

## EFFECTS OF TIMING OF MUSCLE ACTIVATION ON PERFORMANCE IN HUMAN VERTICAL JUMP

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### INTRODUCTION

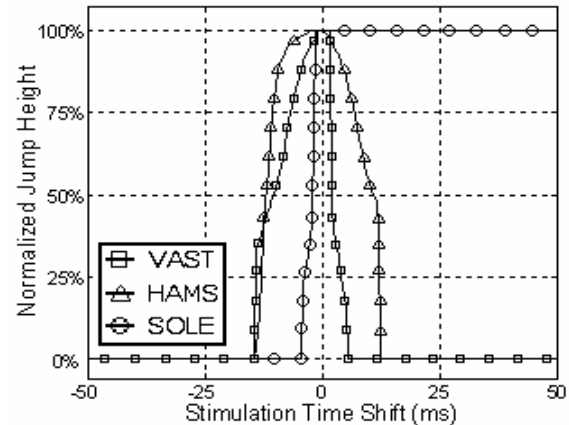
The sensitivity of human movement on precise neural control is noteworthy problem in terms of movement control and sports biomechanics. Previous studies demonstrated that human vertical squat jump is very sensitive to precise timing of muscle action [1,2]. Present study investigates quantitatively the effects of time shift of individual muscles and group of muscles on jump performance. Three research questions were addressed: (i) what is the effect of altered muscle activation timing on jump height and kinematics (ii) how disorder of muscle coordination cause decline in jump performance (iii) what is the minimal shift of muscle activation timing that significantly alter jump height.

### METHODS

Forward dynamics computer simulation of vertical squat jump was used in present study [3]. A human musculoskeletal model of lower extremities was three dimensional and consisted of nine rigid body segments (i.e. head-arms-trunk, right and left upper legs, right and left lower legs, right and left feet, and right and left toes). The body was modeled as 20 degree-of-freedom linkage which was free to make and break contact with ground. A total number of 26 Hill-type musculotendon actuators drove the model. An optimal control of muscles activation pattern was found through numerical optimization where Bremermann's method was applied. As an objective function we used a maximum height reached by the mass centroid of the body. In order to evaluate the effects of timing of muscles activation on the performance of vertical jump, the optimal activation time of each muscle was systematically altered by the interval of 0.1 ms in the range  $\pm 50$  ms. Altered were either muscle onset time, muscle offset time, or muscle switching time (total activation duration remained constant but onset and offset times were shifted equally). Time shift was applied separately to each of eight individual muscles (m. gluteus maximus, m. adductor magnus, hamstrings, m. rectus femoris, mm. vasti, m. gastrocnemius, m. soleus, and other plantarflexors) and to each muscle functional group.

### RESULTS AND DISCUSSION

The numerical optimization procedure generated a natural-looking and smooth squat jumping motion where jump height was 34.6 cm. Muscle control (i.e. muscle activation timing) in jump was very sensitive to a shift applied to onset activation time. It was found the changing activation timing of certain muscles (i.e. mm. vasti, m. soleus and hamstrings) by as little as 2-3 milliseconds resulted in a marked (over 10%) difference in jump height (Fig. 1). Muscle control was the most sensitive to precise tuning of muscles spanning the knee joint and ankle joint, where muscle control at the knee joint depended to a large extent on co-action of the monoarticular knee extensor



**Figure 1:** The effect of time shift applied to mm. vasti, hamstrings and m. soleus. Jump height is expressed as percentage of optimal jump height.

(mm. vasti) with biarticular muscles. Among individual muscles the control of mm. vasti, m. soleus, hamstrings and other plantarflexors were found to be especially important for coordination in jumping. Muscle control was found to be very sensitive to intermuscular coordination. The disintegration in coordination caused by earlier activation of mm. vasti was minimized when the hamstrings activation onset time was decreased by a similar amount. Earlier activation of other plantarflexors was found to reduce jump performance by a significantly smaller amount when hamstrings were activated jointly. Furthermore, the negative effects of other plantarflexors were mitigated by concurrent time shift in mm. vasti activation. Also the effect of later activation of mm. vasti was considerably smaller when m soleus activation was also delayed by the same amount. Mechanical effect of time shift applied to different muscles were found to be virtually the same for: earlier stimulation of mm. vasti and later stimulation of hamstrings; earlier stimulation of m. gluteus maximus and m. rectus femoris; later stimulation of m. adductor magnus and hamstrings; earlier stimulation of m. rectus femoris and m. gastrocnemius; earlier stimulation of m. gluteus maximus and m. adductor magnus; earlier stimulation of m. adductor magnus and m. rectus femoris, earlier stimulation of m. adductor magnus and m. gastrocnemius. A time shift applied to one of these two muscles had virtually the same effect on jump kinetics and kinematics as a time shift applied to the other muscle. Therefore it can be postulated that their action in vertical jump is to some extent mechanically linked.

### REFERENCES

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