MUSCLE FIBER BEHAVIOR DURING DROP JUMP IN HUMAN

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INTRODUCTION

Many human movements such as jumping and running involve muscle actions in which a concentric phase is immediately preceded by an eccentric phases. This is generally referred to as stretch-shortening cycle exercise (SSC). It is generally observed that mechanical power output and efficiency are enhanced in SSC, which has been attributed to some mechanisms, one of which is the storage of elastic energy during pre-stretch and its release. However no research has so far been done to determine in vivo behavior of muscle fibers and tendinous tissues in human movements during SSC. The purpose of the present study is to determine the in vivo behavior of muscle-tendon complex during drop jump by means of real-time ultrasonography and to discuss the functional role of contractile (muscle fibers) and elastic elements (tendinous tissues).

METHODS

Subjects. Eight healthy male subjects (age 23 ± 5 yr, height 1.72 ± 9.9 m, and body mass 68 ± 11 kg) participated in this study. All subjects gave their informed consent to participate in the experiment.

Experimental protocol. Subjects with bare feet performed several drop jumps (DJ) from a height of 0.2 m, keeping with their arms akimbo. During DJ kinematic, kinetic and ultrasonographic data as well as electromyograms from lower leg muscles were obtained simultaneously. The behavior of muscle fascicles (fiber) and tendinous tissues of gastrocnemius medialis were observed by means of real time ultrasonic apparatus (SSD-2000, Aloka, Japan) using electronic linear array probe of 7.5 MHz. The probe was carefully fixed onto the tissue surface with a specially designed tool and elastic tape to prevent oscillation, which may occur during jumping. The length of fiber was measured as the length of the echo that runs diagonally from the superficial to the deep along the fascicle. The fascicle angle (pennation) was obtained as the angle between the deep aponeurosis and the line drawn tangentially to the fascicles. During DJ the ultrasonic images of the MG were stored consecutively in the cine-memory of the ultrasonic apparatus set to operate at 40 frames/sec. The instantaneous length of MTC for MG was obtained from the equations developed by Grieve et al (1978). The length of tendinous structures was calculated from following equation,

$$L_t = L_{mtc} - L_f \bullet \cos\theta$$

where L_f, θ, and L_{mtc} are fiber length, fiber angle and MTC length, respectively.

The force exerted by MG was calculated by the plantar flexion torque and moment arm, under the assumption of that the MG force was equivalent to the relative physiological cross-sectional area of MG to the total plantar flexor area (i.e. 15.4 % by Fukunaga et al 1996). Net joint torque around the ankle and knee were calculated using inverse-dynamics (Winter, 1990).

RESULTS

After touchdown of feet onto the force platform, the downward displacement of mass center of body (MCB) was turned toward upward before 100ms of toe off. During MCB downward-phase, the L_{mtc} increased by 4%, L_f decreased from 43 to 35 mm and L_t increased from 370 to 400 mm. After the MCB turned upward (upward-phase) the L_{mtc} decreased by 7 %, while the L_f kept approximately constant of 35 mm accompanying with decreasing of the L_t by 6.5 %. The fascicle angle changed due to changing L_f . Mechanical work during downward-phase were calculated positive 2.6 J for fascicle and negative 7.6 J for tendinous tissue. During upward-phase the fascicle exerted positive work of 1.9 J and the tendinous tissue performed positive work of 5.8 J.

DISCUSSION

Higher performance in DJ has been explained by the enhancement of mechanical work due to storage and reutilization of elastic energy (Komi, 1992). In the present study during downward-phase the tendinous structures stored elastic energy (equivalent to 66 % of total work of MTC) and remaining work of 34 % was originated from concentric contraction of muscle fiber. In the following upward-phase 76 % of the total mechanical work done by MTC was accounted from reutilize the elastic energy in tendinous tissue. The present results demonstrated that the explosive power during DJ is due to mainly rapid recoil of tendinous structures, allowing the quasi-isometric contraction of muscle fibers.

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