ULTRASOUND MEASUREMENT OF NON-UNIFORM DISPLACEMENT WITHIN THE ACHILLES TENDON DURING WALKING

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INTRODUCTION

Force transducers have previously been used to measure forces in the Achilles tendon (AT) [1,2]. Force transducers are inserted into the tendon and these methods are therefore invasive to varying degrees [1,2]. Ultrasound offers a non-invasive way of visualizing tendons. Velocity and displacement measurements can be made using the speckle tracking method. The aim of this study was to combine ultrasound registrations of the Achilles tendon, EMG activity in the triceps surae and plantar pressure data during walking. The data presented describes the correlation between movements within the tendon and muscle activation during walking.

METHODS

Ten healthy subjects were fitted with a lower leg orthosis not including the ankle to which an ultrasound (US) probe was mounted over the AT (Vivid 7 equipped with a 12 MHz linear probe, GE, Norway). The probe was placed longitudinally over the tendon so that the posterior process of the tibia was visible distally. Muscle activity was recorded for the medial gastrocnemius (gm), soleus (sol) and tibialis anterior (ta) muscles. Pressure distribution under the feet was measured using Pedar insoles (Novel GmbH, Germany) held in place with compression stockings. Subjects walked on a treadmill at two different speeds, 2 km/h and 3 km/h, and 10 trials were performed at each speed. During the post process image analysis of the US loops, a speckle tracking algorithm (Echopac, GE, Norway) was applied to the grey scale images. The speckle tracking algorithm makes use of patterns of tissue generated acoustic reflectors which are followed frame by frame. A region of interest (ROI) was manually placed, vertically to the direction of the tendon, in the first frame. The ROI consisted of three measurement segments (yellow, blue and green) and hence three portions of the tendon (posterior, central and anterior) could be analyzed simultaneously (see figure 1a). The relative velocity and displacement of the three portions were calculated. Data from the sensor insoles identified heel strike (HS), flat foot (FF), heel off (HO) and toe off (TO) for each step.

RESULTS AND DISCUSSION

The ultrasound probe positioning was firm as shown by the good quality ultrasound recordings made during walking
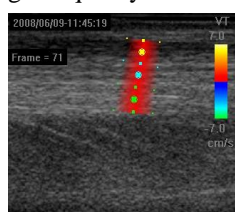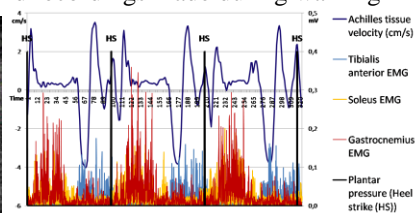

Figure 1a.   Figure 1b.

Figure 1a. The ROI with three measurement segments in the AT.
Figure 1b. Data from three steps separated by black vertical lines. Muscle activation pattern from ta, sol and gm according to EMG are shown at the bottom.. In the upper part corresponding synchronized AT tissue responses are seen.

The results showed a good reliability over multiple gait cycles (see figure 1b) permitting good identification of the different gait phases (see figure 2).
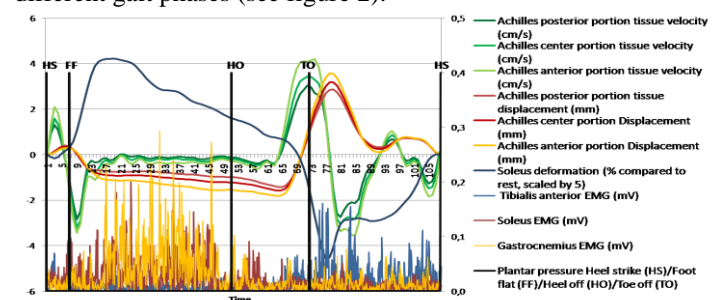

Figure 2. Combined data over one step (US, EMG and plantar pressure).

The vertical black lines in figure 2 represent HS, FF, HO and TO. EMG (RMS) of sol, gm and ta is shown at the bottom. The smooth curves in the middle of the figure show tissue activation consistent with US. Red curves show the velocities in three portions of the tendon, while green curves show the corresponding tissue displacement in each tendon portion. The velocity curves distinctly demark the different stance phases with positive values corresponding to plantar flexion and negative values to dorsiflexion. Table 1 shows the velocity and displacement in each portion of the tendon during activation demonstrating the non-uniform dynamics within the AT.

Table 1. Velocity and displacement in three tendon portions.

Tendon portion	Max velocity (cm/s)	Max displacement (mm)
Posterior portion	3,17	2,13
Central portion	3,50	2,56
Anterior portion	3,94	3,31

CONCLUSIONS

Good reliability was found between subsequent gait cycles and these cycles could be identified in the speckle tracking analysis. Synchronization of US and EMG permitted correlation of muscle activation and tissue dynamic activity during functional real time performances.

REFERENCES

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