BIOMECHANICAL CHARACTERISTICS OF WHOLE-BODY FAST REACHING MOVEMENTS

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Executing a whole-body fast reaching movement is an essential skill in many competitive sports. The present study investigated this kind of movement by biomechanical analyses. Five male university athletes and five fencing team members volunteered as subjects in this study. Each subject was asked to perform whole-body fast reaching movements and end at a stable posture. A motion capture system was used to record the kinematic data. The results demonstrate that the fencers moved the upper extremities earlier than the lower extremities, and the proximal segments started slightly before the distal segments. In conclusion, in executing whole-body fast reaching movements, upper and lower extremities work together as one functional unit, and there may be slightly different strategies adopted by each individual according to their exercise habits.

KEYWORDS: functional synergies, coordination, movement pattern

INTRODUCTION: Although reaching a specified target is required in many tasks, the choice of the trajectory between the initial and the final position remains free (Alexander, 1996). The elbow and shoulder joints have been shown to link together as a single unit when pointing or reaching (Kaminski, 1995). In many athletic competitions, performing whole-body fast reaching movements is even more essential. In this kind of movements, not only the upper extremities but also the lower extremities and the trunk need to participate in the task. At higher speeds, the more pronounced initial posture adjustment and straighter hand path may be necessary to maintain equilibrium because of conflicting dynamic balance and performance constraints (Pozzo, 1998).

When executing whole body reaching movements, a particular synergy among moving joints has been found previously with the focus on upper extremities. We hypothesized that when the target position is fixed, there is a specific sequence of moving body segments for each person. The purpose of this study is to clarify the coordination strategy among moving joints in whole-body fast reaching movements.

METHOD: Ten male university athletes volunteered as subjects in this study, and the subjects are separated into two groups. Group 1 consisted of common male university athletes (subject 1 to subject 5) specialized in different sports, and group 2 consisted of fencing team members (subject 6 to subject 10). Subjects warmed up and practiced the reaching movement before data collection. All reaches started with a standard stance (with right foot ahead of the left one 40% of the leg length), right shoulder in 0^0 of abduction, right elbow in 90^0 of flexion, and left palm on the anterior superior iliac spine. Each subject was asked to perform whole-body fast reaching movements and remain stable after finishing the motion. Rather than reaching for a small target, a large area was used to exclude the possibility of reducing reaching speed for higher accuracy. Each subject had to complete ten trails with barefoot. The stopping posture is specified with right arm straightforward, right knee in 90^0 of flexion, trunk leaning forward and in line with the straight left leg, and both heels remaining on the ground.

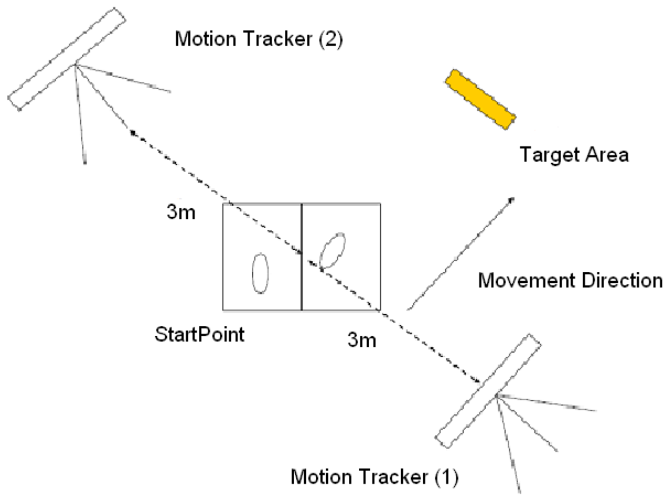

Figure 1. The set up of the experimental condition.

Two Visualeyez motion trackers with the sampling rate of 150 Hz were positioned on both sides of the subjects to record movements. Markers were placed along each side of the body on the acromion, elbow, wrist, sacrum, greater trochanter, femoral epicondyle, lateral malleolus, heel, and the fifth metatarsal. The kinematic data were collected by the software VZSoft, and then filtered by Matlab 7.0 (4th-order butterworth filter with low-pass frequency at 6Hz).

RESULTS: Table 1 shows the timing (% of movement completion) when the maximum angular velocity occurred in each joint in the fastest motion. Table 2 shows the starting timing of extension angular velocity of each joint in the fastest movement. The results demonstrate that the fencers moved the upper extremities earlier than the lower extremities, and the starting timing of maximum angular velocity of the proximal segments (upper arm and thigh) occurred earlier than the distal segments (forearm and shank).

Table 1. Timing of maximum angular velocity

	R_elbow(%)	R_shoulder(%)	R_knee(%)	R_ankle(%)	L_knee(%)	Velocity(m/s)	Time(s)
Group 1	75.55*	74.45*	66.58	69.44	66.57	1.52	0.62
(n=5)	(3.12)	(3.55)	(10.16)	(8.23)	(5.69)	(0.18)	(0.04)
Group 2	52.60*	55.15*	63.41	67.19	73.54	1.42	0.69
(n=5)	(11.47)	(15.10)	(8.13)	(10.03)	(8.99)	(0.17)	(0.09)

The symbol * indicates the significance level p<.05 between the 2 groups.

Table 2. Starting timing of maximum angular velocity

	R_elbow(%)	R_shoulder(%)	R_knee(%)	R_ankle(%)	L_knee(%)	Velocity(m/s)	Time(s)
Group 1	37.36*	29.92*	31.56	36.10	32.77	1.52	0.62
(n=5)	(5.86)	(3.44)	(5.13)	(8.22)	(4.58)	(0.18)	(0.04)
Group 2	13.36*	15.80*	32.05	38.52	41.80	1.42	0.69
(n=5)	(8.15)	(7.42)	(10.41)	(18.10)	(10.88)	(0.17)	(0.09)

The symbol * indicates the significance level p<.05 between the 2 groups.

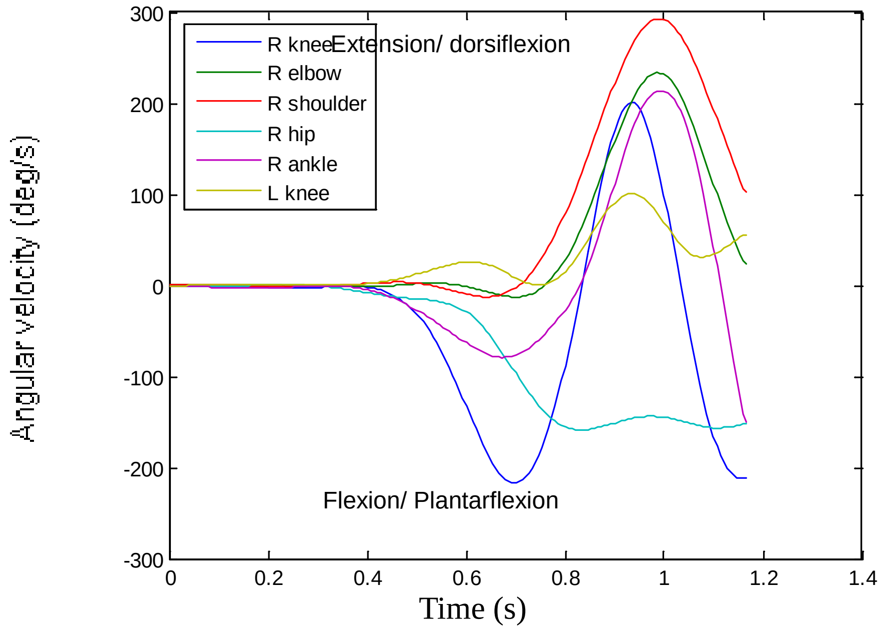

Figure 2. Angular velocity of subject 1.

DISCUSSION: The purpose of the present study is to clarify the coordination strategy among moving joints in whole-body fast reaching movements. In similar studies, Kaminski et al. (1995) showed that elbow and shoulder joints are linked together as a single unit. Kaminski (2007) indicated that the reach and postural synergies became coupled, resulting in the arms, legs and trunk working together as one functional unit to move the whole body forward in reaching motions.

In this study, the maximum angular velocity occurred roughly at the same time of the acromion, elbow, knee, and ankle joints of right side. Most of subjects' maximum angular velocity of left knee occurred around the same time as the other joints. This indicates that upper and lower extremities work together as one functional unit in the motion, similar to the results of previous studies.

The proximal segments started slightly before the distal segments, which conformed to the kinetic chain theory. The fencing members activated the upper extremities earlier than the lower extremities. The reason is that they be training to always move their arm first in order to make their swords hit the opponent as fast as possible. This indicates that exercise habits may strongly affect movement patterns.

CONCLUSION: The results of this current study provide a certain coordination pattern of whole-body fast reaching movements. That is, in executing this kind of movements, upper and lower extremities work together as one functional unit, and the proximal segments started before the distal segments, and there may be slightly different strategies adopted by each individual according to their exercise habits.

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