EFFECTS OF THREE PREPARATORY MOVEMENTS ON SIDEWARD PROPULSIVE MOVEMENT

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This study investigated the effects of three preparatory movements (squat, countermovement and hopping) on the sideward propulsive movement. Seven subjects were analyzed in 3-D to determine how fast they reacted to external signals, using three techniques, to reach an aiming spot. The hopping and the countermovement types were considered better than the squat type in the propulsion. The hopping particularly showed the shortest duration from the external signal to take-off and also recorded high extension moments due to the pre-stretch mechanism for the push-off phase.

KEY WORDS: propulsion, countermovement, hopping, pre-stretch, Stretch-shortening cycle (SSC)

INTRODUCTION: The preparatory movement such as countermovement has a positive effect on performance in human movements like throwing, jumping. Many researchers have found that a countermovement improves task performances, such as jumping height. (Bosco, Viitasalo, Komi, & Luhtanen, 1982; Anderson & Pandy, 1993). It is usually assumed that performance enhancement is caused by effects of the Stretch-shortening cycle (SSC) mechanism, which is related to the pre-stretch of muscles. In other words, the mechanical outputs of muscles in the concentric contraction with pre-stretch are greater than those using a purely concentric contraction without pre-stretch (Bobbert, Karin, Gerritsen, Litjens & Van Soest, 1996).

It is logical to ask however, which types of preparatory movements, are superior even though each movement includes the pre-stretch of muscles. Researches in this area regarding preparatory movements have focused on the movement, without restricting time. The authentic sports like tennis and badminton, however, differ from the situation of previous studies, because they need to perform explosive movements as fast as possible in response to the opposite player or a ball. The purpose of this study was to analyze the effects of three different types of preparatory movement (squat, countermovement and hopping) on a sideward propulsive movement task in response to external signal.

METHODS: Task & Experimental protocol: Subjects performed the right or left propulsive movement using three different types of preparatory movement. 1) squat type: begins with semi-squat position without countermovement 2) countermovement type: begins with semi-squat position with countermovement 3) hopping type: hopping begins with countermovement. Subjects touched switch sensors, which were located 3m from the mid-lines of their body, in response to external signals in the right or left directions. They were instructed to perform as fast as possible using an open step. The three types of the preparatory movement were randomly ordered. Three kinds of external signals (right, left, and middle) were also randomized. The signal of middle direction was added for subjects not to predict signal's direction. As signals were given with the constant time interval (3-2-1-signal), subjects were able to predict the moment in which the external signals were given, and to perform the tasks at the optimal timing.

All subjects had participated in the task adaptation program (2 sessions/week, 30 min/session) before testing, which involved two experimental stages. In the first stage, 15 male collegiate students performed five trials of each preparatory task. The movement time, that indicates the duration from illumination of the external signal to touching the switch, was collected. In the second stage, seven subjects (21.57 $\pm$ 1.7 yrs, 177.6 $\pm$ 2.3 cm, 72.0 $\pm$ 3.2kg) from the larger sample performed two trials of each task and these performances were analyzed biomechanicaliy. Five cameras (two for 125 Hz and three for 60 Hz) and two AMTI.

Table 1 Movement time(M ± SD).

	SQT (a)	CMT (b)	HOT (c)	Post hoc
Movement Time (s)	1.03 ± 0.08	0.93 ± 0.06	0.89 ± 0.07	a<b<c

n= 15, $\alpha = 0.05$

force platforms (frequency 1000 Hz) were used to collect kinematical and kinetic data. Twenty-four reflective markers were placed on subjects' bodies in this process.

Data reduction & analysis: Performances were analyzed using the kwon3d DLT method (Visol, Inc., Seoul, Korea). Image data and GRF data were synchronized using a LED and joint kinetics were calculated using the inverse dynamic approach. Symmetry of movement was assumed, so only the right directional movement was collected and the left side segment was analyzed. The movement was divided into two phases. 1) Preparatory Phase (Pre-Phase): from the signal turned on to the moment reaching the lowest height of the center of the body, 2) Propulsive Phase (Pro-Phase): from the moment reaching the lowest height of the center of mass of the body, to the moment the foot was taken-off the ground. One-way ANOVA and Scheffe post-hoc test were used to identify significant differences between parameters for the three preparatory movements. Significance was set at an alpha level of 0.05.

RESULT AND DISCUSSIONS: Table 1 is the mean time from the external signal to the touch on the switch. The performance of the hopping movement was the quickest, while the squat showed the poorest performance (hopping > countermovement > squat type). The performance of hopping and countermovement squat produced 87% and 90% respectively, of the time relative to the squat type. The result is in accordance with studies on the vertical jump that showed the height of the countermovement jump was higher than that of the squat jump (Bobbert et al, 1996; Anderson & Pandy, 1993).

Table 2 Temporal and CM parameters(M ± SD).

	SQT (a)	CMT (b)	HOT (c)	Post hoc
Duration of Pre-Phase (s)	0.57 ± 0.09	0.41 ± 0.06	0.37 ± 0.10	a<b, c
Duration of Pro-Phase (s)	0.22 ± 0.03	0.236 ± 0.07	0.19 ± 0.05	b<c
Velocity at take-off (m/s)	2.39 ± 0.22	2.52 ± 0.20	2.51 ± 0.36	

n= 7, $\alpha = 0.05$.

Table 3 Maximum value of the net extension moments about the joints for the Pro-phase (M ± SD).

	Joint	SQT (a)	CMT (b)	HOT (c)	Post hoc
Max Joint Moment	ankle	98.97 ± 23.00	108.3 ±21.45	128.1 ± 34.17	a, b<c
	knee	100.0 ±29.63	119.4 ± 27.79	133.2 ± 46.31	
	hip	133.9 ±34.65	171.8 ± 62.01	154.2 ± 56.72	a<b

n= 7, $\alpha = 0.05$

In this task condition, where subjects perform propulsive movement to the aiming spot according to external signals, the countermovement and hopping type preparatory movements are better than the squat type. The time difference, which is from the external signal to the take-off instant (moving the foot from the ground), is the major time factor in differentiating performance. The squat type spent more time in Pre-Phase than other types, however, the hopping type spent the shortest time in both Pre-Phase and Pro-Phase. In other words, the hopping maneuver can reduce the time required to finish the propulsion.

This result is in accordance with Bobbert et al. (1996). It is assumed that the squat type maneuver needs additional time to overcome the initial static condition.
Although the countermovement and hopping type needed shorter propulsive time than the squat type, all types produced similar take-off velocity. It is assumed that pre-stretch by countermovement is a positive factor to make strong power in the aspect of concentric contraction (Table 2).
The maximum extension moment of each joint was recorded during the Pro-Phase. The countermovement and hopping maneuvers produced higher maximum extension moments than the squat at all joints (Table 3). Bobbert et al. (1996) observed that the countermovement jump produced higher joint moments and work output in the Pro-Phase and reported that the initial moment in the Pro-Phase was the important factor in performance. Maximum extension moments in the countermovement and hopping movements were relatively higher than that in the squat action during the Pro-Phase. It is assumed that the maximum extension moment in countermovement action and hopping was related to the rotational movement of each joint and produced higher work output. The hopping movement at the ankle joint produced a significantly higher extension moment than the countermovement maneuver. Hopping type, relatively bigger than the countermovement type in the load of the pre-stretch from landing, seems to produce power more effectively at the ankle joint.

CONCLUSION: The hopping type action is the most advantageous preparatory movement for in moving as fast as possible in response to an opponent or a ball. Hopping type of movement showed the shortest duration from the external signal to the take-off time and the highest extension moments, due to the pre-stretch mechanism for the push-off phase. This study implies that hopping and countermovement generally are the most effective preparatory movements to improve performance in many sports task, which require a quick start or explosive propulsion, such as a volley in tennis, defense in badminton and goalkeeper in soccer.

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