BUCKLING IN HUMAN MUSCLES AT SHORT LENGTHS

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INTRODUCTION

Skeletal muscles (muscle-tendon units) lengthen and shorten when joints move. At very short lengths, muscle-tendon units fall slack. Little is known about the mechanical behaviour of muscle-tendon units below slack length.

Buckling has been observed in muscle fibres and skinned muscle fibres at very short lengths [1]. In addition, buckling has been reported in the surgically exposed tendon of the extensor hallucis longus of a single subject when the ankle was positioned near the extreme of dorsiflexion [2].

Buckling behaviours in intact muscle and tendon may differ from those in muscle fibre preparations or surgically exposed tendon because elastic stability is determined in large part by boundary conditions. We are unaware of any systematic investigation of buckling in intact muscles.

We used ultrasonography to investigate buckling in the human gastrocnemius muscle in vivo. With ultrasonography it is possible to observe muscles and tendons of intact limbs in which muscles and tendons are subject to natural boundary conditions.

METHODS

Eight healthy adults (three men and five women, aged 26 to 45 years) participated. They were asked to remain relaxed as the ankle was passively moved through its physiological range. Relaxation was monitored with surface electromyography. In some trials participants were asked to actively move the ankle through its physiological range.

Images of the distal gastrocnemius muscle were obtained with an Esaote MyLab25 ultrasound system using a 46 mm 2.0-9.0 MHz linear array transducer (Esaote LA522E). Images were sampled in real time at 15 Hz.

RESULTS AND DISCUSSION

With the gastrocnemius muscle at short lengths (knee flexed and ankle near full plantarflexion) buckling of the aponeurosis (intramuscular tendon) or muscle fascicles could be seen in all subjects. Evidence of buckling was only apparent at the shortest lengths, and it always disappeared with even small degrees of lengthening.

Buckling most often occurred near the distal musculotendinous junction. Most frequently it was seen in the distal end of the distal aponeurosis (Figure 1). Occasionally there were several buckles side by side with a periodicity of 2-4 mm. Sometimes buckling was seen in the distal end of distal fascicles. There was also less clear evidence of buckling in the distal end of the proximal aponeurosis or in more proximal fibres. Often vertical "shadows" (hypoechogenic bands) could be observed deep to buckles.

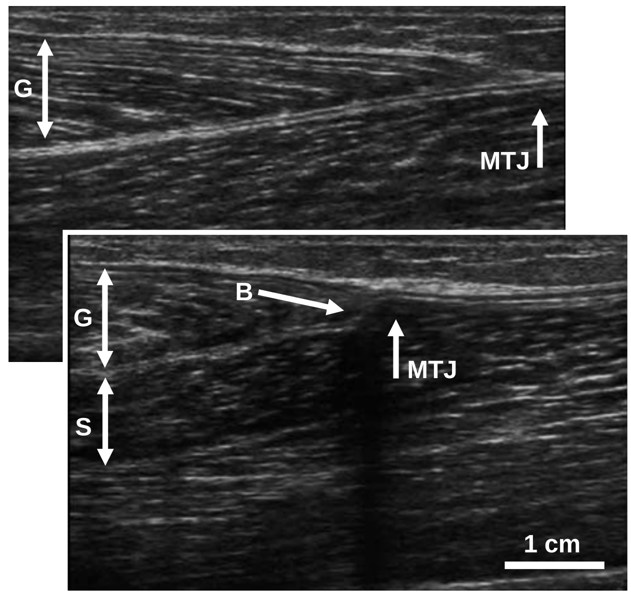

Figure 1: Ultrasound images of the distal gastrocnemius muscle (G). The upper image is with the muscle at a stretched length and the lower image is with the muscle at its shortest in vivo length. The gastrocnemius tapers distally to the muscle-tendon junction (MTJ). The soleus (S) lies deep to gastrocnemius. The oblique arrow (B) identifies buckling in the distal aponeurosis. There is a hypoechogenic shadow deep to the buckling.

The buckling behaviours observed during active contraction to very short lengths appeared to be very similar to those observed during passive shortening.

CONCLUSIONS

To our knowledge this is the first report of buckling in intact human muscles. We observed some evidence of buckling of aponeurosis or muscle fascicles in all the subjects we examined.

We conclude that buckling routinely occurs in the gastrocnemius muscles of healthy subjects at extreme short lengths. Buckling is most evident in the aponeurosis, close to the musculotendinous junction, and may also be apparent in nearby muscle fascicles. The presence of buckling confirm at least some components of the muscle-tendon unit fall slack at short lengths.

REFERENCES

1. Brown LM, et al., *J. Muscle Res. Cell Motil.* **5**:293-314, 1984.
2. Refshauge KM, et al., *J. Physiol*.; **513**: 307-314, 1998.