APPLICATION OF MAXIMUM IMPULSIVE PRINCIPLE IN THE STUDY OF THE COUNTERMOVEMENT VERTICAL JUMP

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The present study aimed to investigate the effect of the am-swing and no arm-swing on countermovement vertical jump **(CMJ)** and to compare the difference of male from female performing **CMJ** by the principle of maximum impulse to achieve movement velocity. On the other hand, we also compared the reaction characteristics of **EMG** signals and kinetics in order to interpret the mechanism of the am-swing during **CMJ.** In experiment 1, the results showed that lengthening the time of applying the force was the main factor to increase jumping height for arm-swing versus no arm-swing, and female jumpers achieved less height due to lesser strength than males. Experiment 2 indicated that the hamstrings might produce the action of plantar flexion during the am-swing of **CMJ** in order to postpone the gastrocnemius and **soleus** accelerating for contraction.

KEY WORDS: countermovement vertical jump, am-swing, electromyography, kinetics.

INTRODUCTION: Biomechanics researchers have often used the countermovement vertical jump (CMJ) as an indication of muscle performance. It is evident that the arm-swing enhances the height of the vertical jump. Harman et al. (1990) examined the effect of the arm-swing by combined squat vertical jump and CMJ, and reported that the arm-swing generated the peak value of vertical ground reaction force for propulsion of the body. The takeoff velocity of the body center of gravity (CG) determines the jump height. The magnitude of the velocity change depends on the magnitude of impulse that comes from force apply to the system over time. Thus, a large area of effective impulse (total impulse, total impulse = area B − area A – area C, see Figure 1.) during a vertical jump corresponds to a great jump height.

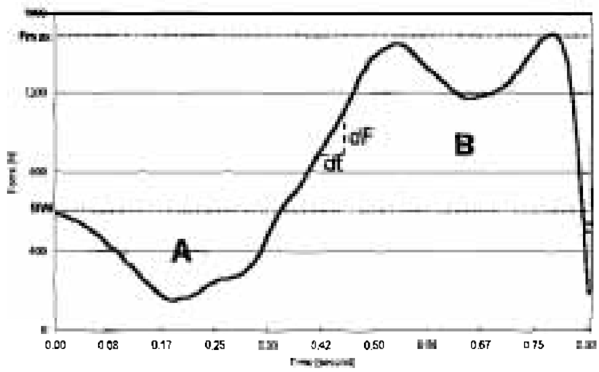

Figure 1 - The vertical ground reaction force component of a CMJ illustrating the negative impulse (area A and area C), positive impulse (area B), peak force F and the slope of force curve **(dF/dt).**

Liu (1998) summarized the impulse-momentum relationship and in his principle of maximum impulse to achieve movement velocity indicated that there are three methods to increase the impulse area: to increase the peak force, to lengthen the time of applied force, and to raise the slope of force curve. In this study differed from Harman's because we used the principle of maximum impulse to detect the effect of the arm-swing. Although it is well known that the male is better equipped for jumping performance than the female, it needs to be assessed from the viewpoint of the principle of maximum impulse to determine whether the difference of takeoff velocity is related to differences in peak force, rate of force development (the slope of force curve), or the time of applied force. The present study was to investigate the effect of the arm-swing and no arm-swing on CMJ by the principle of maximum impulse, and to compare male and female volleyball players on this basis. Further, we compared the reaction characteristics of EMG signals and kinetics to investigate the role of the arm-swing during CMJ.

METHODS: In experiment 1, there were fifteen male varsity volleyball players and twelve female varsity volleyball players served as the subjects for this study. Subjects' information is listed in Table 1.

Table 1 Mean and Standard Deviations of Subjects' **Information**

Group	n	Height (cm)	Body Mass (kg)	Age (years)
Male	15			
Mean		169.8	61.2	20.8
SD		6.6	6.6	1.8
Female	12			
Mean		164.6	56.3	20.4
SD		4.3	6.6	1.0

All the subjects were asked to jump maximally five times for each of two conditions: arm-swing (AS) with CMJ and arms akimbo (AA) with CMJ. One Kistler force platform (model 9287) was used to acquire the vertical ground reaction force when the subjects performed the CMJ. The sampling rate of the force platform was 1000 Hz, and the force data were normalized by every participant's body mass to calculate peak force, impulse, and slope of force curve. BioWare Performance versionl.O was used to calculate the negative impulse (NI), positive impulse (PI), peak force, the maximum slope of the force curve (Max. Slope), and action times. The data were analyzed in 2 (group) x 2 (trial) analyses of variance (ANOVAs), with repeated measures on the last factor. The level of significance was set at α= .01. In experiment 2, a physical education student was the subject. His height, body mass, and age was 172 cm, 60 kg, and 25 years, respectively. The subject was asked to perform the two CMJs as in Experiment 1. One Peak high speed (120Hz), one Kistler force platform (model 9287, 600Hz), and a 16-channel Biovision system (8 channels of pairs of surface electrodes EMG and one channel of trigger signal, 1200Hz) were synchronously used to record and analyze the CMJs' biomechanical data. EMG electrodes were placed on m. gluteus maximus, m. semimembranosus, long head of m. biceps femoris, m. rectus femoris, m. vastus medius, tibialis anterior, m. gastrocnemius, and m. soleus. The raw EMG signals were full-wave rectified, and the output were low-pass filtered by a Butterworth filter (cutoff frequency 50 Hz). The net moments at joints were caculated using an inverse dynamics method. The segmental center of mass, the segmental mass, and the segmental mass moment of inertia were estimated by using Dempster's data provided by Winter (1990).

RESULTS AND DISCUSSION: In experiment 1, the total impulse with an arm-swing was significantly higher than with the arms akimbo. There was no significant between the two trials on the negative impulse, even though the time of negative impulse (TNI) in AS jump was longer than AA jump. There was a significant difference between the two trails on the positive impulse, this was due to AS jump having a longer time of applying force than the AA jump. As the Table 2 indicated, the peak force and the Max. Slope were not significant different between AA jump and AS jump. Therefore, it was concluded that the effect of arm-swing for CMJ was to lengthen the force applied time to the system by the principle of maximum impulse. This result was similar to Boudolos's (1998) study and indicated that the duration of the take-off phase and the relative force applied by the subjects played important roles when jumping with arm-swing.
The difference in the movement time, including TNI and TPI, between male volleyball players and female volleyball players (Table 2) were not significant. However TNI of both AA jump and AS jump seems less in females in males. For male jumpers and female jumpers, the

peak force and the rate of force development (Max. Slope) both influenced jumping performance significantly. Therefore, the major factor to influence the jumping height for sexes was the peak force and the rate of force development, but not the force applied time.

Table 2 Comparison of the Vertical Ground Reaction Force Parameters of Two Groups between Arms Akimbo (AA) with CMJ and Arm-Swing (AS) with CMJ

Group / Trail	*+Jump Height (m)	'+Total Impulse (BW×s)	+NI (BW×s)	+'PI (BW×s)	+Peak Force (BW)	+Max. Slope (BW/s)	TNI (s)	'TPI (s)
Male AA								
Mean	0.565	2.95	1.58	4.62	2.908	17.304	0.398	0.439
SD	0.066	0.20	0.24	0.32	0.488	6.929	0.053	0.040
AS								
Mean	0.657	3.14	1.50	4.78	2.844	18.171	0.491	0.459
SD	0.062	0.19	0.27	0.37	0.423	6.863	0.117	0.032
Female AA								
Mean	0.358	2.29	1.10	3.57	2.404	12.727	0.351	0.389
SD	0.033	0.18	0.08	0.20	0.249	4.327	0.066	0.050
AS								
Mean	0.432	2.45	1.15	3.72	2.347	12.385	0.362	0.460
SD	0.045	0.14	0.15	0.25	0.126	3.055	0.095	0.111

Trial: *$p < .01$ Group: +$p < .01$

The subjects' EMG and kinetics data for Experiment 2 are shown in figure 2. The histories of the hip, knee, and ankle joints indicate that the end of the countermovement and beginning of the push-off were concurrent with the maximum flexion of these three joints during jumping in arms akimbo. For arm-swing CMJ, however, the maximum flexion of hip joint occurred before the upward of the CG and the ankle joint began to extend later than hip joint (80 ms). The force time from the beginning of the countermovement to maximum flexion of the hip joint and the beginning of ankle joint extension to takeoff were similar for AA jumping and AS jumping. This characteristic agreed with the result of Experiment 1 that the AS jump lengthened the force time by about 50 ms to 90 ms. Therefore, we compared the EMG patterns of two jumps and found that there were interruptions in plantar flexors (gastrocnemius and soleus) in AS jump during the minimum hip angle and the minimum ankle angle, and this was different from the AA jump. At the end phase of ankle flexion after hip extension, the plantar flexors acted eccentrically to decelerate the ankle. At the same time that the arms swung forwards and produced the torque to extend the hip joint, the hamstrings (semimembranosus and biceps femoris) were activated to extend the hip joint. Therefore, the activity of the hamstrings was influenced by the arm-swing producing an extension torque on hip joint and to act on the leg to extend the ankle joint. At this time, the hamstrings might be backup for plantar flexors to decelerate the ankle flexion.

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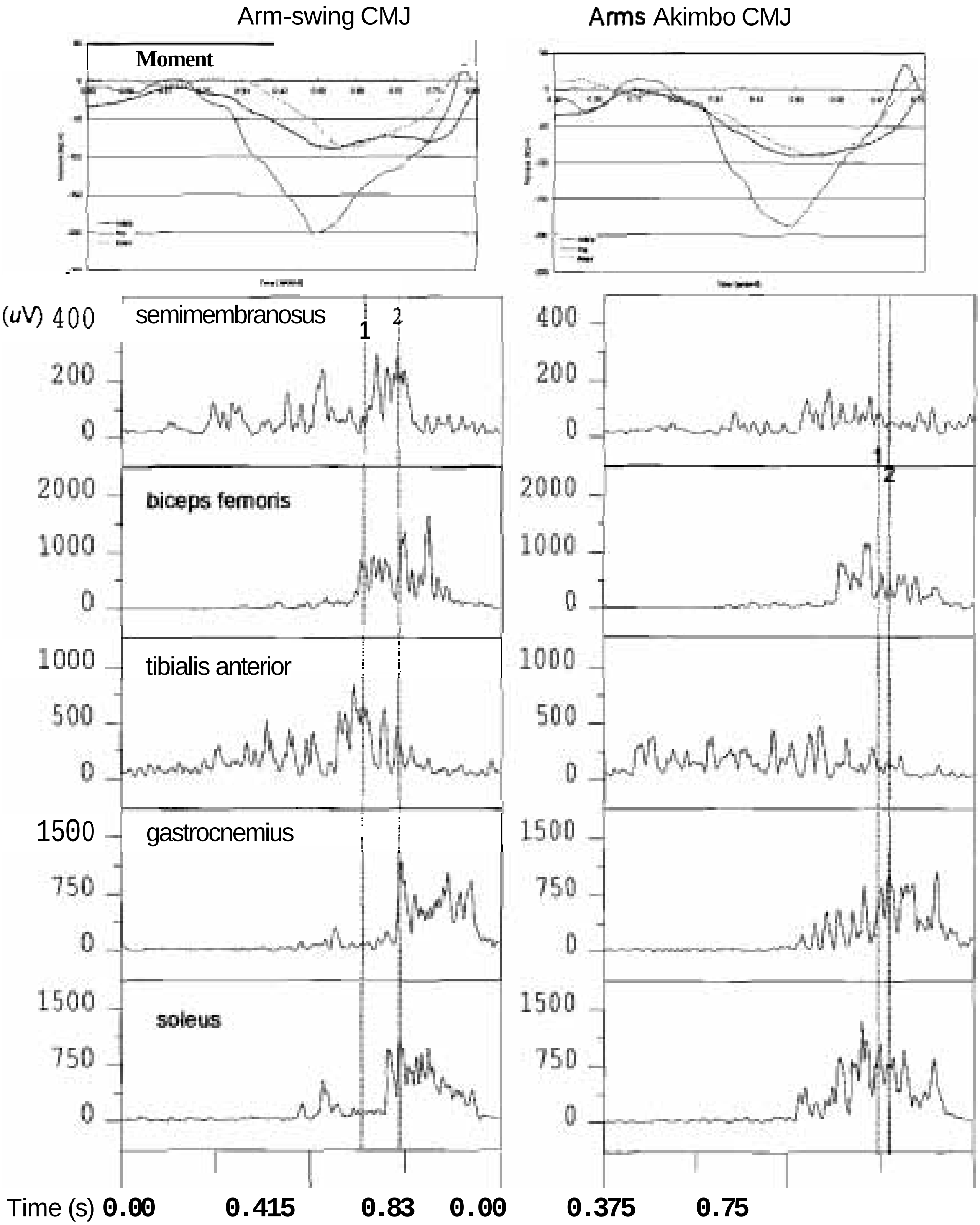

Figure 2 - Joint net moments and EMG for arm-swing CMJ and arm akimbo CMJ. The negative value of moment means extending the joint. The line 1 and line 2 means the event of maximum flexion of hip joint and ankle joint respectively.

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