Measurement of anterior tibial muscle size using real-time ultrasound imaging

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Summary. Cross-sectional images of the anterior tibial muscle group were obtained using real-time ultrasound scanning in 17 normal women. From photographs taken of the images, the cross-sectional area (CSA) and two linear measurements of muscle cross-section were determined. A measurement of the shortest distance of the muscle depth was termed DS, and a measurement of the longest distance through the muscle group was termed DL. Both linear dimensions showed a positive correlation with CSA and the best correlations were obtained when the dimensions were squared or combined (DS x DL). The correlation values were: CSA vs DS², r=0.9; CSA vs DL², r=0.75 and CSA vs DS x DL, r=0.88. An approximate value for CSA could be calculated from DS² by the equation 2 x DS² + 1. A shape ratio, obtained by dividing DL by DS, was consistent within the group [mean 2.1 (SD 0.2)] and characterised the muscle geometrically. The CSA of repeated scans was assessed for repeatability between-days and between-scans by analysis of variance and the coefficient of variation (CV) calculated. Areas were repeatable between-days (CV 6.5%) and between-scans (CV 3.6%). Linear dimensions of the anterior tibial muscle group reflected CSA and their potential for assessing changes in muscle size with atrophy and hypertrophy have yet to be established.

Key words: Ultrasound imaging – Muscle size – Anterior tibial muscle group

Introduction

The anterior tibial muscle group is important in gait which may be seriously impaired if the muscles become weak and wasted. Conditions affecting these muscles include: lower limb trauma such as fractures and overuse injuries, e.g. anterior compartment syndrome; peripheral neuropathy in pathological conditions or, e.g. pressure palsy from plaster of Paris; radicular neuropathy; hemiparesis; neuromuscular diseases.

For the purposes of the present study, the peroneal muscles were included with those of the anterior compartment since the two groups are not easily distinguished with real-time scanning (see below). Assessment of the anterior tibial muscle group is often limited due to the severity of weakness, pain, spasticity, and the presence of fractures. These factors may render strength measurements difficult, unreliable or even impossible. Muscle strength is related to cross-sectional area (CSA) in different muscles, e.g. in the quadriceps where the predictive value of size measurements can be utilised in rehabilitation (Stokes and Young 1986). This relationship applies to men and women of different ages although some young men are stronger than would be expected for the size of their muscles (Maughan et al. 1983; Young et al. 1984, 1985). It would be useful to characterise the anterior tibial muscle group in terms of its size to provide an indication of the muscles’ force generating capacity. The anterior tibial muscle group can be used for muscle biopsy (Dietrichson et al. 1987) both for diagnosis and research studies of fibre size, and histological and biochemical properties. Noninvasive measurement of muscle size would be preferable to biopsy for serial measurements and might also complement biopsy findings.

Measurements of muscle size cannot be made accurately using a tape measure (Young et al. 1980) but diagnostic imaging techniques allow direct, accurate measurement of muscle CSA. These techniques include computerised axial tomography, magnetic resonance imaging and compound ultrasound B-scanning. Their relative usefulness in rehabilitation research has been discussed elsewhere (Stokes 1985; Stokes and Young 1986). Real-time ultrasound scanning is cheaper, more portable and more widely available than the other techniques and is therefore potentially useful for serial measurements in rehabilitation, although validation studies are still required.

With real-time ultrasound scanning, an image of only part of a section through a limb can be obtained,
so the CSA of large muscles such as the quadriceps cannot be measured. The anterior tibial muscle group is small enough for the whole cross-section to be included in one image if the scanning probe is large enough. Despite this, some workers have used linear measurements to estimate the size of the anterior tibial muscle group (Gershuni et al. 1982; Brahim and Zaccardelli 1986). Other muscles have also been measured using linear dimensions to study muscle wasting (Doxey 1987; Heckmatt et al. 1988a) and hypertrophy (Heckmatt et al. 1988b; Weiss et al. 1988). None of these studies attempted to validate the use of linear dimensions as predictors of CSA.

The present study therefore examined the relationship between linear dimensions of the anterior tibial muscle group and its CSA to assess the validity of their use to estimate muscle size in young women.

**Methods**

*Subjects.* Seventeen healthy women, aged 18–35 years, were studied. None had a history of significant lower limb or back injury, neuromuscular or musculoskeletal disorders. None had tightness of the calf restricting ankle dorsiflexion past plantigrade, or were elite athletes or undergoing regular training for competition, or ingesting any drugs which might affect muscle function. All subjects were volunteers and gave their written, informed consent to participate in the study.

*Experimental equipment.* Two real-time ultrasound scanners were used as one machine broke down during the study. One machine was a Pie Data medical scanner 700, Pie Data Ltd, Maastricht, The Netherlands, with a 5 MHz linear array transducer containing 56 elements with an array length of 6 cm. A “freeze-frame” facility allowed an image to be stored and then photographed using a Shackman 700 polaroid camera, Pie Data Ltd, Maastricht, The Netherlands. The second machine was a Toshiba SAL-32B, Toshiba Ltd, Nasu, Japan, with a 5 MHz transducer with 64 elements and an array length of 8 cm. Both machines were calibrated before and after the study period.

An image analyser (Delta T Devices area meter, Delta T Devices Ltd, Cambridge, UK, with Kaga television monitor, Kaga Ltd, Tokyo, Japan, and ITIC Ikegami video camera, ITIC Ltd, Tokyo, Japan) was used to measure muscle CSA.

*Scanning Technique.* The leg preferred for kicking was studied. With the subject supine, the lower limb was positioned with the hip in neutral, the knee extended and the ankle in neutral. This position was maintained by a padded wooden brace and sandbags.

The level of scanning was selected after anatomical consideration (Warwick and Williams 1973) and previous studies which indicated that maximal muscle mass is found at 20% of the distance from the head of the fibula to the lateral tip of the lateral malleolus (Gershuni et al. 1982; Brahim and Zaccardelli 1986). This site was marked on the skin with a marker pen.

The principles of ultrasound scanning have been described elsewhere (e.g. Lunt 1978; Stokes and Young 1986). Briefly, the ultrasound transducer acts as a receiver and a transmitter as sound pulses emitted from the transducer are reflected back to it from tissue interfaces which are at, or near, 90° to the beam. Each interface appears as a dot on the screen and the position of the dot depends on its distance from the transducer, estimated by the time taken for the emitted pulse to be reflected back to the source. In a linear array real-time ultrasound transducer, there are a number of crystals emitting sound pulses in parallel so that the dots appear as lines showing the muscle boundaries and bone surfaces. The image is displayed on the screen where it can be measured directly or photographed (Fig. 1). The muscles in the anterior tibial group scanned at this level included tibialis anterior, extensor hallucis longus, extensor digitorum longus and the peronei. This whole group was considered to constitute the anterior, as opposed to posterior, muscle tibial group for the present purposes.

Ultrasound coupling gel (Littmann TM, 3M Australia Ltd, Thomleigh, NSW Australia) was spread over the skin and the transducer. A piece of semi-solid stand-off gel (Kitecko, 3M Australia Ltd, Thomleigh, NSW Australia) 3.5 cm thick was used to increase the field of view and to prevent skin compression during scanning. The probe was placed on the gel at the required level on the leg, with the transducer held at such an angle that the ultrasound beams were aimed at 90° to the muscle borders to ensure a clear image. Controls for contrast, brightness and near and far gain were adjusted to obtain a satisfactory image.

The CSA of the muscle group was bordered antero-laterally by subcutaneous fat, posteriorly by fascia between this group and the soleus muscle, medially by the fibula and interosseous membrane and antero-medially by the tibia (Fig. 2a). The outline of the muscle group was traced on to a transparent sheet and the following two linear dimensions were measured with a metric ruler:

1. The shortest distance from the mid-point of the muscle group border with the interosseous membrane and fibula to the outer border of the muscle group (Fig. 2a); this distance was termed DS and runs between points A and B in Fig. 2b.
2. The distance between points C and D in Fig. 2b was the longest distance through the muscle group and this was termed DL. Thus, DS could be considered to be a measure of muscle depth or thickness (Gershuni et al. 1982; Brahim and Zaccardelli 1986) and DL a measure of muscle length in cross-section.