DOUBLE TWITCH CHARACTERISTICS OF THE TRICEPS SURAE MUSCLES - RELATIONSHIP TO MAXIMAL BOUNCE JUMPING.

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INTRODUCTION

The predominantly fast twitch gastrocnemius and the slower soleus muscle act in synergy around the ankle joint. These two muscles represent the final link in the kinematic chain for producing work around this joint during a jump. During one-legged jumping it has been suggested that the biarticular gastrocnemius muscle is responsible for some 25% of the total work done around the ankle in the push-off phase (Bobbert et al. 1988). In earlier studies, a preferential involvement of soleus was seen in postural tasks with an increase in activation of gastrocnemius with increasing demands of force and speed in tasks such as hopping and running (Moritani et al. 1991a & b). This task specific activation of soleus and gastrocnemius was demonstrated both at the muscular and spinal level through the use of electromyographical and H-reflex techniques, respectively (Moritani et al. 1990a). In another study, electromyographic evidence of selective fatigue during the eccentric phase of bounce jumping was found (Moritani et al. 1990b). In a group of subjects dominated by athletes with vast experience in training for power, electromyographic activity of the relatively fast-twitch gastrocnemius muscle was affected by fatigue to a much greater extent than the slow-twitch synergist soleus. The purpose of this study was to relate mechanical twitch characteristics and electromyographical fatigue properties of the triceps surae muscles to jumping performance in subjects with major differences in their training history.

METHODOLOGY

Eight males, including a former elite volleyball player, a former elite gymnast, four elite runners (two middle distance and two long distance) one triathlete and one sedentary subject participated in the study. Their selection represented sports with large differences in the demands of endurance and power. Their mean (±1 standard deviation) body mass, height and age were 59.6±8.9 kg, 1.70±0.06 m and 25.9±8.8 years, respectively. Maximal twitch responses of the ankle extensor muscles were recorded before fatigue with the right foot tightly strapped to a mechanical device instrumented with a strain gauge. The tibial nerve in the popliteal fossa was electrically stimulated at supramaximal level through surface electrodes using either a single or double 1 ms pulse. The double twitch protocol ranged from 2.5 to 200 Hz (Fig. 1). Each subject performed maximal bounce jumping (BJ) on a force plate for 80 s with the instruction to hold their hands on their hips and maintain minimal ground contact time and maximal jumping height throughout the test. Electromyographic activity was recorded (EMG) with surface electrodes from the medial gastrocnemius and soleus muscles. The raw EMG signal was rectified and integrated for further comparative analysis during preactivation (activity prior to landing), eccentric muscle action (activity from landing until peak force) and concentric muscle action (activity from peak force until cessation of muscle activity). Myoelectric signals were bandpass-filtered (5-1000 Hz) amplified and digitized together with the force signals at a sampling rate of 2 kHz by an on-line computer system. For further description of the experimental setup and data analysis procedures see Moritani et al. 1990b & 1991a.

RESULTS

Twitch responses

An example of twitch fusion for the different stimulus frequencies is shown in figure 1. First sign of fusion between consecutive twitches was seen between 4 and 5 Hz for all subjects. Maximal fusion occurred at frequencies ranging from 30 to 200 Hz for the different subjects. Single twitch peak force ranged from 100-184 N (135±26 N, Mean±1SD) and the double twitch between 188-336 N (264±52 N) respectively. This corresponded to a single to double twitch force ratio between 1.89 and 2.31 indicating that some subjects did not double the single twitch peak force in the double twitch protocol.

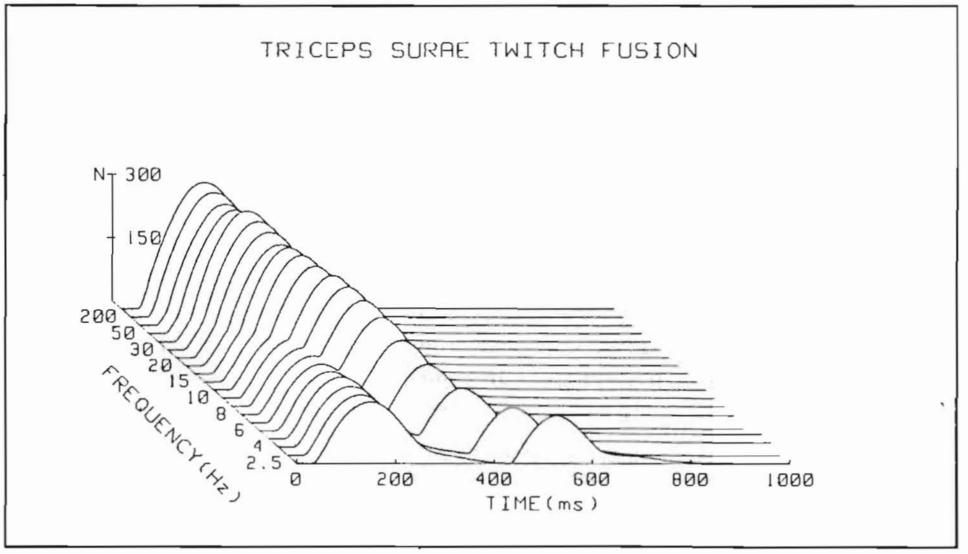

Figure 1. An example of twitch fusion for one subject during gradually increasing stimulation frequency.

There was a negative correlation between fusion rate at 200 Hz and the effect of fatigue during BJ measured as loss of height at the end of the fatigue test in relation to initial BJ height. Thus, subjects with a high degree of fusion showed a higher degree of fatiguability ($r=0.71$, $p<0.05$). If the sedentary subject was excluded from the analysis there was a significant relationship between the rate of increase in twitch force (dF/dt, N/ms) at 20 Hz stimulation and BJ height ($r=0.77$, $p<0.05$).

EMG responses

Figure 2 shows the relative amount of preactivation in soleus and gastrocnemius in the initial phase of the fatigue test (part of the integrated activity appearing before landing) in relation to maximal BJ height. This relationship was highly significant for soleus ($r=0.92$, $p<0.05$) but non-significant for gastrocnemius (Fig. 2). Subjects with a low BJ height showed less preactivation of the soleus muscle. The sedentary subject had low preactivation levels in both muscles (Fig. 2). The relative integrated EMG level of the soleus muscle remained similar in the preactivation and eccentric phases of contraction during 80 s of BJ. The individual differences in these phases were rather large. However, in the concentric phase there was a marked decrease in activity level (59±17% of the initial value for soleus). This was parallelled by a significant decrease in BJ height (74±15% of initial height). Similar changes were seen for gastrocnemius (59±20%).

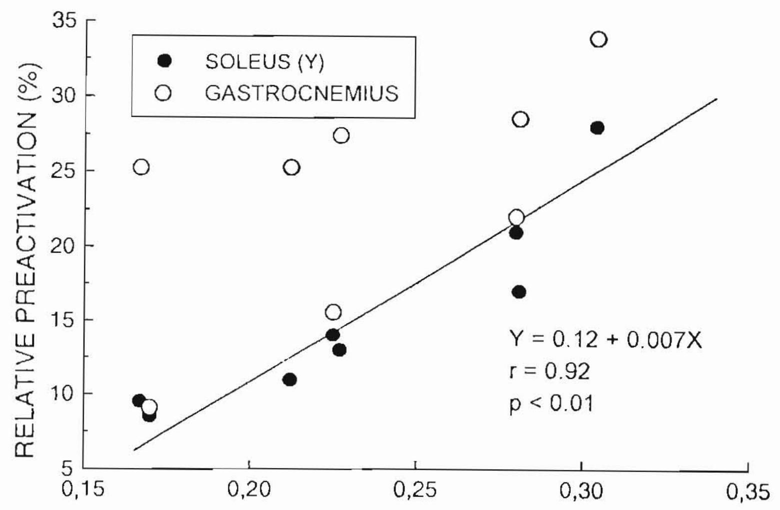

Figure 2. The relationship between maximal jumping height and level of preactivation in the gastrocnemius and soleus muscles during BJ.

DISCUSSION

The results of this study have demonstrated a close relationship between twitch and fatigue responses of the triceps surae muscles and performance in a complex task such as bounce jumping. Interestingly, subjects unable to double the single twitch peak force in the double twitch protocol were middle- or long-distance runners with a history dominated by endurance training. A similar tendency was also seen for the maximal rate of force increase during single and double twitch, i.e. endurance trained subjects did not double their df/dt value whereas the others did, including the sedentary subject. Furthermore, endurance athletes displayed lower jumping heights and markedly less preactivation of the soleus muscle during bounce jumping than subjects involved in sports demanding higher levels of power. The only sedentary subject in the study showed low levels of preactivation in both muscles. The results are generally in agreement with our earlier findings except that gastrocnemius EMG decreased in all phases of the movement in a group dominated by skilled jumpers, whereas in this group the decrease was mainly seen in the concentric phase (Moritani et al. 1990b).

CONCLUSION

These results demonstrate that subjects involved in long term endurance training may show less preactivation of the soleus muscle during maximal bounce jumping than subjects with a history of power dominated training. This may indicate that training history can influence the distribution of muscle activity within a muscle synergy. The results also indicate that mechanical twitch characteristics can be used to evaluate jumping performance. Such knowledge is important for coaches to objectively evaluate progress in the training process.

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