GASTROCNEMIUS MUSCLE TENDON UNIT INTERACTION UNDER VARIABLE GAIT CONDITIONS

[1] Glen Lichtwark, [1]Kostas Bougoulias and [1,2]Alan Wilson
[1]Stucture and Motion Laboratory, Institute of Orthopaedics, University College London. Email: g.lichtwark@ucl.ac.uk
[2]Structure and Motion Laboratory, Veterinary Basic Sciences, Royal Veterinary College. Website: www.rvc.ac.uk/sml

INTRODUCTION

The interaction of a muscle and its attached tendon during dynamic activities such as locomotion is critical for both force production and economical movement. Sonomicrometry studies have revealed that compliant tendons can store and return elastic energy to change the timing and magnitude of muscular work and allow the contractile components to act nearly isometrically, despite substantial length changes in the muscle-tendon unit [1]. This produces higher forces and reduces the energetic requirements of the muscle fibres. Similar results have been reported for human muscle fibres using ultrasonography during slow walking [2].

Using a novel ultrasound probe and setup, we tested the hypotheses that –

1. the *medialis gastrocnemius* (GM) muscle undergoes a homogenous length and structure change across three sites along the length of the muscle (distal, middle and proximal) during walking and running;
2. the GM muscle fibres shorten more during running than during walking .
3. the elasticity of the Achilles tendon enhances GM muscle fibres efficiency under different locomotion conditions

METHODS

6 volunteers (3 male and 3 female) participated in the study. Participants walked and ran on a treadmill at speeds of 4.5km/h and 7.5 km/h respectively. A flat ultrasound probe was attached to the *gastrocnemius medialis* (GM) muscle such that it imaged a transverse section to the leg in the same plane as line of action of the muscle fibres at a rate of 25Hz. Measurements were made at three levels of the muscle; the midbelly and distally and proximally to this position. Muscle fibre length and pennation angle was measured throughout 3 complete gait cycles for each gait condition for each subject. Sagittal plane kinematics were recorded with an active LED motion analysis system (CODA, Charnwood Dynamics, England) and synchronised with the ultrasound data using a sonomicrometry crystal mounted on the ultrasound probe. Length changes of the *gastrocnemius medialis* (GM) muscle-tendon unit length were derived from joint angle data using the equations derived from Grieve *et al* (1978) [3]. Muscle fibre lengths and the pennation angle from the ultrasound images were used along with the whole muscle-tendon length to estimate the tendon elongation [2].

Identical measures were made with 6 male participants during walking (5km/h) at grades of –5,0 and 10% and also during running (10km/h) at grades of 0 and 10%.

RESULTS AND DISCUSSION

The results of the study show that muscle fibres perform similar functions along the length of the human MG muscle during locomotion, regardless of speed or gait. However, they do not act totally homogenously along the muscle lengths

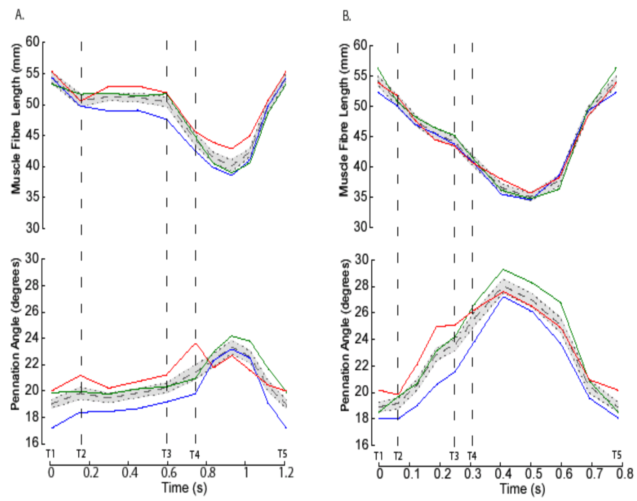

Figure 1: Average length and pennation angle of muscle fibres across one complete stride (heel on to next heel on) during walking (A) and running (B) for each of three three ultrasound sites (distal = blue; midbelly = green; proximal = red). The dashed line represents the average muscle fibre length and pennation angle across all three sites (shaded area is 95% confidence interval). The stride is divided up into the following specific events averaged from the kinematics: T1-Heel strike; T2 – Foot flat; T3 – Heel off; T4 - Toe off; T5 – Heel strike.

(Figure 1). The distal fibres tend to shorten more and act at greater pennation angles than the more proximal fibres. The fibres also shorten more during running compared to walking so that they can produce the forces required to support the body and propel it upwards and forwards. A tendon stretch of approximately 18mm and 25mm during walking and running respectively was estimated. The maximum shortening speed of the muscle tendon complex (6 muscle fibre lengths/s) occurs during the take-off phase of stance. However the muscle fibres never exceed a shortening velocity of above 1.5 lengths per second, even during running. This is a more optimal shortening speed for both power output and efficiency. With variations in grade, the stretch of the Achilles tendon and hence storage of elastic energy is modulated by a change in muscle fibre length. The muscle fibres respond to increases in work demands by activating in an efficient manner to produce the required power output.

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