LOWER EXTREMITY MUSCLE FUNCTION DURING ERGOMETER ROWING

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Introduction

Biomechanists have relied upon several ways to determine the functional role of muscles. It is generally agreed that, to do positive work at one joint, a muscle must be shortening. If the pull from the muscle geometrically corresponds to the direction of the joint's motion, the muscle is said to be an agonist to the movement. This simplistic approach needs to be somewhat expanded when one wants to determine the role of a muscle that bridges more than one joint. In spite of the numerous publications that have emerged on this topic over the past decade, researchers' interest in the assessment of biarticular muscle function is not recent. Cleland (1867), Lombard (1903), Elftman (1939), Molbech (1965) and Rasch and Burke (1978) have presented various explanations of two-joint muscle behaviour. One interesting suggestion from the literature is the possibility for a biarticular muscle to act in a paradoxical fashion, that is to generate work in a way that differs from its expected anatomical role.

Purpose

The purpose of this study was to determine the functional role of six prominent leg muscles, three of which are biarticular, during the extension of the knee joint.

Classification Scheme for Muscle Function

The scheme proposed to define the functional role for each of the six muscles under investigation comprises four mandatory criteria. To assess whether a biarticular muscle behaves paradoxically, the following conditions must hold. First, the net moment of force at the joint must produce positive work (*i.e.*, positive power). Second, the biarticular muscles must be in a state of contraction. The basic criterion for the determination of significant muscle activity is chosen as 25% or more of the maximum pre-recorded EMG level (which was based on one MVC). Accordingly, an EMG level of less than 25% of the maximum is considered too low for the muscle to contribute significantly to the movement. Third, the muscle must be contracting concentrically, that is, it must be shortening. An isometric or an eccentric contraction of the muscle would imply a stabilizing function. Fourth, the generally accepted anatomical role of the muscle must be compared to the direction of the net joint moment of force: if both are in accordance, the muscle is defined as an agonist to the motion. If both are opposite, the muscle is depicted as a paradoxical agonist. It must be pointed out that, in this study, the possibility of waste through inefficient antagonist muscle contractions was rejected based on the premise that, in skilled athletes, each muscle contraction has a purpose.

Methods

Since the rowing motion constrains the extension of the knee while the sliding seat allows for free steered movement in the sagittal plane, a rowing ergometer (Gjessing) ErgoRow) was used and instrumented. To provide direct three-dimensional measurement of the forces applied by the subject's feet, a force platform (Kistler) was mounted on an incline and inserted to support the foot stretcher. The muscles investigated were the monoarticular vastus lateralis, soleus, gluteus maximus and the biarticular biceps femoris, rectus femoris and gastrocnemius. Four female and four male elite rowers performed on the ergometer while kinematic information was recorded at 50 Hz on 16 mm cinefilm. The force applied to the stretcher, the force applied to the oar handle and the linear envelope EMG were sampled simultaneously at 200 Hz for twelve rowing cycles.

The instantaneous length of each muscle was computed from the digitized image of the cinefilm with an adaptation of Frigo's and Pedotti's (1978) muscle length model. Through inverse dynamics, the net moments of force produced at the ankle, knee and hip joints and the powers from these moments were computed for one cycle using the Biomech package (University of Waterloo). The change in muscle-tendon length and the EMG activity of the muscles were looked at in conjunction with the results from an inverse dynamics analysis.

Results

The following results pertain to one subject and are presented as representative. The results obtained from each athlete were looked at individually to prevent the loss of information that would have ensued from averaging between subjects. A sample of the normalized linear envelope EMG obtained from each of the six muscles is displayed in Figure 1; the curves represent the amplitude averaged over ten entire cycles for that subject. The shortening rates of the same muscles (time normalized to the duration of the drive) are plotted in Figure 2.

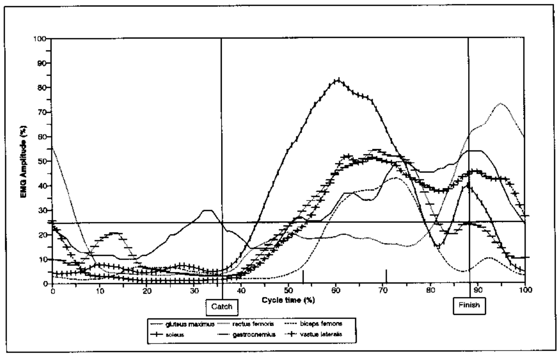

Figure 1. Linear envelope EMG for the six muscles) male subject) rmdh.

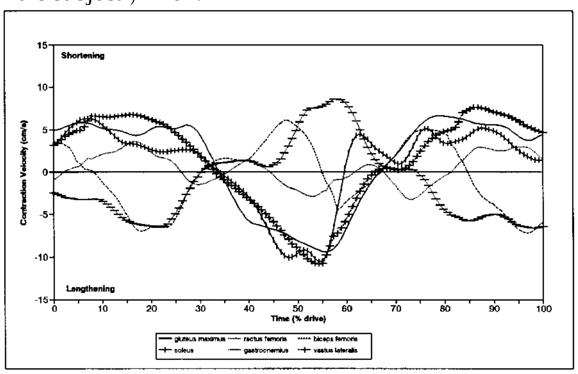

Figure 2. Muscle kinematics: contraction velocity for the six muscles) male subject) rmdh.

The third figure is a sample graph from the same male subject and depicts, for the knee joint, the angular velocity, the net joint moment of force and the power from the moment of force. To provide more accuracy, the drive phase has been divided in three equal parts; each criterion delineated by the classification scheme was verified for each muscle during each third of the drive. According to the classification system, the biceps femoris and the gastrocnemius muscles emerged as paradoxical agonists during the extension of the knee in four and three subjects (out of a total of eight), respectively. The rest of the drive time, when active, these muscles were mainly used to stabilize the joint(s). A novel action has also been found for m. rectus femoris which appeared to act as a paradoxical agonist for hip extension in six out of eight subjects.

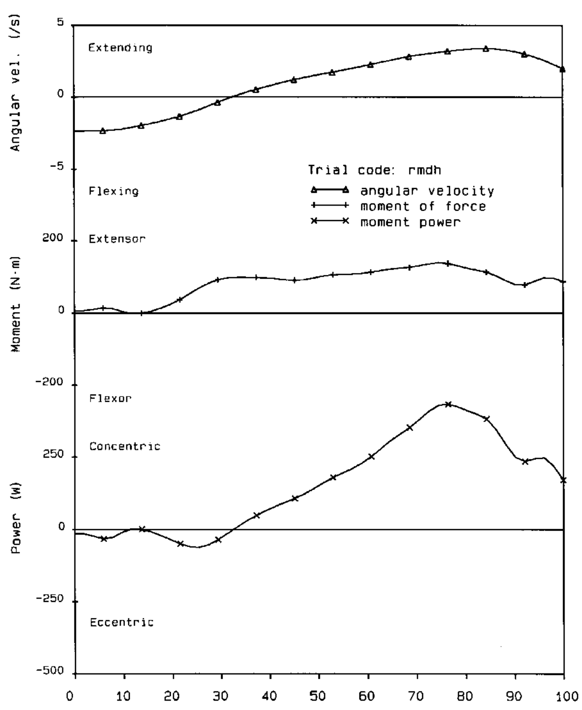

Figure 3. Knee angular velocity, net moment of force and power) male rower) rmdh.

Discussion

The EMG curves in Figure 1 show that most muscles contracted in phase with each other; in this instance, most were active (EMG > 25%) during mid-drive. The contraction velocity curves (shortening rates) presented in Figure 2 suggests a triphasic trend: while some of these muscles shorten, the others lengthen and *vice-versa*. The angular velocity curve portrays relatively slow joint motion (below 4 rad s^{-1}). The moments of force at the knee were considerable but not large since the work was done by both legs. In this case concentric power was extending the knee during mid- and late drive. With regard to paradoxical behaviour, a reduced need for stabilization of the joints)the rowing motion being performed in a steered sitting position)may account for the peculiar character of these observations.

Conclusions

Paradoxical activity appeared to take place in the recruitment of the biarticular gastrocnemius and biceps femoris during the extension of the knee. More intriguing was the detection of paradoxical activity from the action of m. rectus femoris at the hip which it seemed to extend.

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