INTERSEGMENTAL DYNAMICS ANALYSIS OF "JUMP-SLAP-KICK" IN CHINESE MARTIAL ARTS

Long-Ren Chuang, Yu Liu, Chinese Culture University, Taipei, Taiwan,
Chung-Yu Chen, Chen-Fu Huang,
National Taiwan Normal University, Taipei, Taiwan

INTRODUCTION: From a biomechanical point of view, human limb movements are determined and controlled by torques at joints. According to Hoy & Zernicke (1986), limb movements are influenced not only by active muscle torque, but also by gravitational torque and passive interaction torque created by segment movement. The Jump-Slap-Kick in Chinese Martial Arts (CMA) is a jump action which includes support and flight phases. After take off (TO), the action leg moves upwards as quickly as possible and one hand slaps the foot in the highest position (HF) during the flight phase.
The purpose of this study was to analyze how active and passive torques influence limb motion and to investigate, from a biomechanical point of view, the motor control mechanisms of the “Jump-slap-kick” in Chinese Martial Arts.

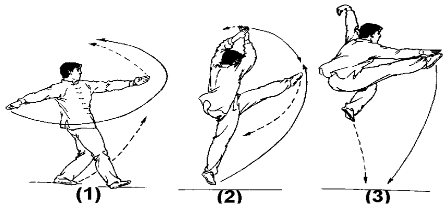

Fig.1: Jump-Slap-Kick. (1) Touch Down (TD), (2) Take Off (TO), (3) Hand slaps Foot (HF)

METHODS: Five well-trained CMA students performed the Jump-Slap-Kick. The Peak Performance high-speed video camera (120Hz) and Kisterler force platform (600Hz) were used synchronously to collect kinematic and dynamic data. To calculate the muscle control torques and the dynamic interactions among thigh, leg and foot, the model in our earlier study (Liu, 1993) was used and the intersegmental dynamics formulation of Hoy & Zernicke (1986) was modified. The form of the model used here allows quantification not only of how muscles and gravity influence limb motion, but also of how the motion of one segment affects other segments, and thus it is called ”intersegmental dynamics.” At each of the joints of the linked segments, the torques can be divided into five categories: net joint torque, gravitational torque, motion-dependent torques, contact torques and generalized muscle torque (Zernicker & Smith, 1996):
Net joint torque (NET) = gravitational torque (GRA)
+ motion-dependent torques (MDT)
+ contact torques (EXT)
+ generalized muscle torque (MUS)

RESULTS: The limb dynamics analyses reveal that during the take-off support phase of Jump-Slap-Kick the active muscle torque (MUS) functioned to counterbalance the effect of the torque due to ground reaction force (EXT), while

the motion-dependent torque (MDT) and other kinds of torques were smaller in this phase and have no significant contribution to joint motion (Fig. 2).
At both the ankle and the hip, the extensors dominated during all support phases, and the maximal values of ankle and hip extensor torques were 2.88±1.1 and 4.92 8±1.2 [Nm/kg] respectively. At the knee, the dominant torque at the beginning of

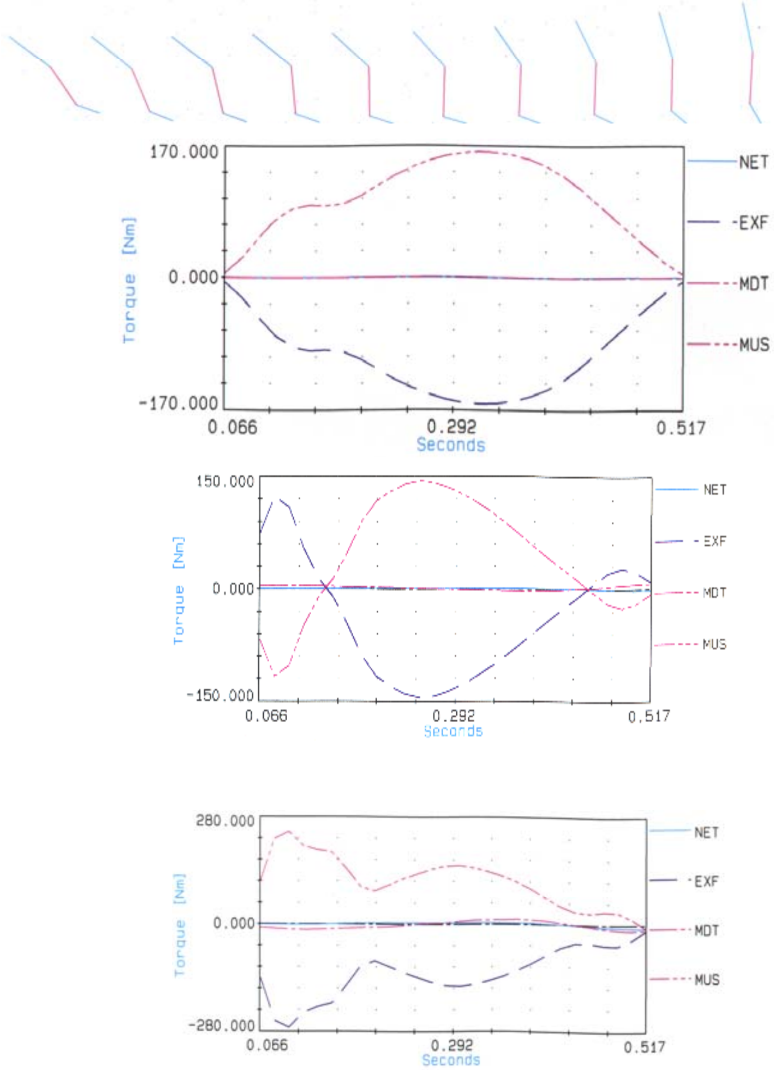

Fig. 2: Times curves of joint torques at ankle, knee and hip during support phase. Positive values indicate extensor torque, negative values indicate flexor torque. NET - Net joint torque, MDT - Motion-dependent torques, EXT - External torque due to ground reaction force, MUS - Muscle torque support phase was created by knee flexor, and followed at the middle of the support phase by knee extensor.

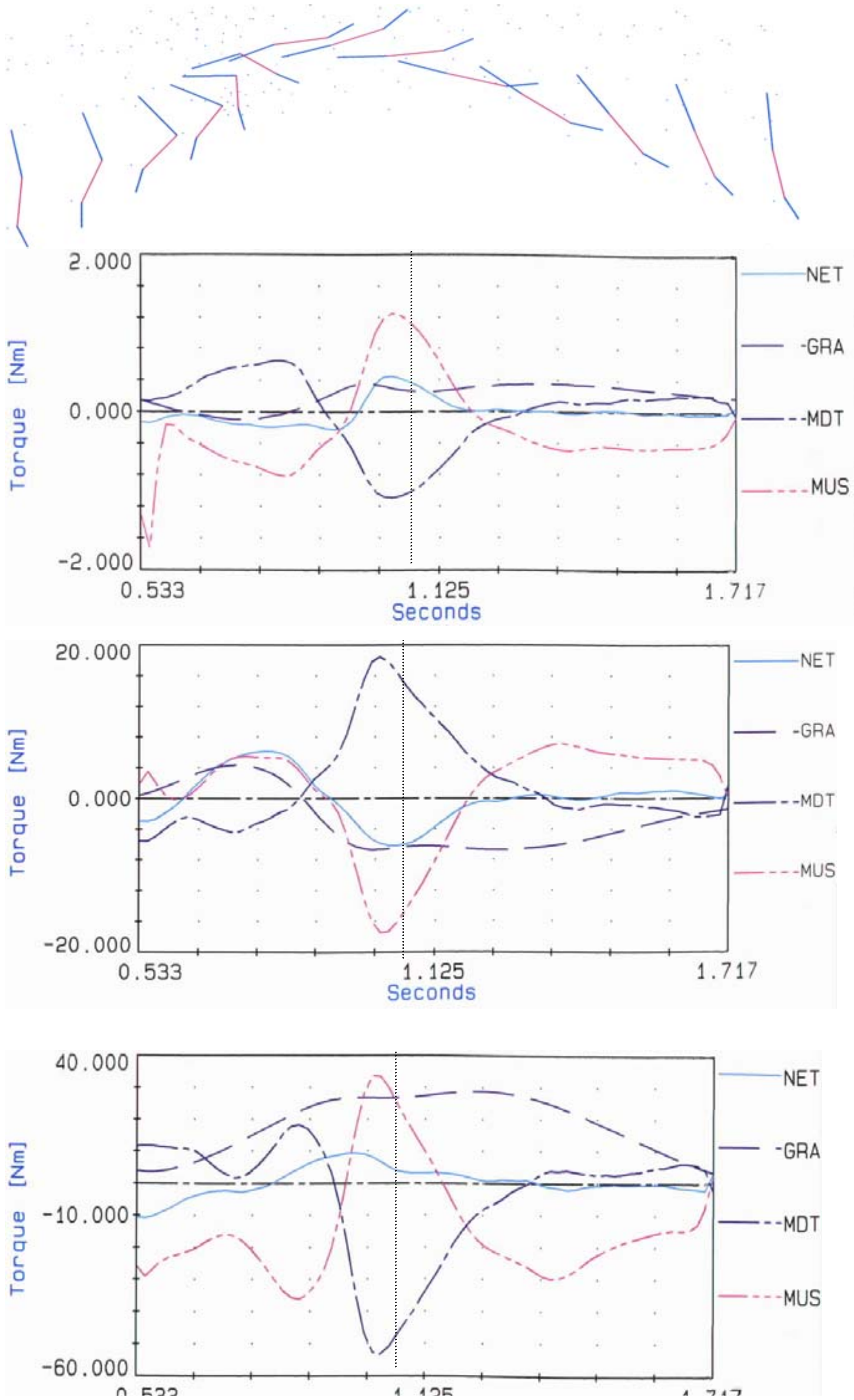
2.000
0.000
-2.000
Torque [Nm]
0.533
1.125
1.717
Seconds
NET
-GRA
-MDT
MUS
20.000
0.000
-20.000
Torque [Nm]
0.533
1.125
1.717
Seconds
NET
-GRA
-MDT
-MUS
40.000
-10.000
-60.000
Torque [Nm]
NET
-GRA
-MDT
-MUS

Fig. 3: Times curves of joint torques at ankle, knee and hip during flight phase. Positive values indicate extensor torque, negative values indicate flexor torque. NET - Net joint torque, GRA - gravitational torque, MDT - Motion-dependent torques, MUS - Muscle torque

The function of the knee flexor torque was to counteract the external torque (EXT) due to ground reaction forces that pass through in front of knee joint. The magnitude of maximal knee flexor torque was 4/5 of maximal knee extensor torque (3.31±1.54 [Nm/kg]). This means that the maximal strength of the knee flexor should be 4/5 of the maximal strength of the knee extensor for performing Jump-Slap-Kick. During the flight phase, the active muscle torque (MUS) functions mainly to counteract the motion-dependent torque (MDT) created by the mechanical interactions between limb segments (see Fig. 3, the stick figure and the curves). While the hand slaps the foot (HF) in the highest position in the flight phase, this counteraction reaches its maximum and is followed by a counteraction between the muscle torque and the gravitational torque (GRA). The MDT was created at the ankle mainly by the leg acceleration, at the knee by the thigh and leg acceleration and at the hip by the leg acceleration. The magnitude of the counteraction torques at the hip is greater than at the knee (about 2 times) and at the ankle (about 20 times).

CONCLUSION: In conclusion, the active muscle torque can function directly to cause and control limb movement or to counteract the external torque created by ground reaction force (in support phase) and interactive torques arising from mechanical interactions between limb segments (in flight phase). Under the regulation of the nervous system, the muscle functions to employ and/or to counteract (counterbalance) the varied passive torques in order to achieve efficient and coordinated limb motions.

REFERENCE:

Bernstein, N. (1967). Coordination and Regulation of Movement. New York.

Hoy, M. G., Zernicker, R. F. (1980). The Role of Intersegmental Dynamics during Rapid Limb Oscillations. *J. Biomechanics* **19**, 867-887.

Liu, Y. (1993). Kinematik, Dynamik und Simulation des leichtathletischen Sprints. Frankfurt/Berlin: Lang.

Zernicke, R. F., Smith, R. A. (1996). Biomechanical Insights into Neural Control of Movement. In L. B. Rowell, J. T. Shepherd (Eds.), *Handbook of Physiology. Sec. 12* (pp.293-330). Oxford, NY: Oxford University Press.