COMPARISON OF THE DYNAMICS OF THE SWIMMING GRAB START, SQUAT JUMP, AND COUNTERMOVEMENT JUMP OF THE LOWER EXTREMITY

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The purpose of this study was to compare the dynamics characteristics of different jumps including the swimming grab start, squat jump, and countermovement jump. The subjects, who have over ten years experiences in swimming grab starts. One Peak-Performance high-speed video camera operating at 120 Hz and one Kistler force plate were synchronized to collect the data. A mathematical model of inverse dynamics was used to calculate net muscle joint moment and power. The results indicated that the grab start had a more complicated pattern of net muscle joint moment and power than other jumps. Based on the results of this study, it has been suggested that coaches should focus on the key points of grab start dynamics characteristics when instructing and training.

KEY WORDS: inverse dynamics, grab start, moment, power

INTRODUCTION: The start is one of the important factors in swimming competitions. Especially in sprints, athletes have to pay more attention on to the technique training of the start to gain more benefit. The grab start (GS) technique has been almost universally accepted as the most effective start because of its potential biomechanical advantages. Ground reaction force gives athletes a force to take off from starting platform, lower extremity is affected by ground reaction force directly during swimming start. Breed & McElroy (2000) investigated grab, swing and track starts in swimming. The force of contribution of the hands and feet were collected, separately. The results showed that almost all of the horizontal drive came from the legs during GS.
Most of the research (Welcher et al., 1999; Gehllsen & Wingfield, 1998; and Gambrel et al., 1991) has been involved with comparing different techniques and analyzing biomechanical characteristics. From the view of kinematic variables, the characteristics of the GS on the block are similar to two certain kinds of jump—first:, the set posture of the lower extremity of GS is similar to the squat jump; and second, the procedure of movement is similar to the countermovement jump (each joint of the lower extremity flexes slightly, extends and then becomes fully stretched).
Kinematic parameters, such as velocity, acceleration, and angle were the appearance of starting movement, and muscle contractions were the cause of this appearance. Liu (1999) indicated that almost all of the ground reaction was by net muscle joint moment. Therefore, to understand the characteristics of muscle work during swimming start is necessary. The purpose of this study was to investigate the pattern of muscle contraction characteristics of the lower extremity during the GS grab star, and compare to the squat jump and countermovement jump.

METHODS: Subject—Four male and one female elite competitive swimmers served as subjects. They were asked to perform three movements: squat jump (SJ), countermovement jump (CMJ) with akimbo and swimming grab start (GS).
Experimental set up—A video camera was synchronized to the force plate. One Peak Performance high speed video camera (120Hz) which videotaped the movement at in the sagittal plane used to collect kinematics variables. Horizontal and Vertical vertical force components by at the feet were measured using a Kistler (model 9287) force plate which (sampling rate was of 600Hz). The contribution from the hands pushing was separated from the feet by pushing with the hands on another bar to make sure that force data was completely from the feet.
Inverse dynamics model: An inverse dynamics model mentioned in(Winter, (1990) was used to determine force (Fx and Fy) and kinematics (position, velocity, acceleration, angle, and angular velocity) data. After the inertia parameters of for body segments were adopted from Dempster (1955), then the net muscle joint moments and power of the lower extremity were calculated. Net muscle joint moment was the resultant of some certain muscles (net moment),

and it can not be known which muscle precisely involved in net muscle joint moment in this study. If net muscle joint moment was positive, it means that extensors worked stronger. If the power was positive, it means that the muscle was concentrically contracted.

RESULTS AND DISCUSSION:

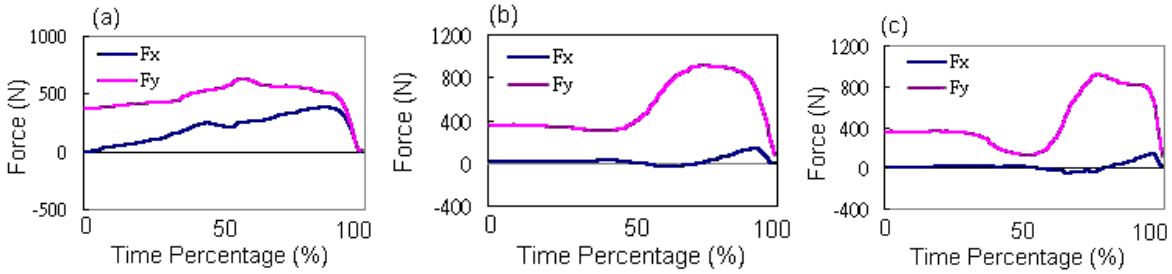

Figure 1 - The force (Fx: horizontal, Fy: vertical) related related to the ground during contact phase in (a) grab start (b) squat jump (c) countermovement jump of one subject .

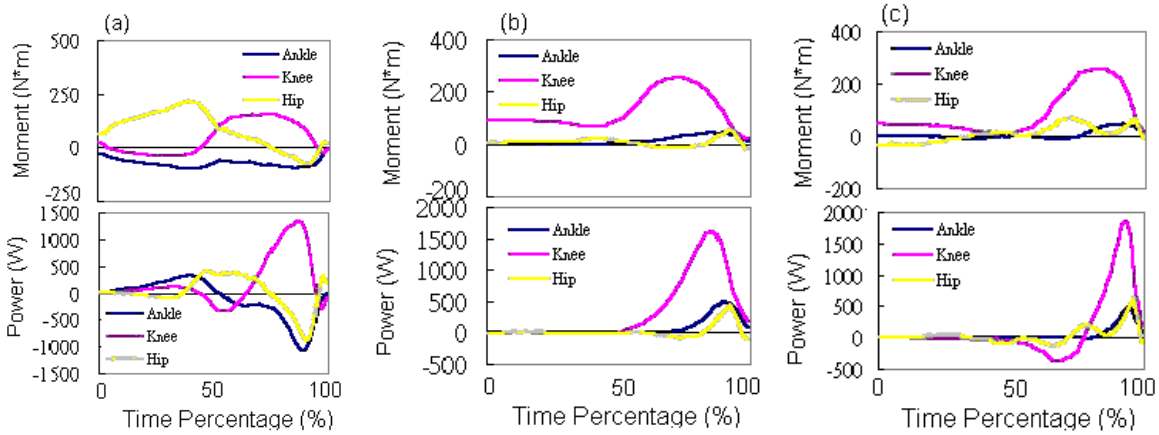

Figure 2 - The net muscle joint moment and power of the lower extremity during the contact phase in (a) grab Start (b) squat Jump (c) countermovement jump of one subject.

Although the movement of the lower extremity in the GS was similar to the SJ and the CMJ for the kinematics, the force in the horizontal direction kept increasing (Figure 1), and the work pattern of the muscle was quite different. Net muscle joint moment and power of the GS were much more complicated than that of the SJ and CMJ. (Figure 2).

The definitions of net muscle joint moment in this study were: positive mean joint extension, negative mean joint flexion. Positive power mean muscle contracted concentrically, negative power mean muscle contracted eccentrically. In the SJ, when the subject extended the knee joint and during the take- off, the extensors of the knee, hip, and dorsiflexors were concentrically contracting. In the CMJ, as the subject started to squat down the joint angle became smaller, and the extensors of the knee and hip were eccentrically contracting. After squatting to the lowest point, the subjects started to extend their joints to jump. In this period, the extensors were concentrically contracting. The hip curves in Figure 2 were more fluctuated because the hip extensor sometimes did not contract actively. During knee extension, the thigh segment moved, resulting in the hip being extended passively. In the GS, the patterns of muscle work in the four subjects were similar. The hip muscle group showed a sequence of extensor eccentric extension, extensor concentric extension, and flexor eccentric contraction flexion. The knee muscle group was in a sequence of flexor concentric flexion, extensor eccentric extension, and extensor concentric extension contraction. The plantarflexors contracted concentrically and then eccentrically. More detail of the pattern of powers and moments of the lower extremity are shown in Figure 3.

Each of the three movement jumps began from contact with ground, and then jump to leave the ground, but the set posture and the end position (movement direction) were different. Riddweikhoff et al. (1999) investigated squat jumps in the conditions of vertical jump, long jump and inclination angles of the body related to horizontal of 75° and 65 °. The results showed that there was no significant difference found among the jumps with different inclination angles in the magnitude of the peak ground reaction force. The pattern of net muscle joint moment did not change as the inclination angle became smaller, but net knee joint moment increased whereas net hip and ankle moment decreased. In this study, the movement directions between GS, SJ, and CMJ were not the same, but the results were very different from the previous study.

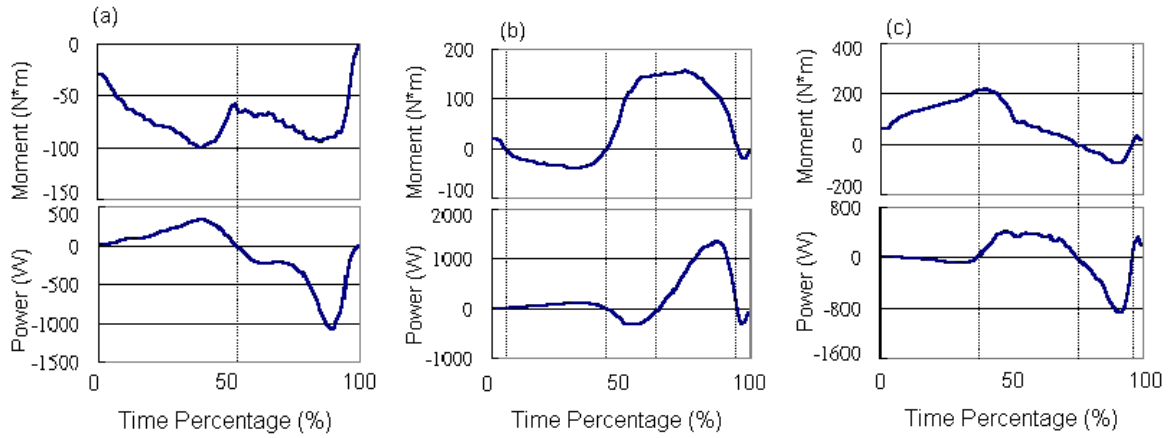

Figure 3 - The net muscle joint moment and power of (a) ankle (b) knee (c) hip during the block phase of the grab start in swimming.

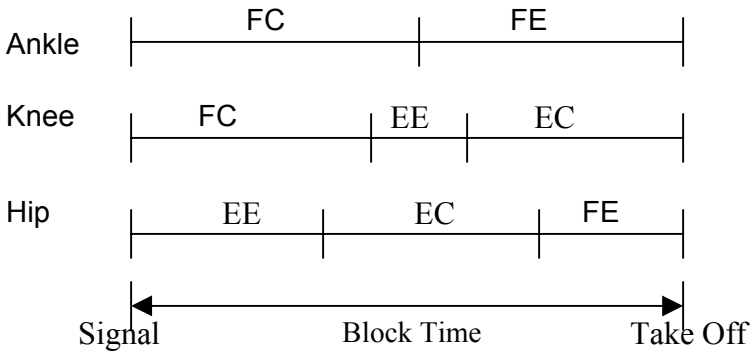

Figure 4 - The pattern of muscle contraction of lower extremity during grab start.
FC: Flexors Contract Concentrically EC: Extensors Contract Concentrically
FE: Flexors Contract Eccentrically EE: Extensors Contract Eccentrically

Although the set posture of the lower extremity in the SJ and GS jumps were similar, the hip angle of the GS was much smaller than in the SJ. When swimmers performed the CMJ, the hip extensors contracted eccentrically against the gravity of mass during the period of the squat down. There was no eccentric contraction of the knee joint in the early period of the GS, and the position of the center of mass at the set posture was more forward compared to the CMJ. After signal happened, the swimmers started to squat and moved forward slightly (rotated related to the horizontal from its the initial squatted posture), the knee and plantarflexors contracted actively, and the thigh segment moved resulted in hip extensors eccentrically contracted. Then swimmers moved more forward, the arms swung toward the side of the head, and the hip extended actively. At this moment, the knee extensors were eccentrically contracted in order to act against the gravity of the body mass, and then contracted actively to push off from the start block. The characteristics of muscle work during this period were like the CMJ, in that the muscles were pre-stretched, and then contracted actively. Bobbert et al. (1996) indicated that CMJ allowed the muscle to build up a higher level of active state and force than the SJ before

the start of shortening, and they were be able to produce more work over the first part of their shortening distance. So, when swimmers perform the GS, they still need to pre-stretch the muscles (squatted) to gain more benefit, although their knees are flexed during the set posture. Because of the contraction of knee extensors, the thigh segment movement resulted in the hip flexors contracting eccentrically. In this period, the plantarflexors were eccentrically contracted because the hip and knee joints were extended strongly.

The grab start is a continual movement, each neighbor segment affected each other. Through inverse dynamics method, the net muscle joint moment and power could be calculated, and the work pattern (shown in Figure 4) of the muscle in the grab start was understood. The patterns of the subjects were similar, but the timing was the same. This pattern may provide some key points to instructors when instructing novices. For example, swimmers have to squat in the early period of start, then the hip extensors should contract actively before the knees extend strongly. Furthermore, coaches may also test swimmers' start technique and strength of muscle group by the method of this study, and focus on the disadvantages then improve it.

CONCLUSION: The pattern of muscle contraction in the grab start was different from the squat jump and the countermovement jump. It was more complicated in the grab start because of its set posture and the direction of movement. This pattern provides a key point to squat at the initial period.

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