INTRODUCTION

Recent studies of walking at self-selected speeds have shown how individual muscles work in synergy to satisfy task demands including support, forward progression and swing initiation (e.g. Neptune et al., 2001; Anderson and Pandy, 2003). However, how muscle activity changes with increasing walking speed is not well understood, since all the task demands should not be expected to change in a same manner. Intuitively, increasing walking speed would necessitate an increase in activity for muscles that contribute to forward progression. However, since increasing walking speed is associated with longer stride lengths (e.g., Holden et al., 1997), which also increase the vertical excursion of the body’s center-of-mass, increased output may be required from muscles contributing to swing initiation and vertical support. However, in addition to mechanically inspired increases in muscle force, muscle activity may increase due to intrinsic factors such as muscle force-length-velocity relationships. Previous studies have examined the effect of walking speed on muscle activity using EMG measurements, but these studies either examined a limited set of muscles or walking speeds (e.g., Yang and Winter, 1985). Therefore, the goal of the present study was to examine EMG patterns of the major lower extremity muscle groups across a wide range of speeds to assess whether all muscle activity systematically increases in response to increasing walking speed.

METHODS

Ten subjects walked at speeds of 0.7, 1.0, 1.3 and 1.6 m/s on a split-belt treadmill instrumented with force plates while simultaneous ground reaction force, EMG and 3D motion data were collected. EMG data from the gluteus maximus (GMAX), rectus femoris (RF), vastus medialis (VAS), biceps femoris long-head (BF), tibialis anterior (TA), soleus (SOL) and medial gastrocnemius (GAS) were collected at 1200 Hz and full-wave rectified, low-pass filtered and normalized to the maximum value observed for each muscle at the highest walking speed. For the motion data collection, a modified Helen Hayes marker set was used to establish lower extremity joint kinematics. At each speed, data were averaged across trials within each subject and then across subjects.

RESULTS AND DISCUSSION

As walking speed increased, muscle EMG also systematically increased in a mostly linear fashion from 0.7 to 1.6 m/s, although there was a more dramatic increase in GMAX, RF, BF and SOL from 1.3 to 1.6 m/s (Fig. 1). The only instances of muscles not increasing activity with speed were SOL and GAS, which showed a negligible increase in activity from 0.7 and 1.0 m/s. This is intriguing considering their importance in meeting the task demands of support, forward progression and swing initiation (e.g. Neptune et al., 2001). For 8 of 10 subjects, the difference in ankle angular velocity at the two slowest speeds was also negligible, suggesting that the SOL and GAS fiber velocities may be operating at the same contraction speeds at 0.7 and 1.0 m/s, and therefore do not have to increase activity to compensate for force-velocity effects to produce the same amount of force.
In addition, at the highest walking speed, secondary bursts of RF and VAS activity developed during late stance (Fig. 1). These bursts may be related to the inability of SOL to satisfy the energetic requirements during preswing, since RF, VAS and SOL act to accelerate the knee into extension in late stance phase. Interestingly, the secondary bursts of activity are also a phenomenon observed in transtibial amputees when the plantar flexors are absent (e.g., Winter and Sienko, 1988).

There are many factors that influence muscle activity including the force-length-velocity relationships, increased negative muscle work and changes in the energetic demands of the task. Future work will be directed at understanding these complex interactions and how they influence the required muscle activity as walking speed increases.

REFERENCES


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