiley.com/doi/abs/10.1111/sms.13303?af=R

ORIGINAL ARTICLE

WILEY

High-density electromyography activity in various hamstring exercises

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Abstract
Proximal-distal differences in muscle activity are rarely considered when defining the activity level of hamstring muscles. The aim of this study was to determine the inter-muscular and proximal-distal electromyography (EMG) activity patterns of hamstring muscles during common hamstring exercises. Nineteen amateur athletes without a history of hamstring injury performed 9 exercises, while EMG activity was recorded along the biceps femoris long head (BFlh) and semitendinosus (ST) muscles using 15-channel high-density electromyography (HD-EMG) electrodes. EMG