ANALYSIS OF THE KICKING LEG IN TAEKWONDO

Inseong HWANG

Department of Physical Education
Yonsei University
Seoul, Korea

The kinetic analysis using engineering dynamic equations have been used to enhance the understanding of segmental movements. The resultant muscular torque, the results of the kinetic analysis has provided insight on the interplay between muscular action and movements of the body segments (Dillman, 1970; Miller and Nelson, 1976).

Elftman(1940) studied a sprinter to determine the rate of muscular work while Plagenhoef(1968) investigated the patterns of muscular torque for the leg during distance running. Plagenhoef(1968) also compared the muscular torque patterns of the leg during a subject ran with and without ankle weights in the study and reported that an entirely different pattern of muscular torque was observed when running with ankle weights. Dillman (1970) developed the techniques for performing a kinetic analysis and showed the way of obtaining various types of information that may be obtained from such an analysis. He reported resultant muscular torque patterns, sequence of dominant muscular group activity and pattern of the types of muscular contraction of the recovery leg during sprint running using six male subjects in the study. R.F. Zernicke and E.M. Roberts(1976) analyzed the relative contribution of selected kicking limb segments to systematic increments in resultant limb velocity using the dynamic equations based on a total of 45 soccer toe kicks. Phillips, Roberts and Huang(1978) calculated the non-muscular interaction of the thigh and shank in the soccer kick. Phillips and Roberts(1980) also modeled and calculated the nonmuscular interaction of the thigh and shank in the swing limb of runners.

Although the kinetic analysis of the segmental movements provides important informations, the reported research has been limited to running and soccer kick. In order to increase our understanding about the segmental movements many segmental movements involved in other sports skill must be analyzed.

The Taekwondo, Korean traditional marshal art, has been developed as an world wide sport and involved various kind of kicking techniques. However very little of the reported research has been devoted to their investigations.

PURPOSES

It was the primary purpose of this study to conduct a kinetic analysis of the kicking leg during the Ap Cha Gi (front kick) in Taekwondo. The questions and concerns initially posed were : 1) What are the patterns of hip, knee and ankle muscular torques? 2) What are the sequence of dominant muscular group activity? 3) What are the patterns of the types of muscular contraction? 4) What are the ranges of segmental motion where effective muscular torques were applied? Finally these same questions and concerns directed to the Ap Cha Gi without target which usually use for practice, and compared them with the Ap Cha Gi with target to provide informations for the training.

METHODOLOGY

Three highly-skilled male Taekwondo players were filmed twice while they performed Ap Cha Gi with target and without target. All subjects were members of the 1985 Taekwondo team of Yonsei University. These athletes were 18 and 19 years old, ranged in height from 170 to 172 cm, and in weight from 59 to 63 Kg.

The three subjects were filmed at an outdoor rubberized asphalt track. A Photosonic, motor-driven, 16 mm camera was positioned perpendicular to the plane of motion at a distance of 11 m and set at an operating speed of 64 frames per second. The optical axis of the camera horizontally bisected the middle of the filming area and was 1.2 m above the ground.

The subjects were instructed to kick the target which was an Webster dictionary at their maximum controlled speed. The camera was started one second before the subject performed the kicks to allow time for the desired frame rate to be attained. A calibrated marker was photographed in the plane of movement to provide a reference distance for determining real distance.

The joints of the hip, knee, ankle, and metatarsophalangeal were marked with white dots on kicking leg for each subject prior to filming. These markings were positioned using the joint center locations suggested by Dempster(1955).

Data Reduction

A motion analyzer which developed in Yonsei University by interfacing DP-114 degitizer and IBM micro computer (IBM XT) was used to quantitatively analyze the films. Horizontal (x) and vertical (y) coordinates were recorded for the hip joint, knee joint, ankle joint and metatarsophalangeal joint of the kicking leg. These coordinates were then smoothed using Second-Order Low-Pass Digital Filtering (Winter, 1979).

The net muscular torques acting about the hip, knee, and ankle joints were then calculated using Newtonian equations of motion. The required body segment parameters were estimated from data published by Dempster(1955).

The kinematics of the kicking leg included the determination of the horizontal and vertical movements of the leg segmental centers of gravity and the obsolute angular displacements of the leg segments. Once the required body segment parameters were calculated and the kinematics of the motion of the kicking leg determined, these values were input into the equations of motion. The computer programs were developed by Hwang and Ko(1986) to perform the necessary computations in solving the equations of motion.

RESULTS AND DISCUSSION

Initially a kinematic analysis was conducted for the kickings to obtain a general information about the kicks. However only the velocity pattern of the kicking foot in relation to the target is reported here. The velocity patterns between the kick with target and the kick without target showed different pattern. However within the same kicking, the patterns between the subjects were similar. The absolute speeds of the kicking foot at the target or at the position which assumed the target positioned were between 10.3 m/sec. and 11.7 m/sec. in the kicking with target(Figure 1) and between 0.8 m/sec. and 1.0 m/sec. in the kicking without target(Figure 2). The maximum foot speeds of both kicks were between 11.6 m/sec. and 13.4 m/sec. Zernicke(1975) reported that in the slow kick foot speed does increase fairly gradually, but in the fast kick which demands the most effective functioning of the system, there is a brief slow down followed by a marked acceleration and reported the velocity of the foot when perform medium soccer toe kick was about 16.5 m/sec. The velocity pattern of the foot in Ap Cha Gi increased gradually showing no rapid changes untill it reached maximum speed. Therefore, the Ap Cha Gi performed in this study were controlled kick with medium effort. The maximum foot speeds reached prior to the target in all Ap Cha Gi. The foot speeds at target spot in Ap Cha Gi without target occurred at the end of the bell shaped speed curve and found to be ineffective for kicking power. These decreasing tendency of the speed at target area was due to the decreasing of the horizontal component of the velocity.

An analysis of the resultant muscular torque functions about each of the joints for

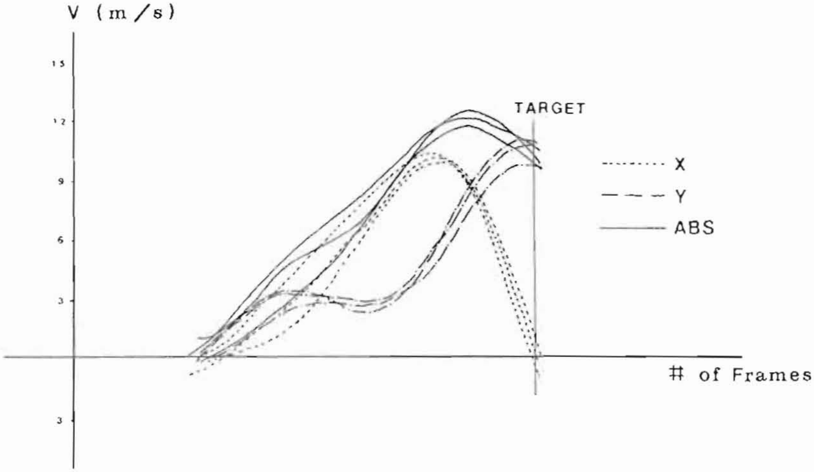

Figure 1. Linear velocity of the kicking foot during front kick (with target)

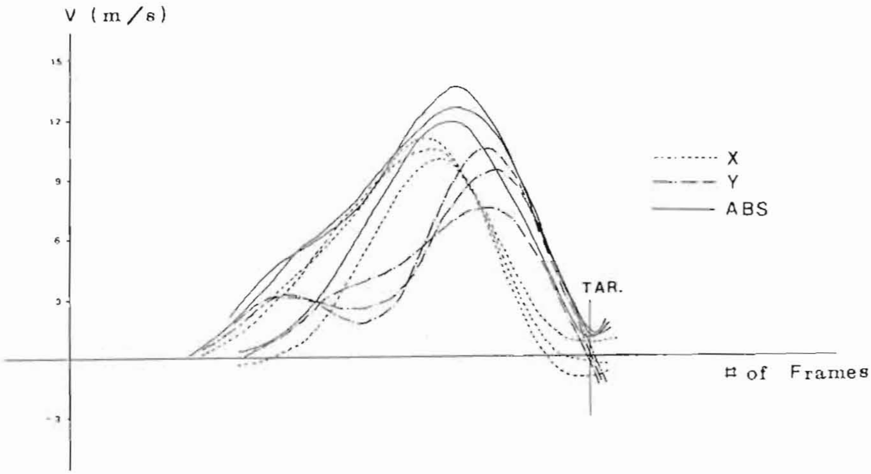

Figure 2. Linear velocity of the kicking foot during front kick (without target).

the kicking leg resulted in very similar patterns for all subjects. The muscular torque functions about the hip, knee, and ankle joint of the two kind of kicks are presented graphically in Figure 3 and in Figure 4 as a function of time for Subject(C). The torque patterns for Subject(C) were typical of those found for all subjects. The largest torque was observed about the hip joint with the next highest being produced about the knee joint. The same general pattern occurred for all functions in that they started out positive, decreased to zero, increased negatively, and then approached again to zero. However the

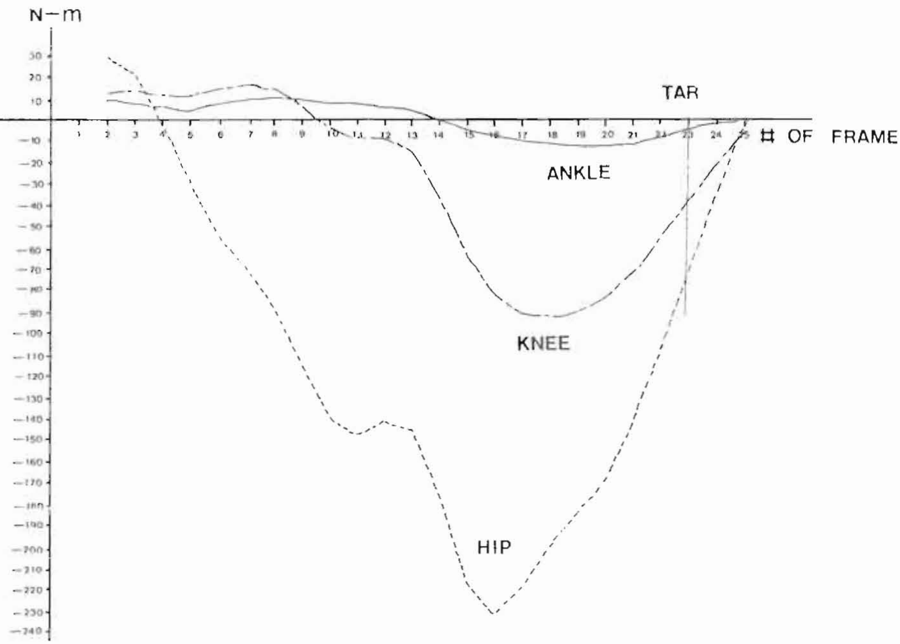

Figure 3. Resultant muscular torques about the three segmental joints for subject C during front kick (without target).

torque patterns about all three joints in Ap Cha Gi with target were smaller than the torque patterns in Ap Cha Gi without target and the ankle joint torques in Ap Cha Gi with target were all positive torques. The differences among the three functions and between the torque patterns of the two kicks existed in the magnitudes and the timing sequence of the changes.

The resultant muscular torques calculated from the equations of motion represented the sum of all the muscular forces acting on a limb. These equations were derived in such a manner that the sign of the resultant muscular torque indicated which muscle group was applying the greatest tension. The muscle group which exerted the greatest force was called the dominant muscle group. Table 1 lists the dominant muscle groups about each joint for the respective signs of the resultant muscular torques.

The dominant muscular group about the hip joint was initially the hip flexors until about one third of whole kicking phase when the hip extensors became dominant. The knee extensors were the dominant muscular group about the knee until about two third of whole kicking phase when the knee flexors became dominant. The dominant muscular group about the ankle joint was the dorsiflexors. However the dominant muscular group about the ankle joint in the kicking without target was changed to the plantarflexors at the later phase of the kicking. The magnitues of the torque curves showed that the dominant muscular group activity of the kicking without target was larger than the dominant muscular group activity of the kicking with target. However the positive torque phases, the muscular activity to the direction of motion, of the kicking with target were longer than the phases of the kicking without target. This difference of the coordination of the dominant muscular activity seems the reason of higher speed of the foot at target area in the kicking with target than the speed of the kicking without target eventhough larger amount of muscular activity was involved in the kicking without target. Table 2 showed the relative phases

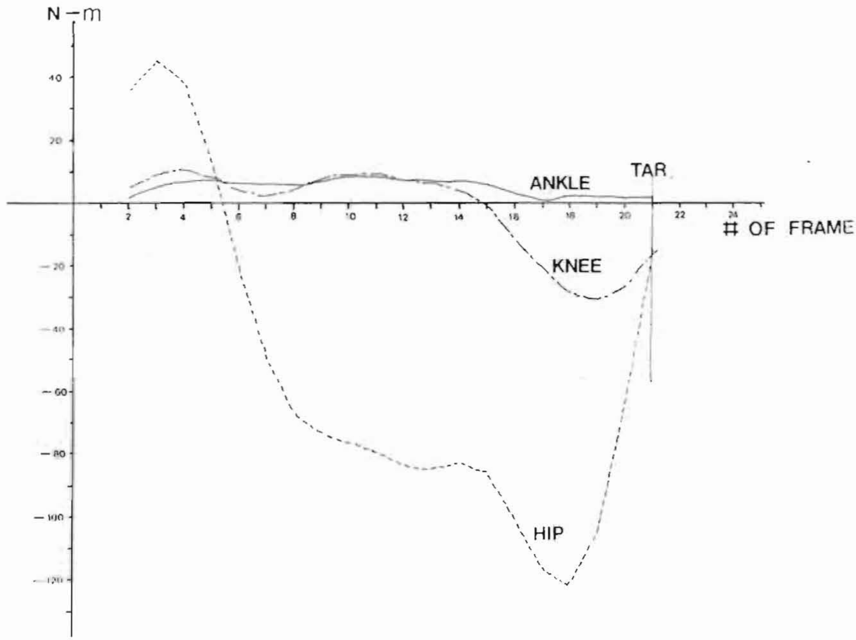

Figure 4. Resultant muscular torques about the three segmental joints for subject C during front kick (with target).

TABLE 1.
DETERMINATION OF DOMINANT MUSCULAR GROUPS FROM DIRECTION OF RESULTANT MUSCULAR TORQUES

Joints	Signs of Muscular Torque	Dominant Muscle Group
Hip	+ -	Hip Flexors Hip Extensors
Knee	+ -	Knee Extensors Knee Flexors
Ankle	+ -	Ankle Dorsiflexors Ankle Plantarflexors

of average positive torques about the three joints between the two kicks.

The types of dominant muscular contractions were determined by relating the resultant muscular torques to the angular displacement of the limb (Dillman, 1970). For example, if the resultant muscular torque about the knee joint was positive this indicated that the dominant muscular group was the knee extensors. If the lower leg was extending during this time then the type of dominant muscular contraction was termed concentric. Concentric dominant muscular contraction occurred when the dominant muscular group shortened as force

TABLE 2.
THE RELATIVE PHASES OF AVERAGE POSITIVE TORQUES
ABOUT THE THREE JOINTS

	WITHOUT TARGET	WITH TARGET
HIP	22.7 %	38.3 %
KNEE	42 %	73 %
ANKLE	52.3 %	100 %

was applied to the limb. Conversely, if the knee was flexing while the knee extensors were dominant, then the type of dominant muscular contractions was called eccentric. Eccentric dominant muscular contraction occurred when the dominant muscular group exerted tension while lengthening (Figure 5). Table 3 presents the types of dominant muscular contrations based on dominant muscular group activity and direction of angular movement for the thigh and lower leg. Applying this scheme of analysis to the resultant muscular torque patterns about the three joints, the sequences of the type of dominant muscular contraction were determined throughout the kicking period.

There were one concentric phase and one eccentric phase about hip joint and two

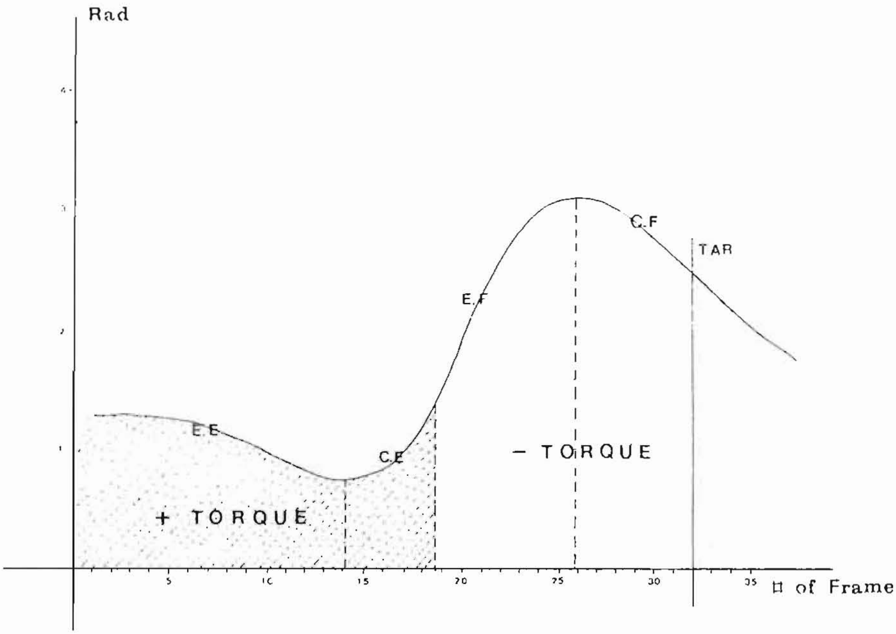

Figure 5. Angular displacement and type of contraction of dominant muscular group for kicking shank of subject C.

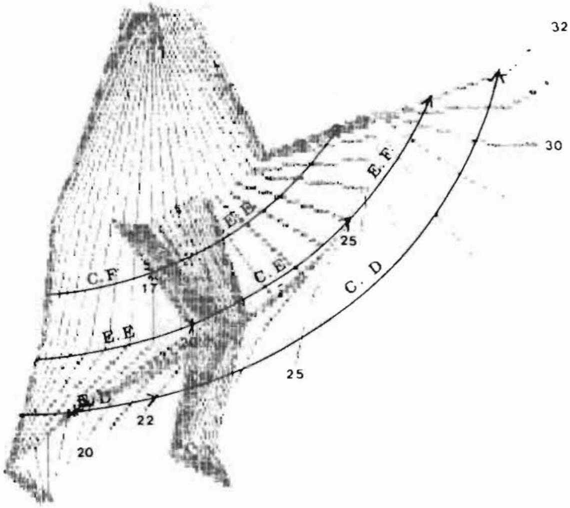

Figure 6. Types of dominant muscular contraction and relevant phases about the three segmental joints for subject C during front kick (with target).

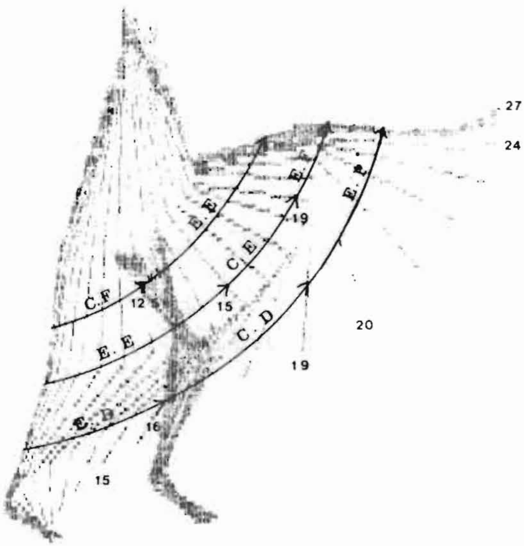

Figure 7. Types of dominant muscular contraction and relevant phases about the three segmental joints for subject C during front kick (without target).

TABLE 3.
TYPES OF DOMINANT MUSCULAR CONTRACTION BASED ON DOMINANT MUSCLE GROUP AND ANGULAR MOVEMENT OF SEGMENTS DURING FRONT KICK.

Joints	Dominant Muscle Group	Angular Movement of Segment	Type of Dominant Muscular Contraction
Hip	Flexors Extensors	Flexion Flexion	Concentric Eccentric
Knee	Extensors Extensors Flexors	Flexion Extension Extension	Eccentric Concentric Eccentric
Ankle (without target)	Dorsi Flexors Dorsi Flexors Plantar Flexors	Plantar Flexion Dorsi Flexion Dorsi Flexion	Eccentric Concentric Eccentric
Ankle (with target)	Dorsi Flexors Dorsi Flexors	Plantar Flexion Dorsi Flexion	Eccentric Concentric

eccentric phases and one concentric phase about knee joint. The sequence of dominant muscular contractions about hip joint was 1) concentric, and 2) eccentric and the sequence of dominant muscular contractions about knee joint was 1) eccentric, 2) concentric, and 3) eccentric. The same results were obtained when an analysis of the types of dominant muscular contraction of the kicking without target were made. However the types of dominant muscular contraction about the ankle joint showed different sequence between the two kicks. The sequence of the kicking with target was 1) eccentric and 2) concentric while the sequence of the kicking without target was 1) eccentric, 2) concentric and 3) eccentric. Figure 6 and Figure 7 presents the duration of the types of dominant muscular contraction about the three segmental joints of the kicking with target and without target respectively. At the last phase of the kickings without target the extensors of hip, flexsors of knee and plantarflexors of ankle, which are the antagonists, were active. Same results were obtained in the kickings with target except the ankle joint. The dominant muscular group about the ankle joint in the kicking with target was dorsiflexors with concentric contraction which indicated full release of foot was accomplished. The eccentric contraction phase of the antagonists about hip joint was longer than that about knee joint. This results indicated that first the proximal segment slow down the forward angular velocity followed by deceleration of the next segment. Thus the mechanical advantage by doing whipping motion (Alexander, 1983) could be abtained for the sudden acceleration of the last segment toward its final velocity. However eccentric contraction of the plantarflexors was occurred in the kicking without target and full release of the foot did not occurred.

These findings have important implications for the training of Taekwondo player. Knowing these phases of specific muscular action should assist in the development of specific training programs to increase the capacity of the muscles to apply force within these ranges of motion. However causions must be given to make training programs since the training programs should be devised to simulate the exact pattern of the types of muscular contraction and the small different situation, with target and without target, made big different pattern of muscular activity and coordination. According to the findings of this study, the Ap Cha Gi have to be practiced with proper target to simulate the exact pattern of muscular activity.

COCLUSIONS

The following conclusions are warranted :

1. There is a general pattern of resultant muscular torque about each of the three joints of the kicking leg during Ap Cha Gi in Taekwondo.

2. There is consistent sequence and types of dominant muscular activity about each of the three segmental joints of the kicking leg during Ap Cha Gi in Taekwondo.

3. Differences are existed between the kicking with target and without target in the coordination of muscular activity and the dominant muscular activity about the ankle joint.

ACKNOWLEDGEMENTS

This project was funded by the ministry of education of Korea.

REFERENCES

Alexander, M. The pattern of body segment movement in high speed sports skills. Coaching Science Update, Coaching Association of Canada, 1983.

Dempster, W. Space requirements of the seated operator. USAF, WADC, Tech, Rep. 55-159. Wright-Patterson Air Force Base, Ohio, 1955.

Dillman, C.J. A kinetic analysis of the recovery leg during sprint running. Proceedings of the C.I.C. Symposium on Biomechanic, 137-165, 1970.

Elftman, H. The work done by muscles in running. American Journal of Physiology, CXXIX, 672-684, 1940.

Hwang, I. and Ko, H. Micro computer programs for obtaining kinetic data on human movement. Yonsei Nonchong, Vol. 22, The Graduate School, Yonsei University, Seoul, Korea, 1986.

Miller, D.I. and Nelson R.C. Biomechanics of sports. Philadelphia : Lea & Febiger, 1976.

Phillips, S.J. and Roberts, E.M. Muscular and non-muscular moments of force in the swing limb of masters runners. In John M. Cooper and Betty Haven(Ed.), Proceedings of the biomechanics symposium, Indiana State University, The Indiana State Board of Health, 1980.

Phillips, S.J., Roberts, E.M. and Huang, T.C. Prediction of distal extremity motion following relaxation of knee muscle forces. Journal of Biomechanics, 11. p. 210 (Abstract), 1978.

Plagenhoef, S.C. A kinetic analysis of running. Track and Field Quarterly Review, October, 56-63, 1968.

Winter, D.A. Biomechanics of human movement. John & Sons, U.S.A., 1979.

Zernicke, R.F. Human lower extremity kinetic parameter relationships during systematic variations in resultant limb velocity. (Doctoral dissertation, University of Wisconsin-Madison, 1974), Dissertation Abstracts International, 35, 5105-A, 1975.

Zernicke, R.F. and Roberts, E.M. Human lower extremity kinetic relationships during systematic variations in resultant limb velocity. In P.V. Komi(Ed.), Biomechanics V-B, Baltimore : University Park Press, 1976.