The Influence of the Upper Extremities Movement on Take-off in Vertical Jump

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INTRODUCTION

The positive influence of the upper extremities swing on the effect of take-off in jumping is well known. Such movement is used in vertical jump, long jump, high jump and others. This effect causes increase of the ground reaction force produced by each segment (Luhtanen and Komi, 1978) and in addition the upper extremities swing has also a coordinative meaning, for example while double overarm movement at running is to be change into parallel movement at take off (high jump). There are also such situations like in basket ball and volley ball (Wielki and Dangre, 1983; Wilkerson, 1983) in which the desired arms swing is limited by the other task which has to be performed like blocking or passing the ball.

Loss in the height of the vertical jump — while the arms swing is not executed — and diminishing ground reaction force at take-off and the possible changes in biomechanical variables during take-off, are the object of this experiment.

MATERIAL AND METHOD

The investigation was carried out on 28 subjects who volunteered in experiment with different kinds of vertical jump. Their characteristics are presented in Table 1.

TABLE 1

Characteristics of investigated subjects (N=28)

	x̄	S
Age (years)	23,61	6,76
Body height (cm)	176,82	5,94
Body mass (kg)	72,43	5,90

Vertical jumps were performed on Kistler force plate and the height of jumps was based on the calculation of these records (Lamb and Stothart, 1978). In synchronization with ground reaction time an electrogoniometer was applied to measure the angular changes in knee joint. The dynamometric and electrogoniometric data were registered, using analog-digital converter on floppy disks of minicomputer ZX Spectrum (Figure 1).

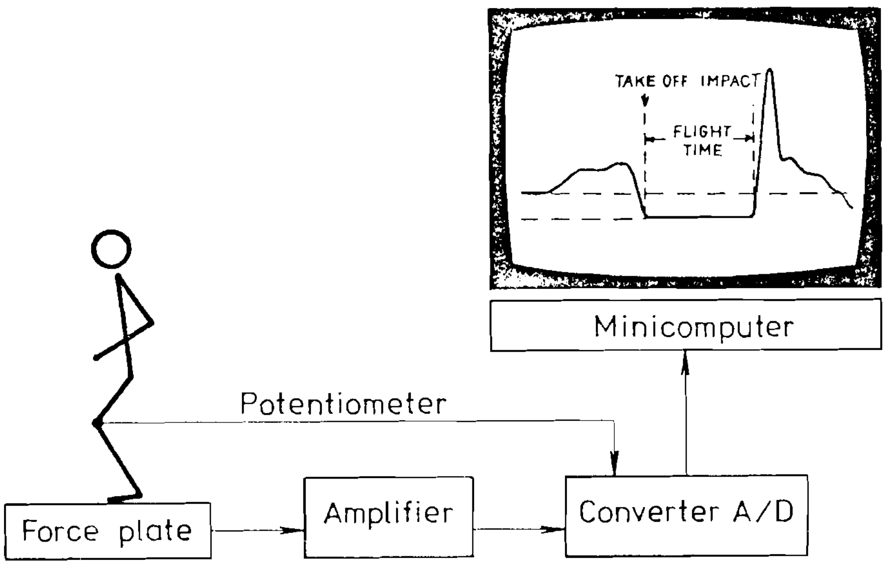

Fig. 1. The set up for measuring biomechanical variables of take-off.

Every subject performed two trials of each of the following jumps:
squatting jump with upper extremities akimbo (SJ)
squatting jump with upper extremities swing (SJA)
counter movement jump with upper extremities akimbo (CMJ)
counter movement jump with upper extremities swing (CMJA)
The registered data served for calculation of the jumping height, time of trial, angular changes in knee joint (positions, velocities) and ground reaction force (minimal, maximal, tangential).

RESULTS

The results of the jumps and biomechanical variables: knee angle, angular velocity and force parameters are presented in Tables 2 and 3. The comparison between SJ and SJA and between CMJ and CMJA shows that the arms swing influences positively on the height of jump. The gain in height is 11% for squatting jump and 10% in counter movement jump.

TABLE 2

Comparison of height of jump and biomechanical variables of take-off between squatting jump (SJ) and squatting jump with arms swing (SJA)

Biomechanical variables	Symbols	Units	SJ		SJA	
			$\bar{x}$	S	$\bar{x}$	S
Height of jump	h	cm	31.67	4.79	35.50	5.13
Knee:						
time of extension	t_p	s	0.326	0.071	0.364	0.097
starting position	at_0	degrees	84.31	12.10	87.44	12.90
minimal+	at_2	degrees	78.24	12.04	79.29	11.15
at end of taken-off	at_3	degrees	157.68	12.66	158.92	14.46
angular velocity of flexion (max)	ω_E	degree/s	34.55	32.43	52.02	44.87
angular velocity of extension (max)	ω_C	degree/s	599.37	158.43	594.06	167.95
Reaction force:						
minimal+	F_{min}	kG	55.83	11.05	47.68	14.47
maximal	F_{max}	kG	153.89	22.58	165.50	22.91
Tangential force	G_F	kG/s	760.27	315.88	733.45	204.58

+ Note, that minimal angle (at_2) should not differ from starting one, the angular velocity of flexing· (ω_E) should be zero and F_{min} should be equal to body weight.

TABLE 3

Comparison of height of jump and biomechanical variables of take-off between counter movement jump (CMJ) and counter movement jump with arms swing (CMJA)

Biomechanical variables	Symbols	Units	CMJ		CMJA	
			$\bar{x}$	S	$\bar{x}$	S
Height of jump	h	cm	33.53	4.90	37.17	5.60
Knee:						
time of extension	t_p	s	0.331	0.09	0.34	0.06
starting position	at_0	degrees	168.56	8.75	168.38	9.70
minimal	at_2	degrees	68.40	15.79	69.51	13.34
at end of take-off	at_3	degrees	149.64	13.94	153.49	12.42
angular velocity of flexion (max)	ω_E	degree/s	248.29	110.21	262.71	47.86
angular velocity of extension (max)	ω_C	degree/s	584.30	163.72	589.08	160.22
Reaction force:						
minimal	F_{min}	kG	32.03	12.11	31.78	12.30
maximal	F_{max}	kG	164.40	27.54	162.09	21.12
Tangential force	G_F	kG/s	745.86	330.39	788.85	293.54

For statistical analysis test «t» was applied and results were 2.832 for squatting jumps and 2.543 for counter movement jumps. These results are statistically significant at 0.05 level. The analysis of knee angle and angular velocity of knee bending reveals, that it is very difficult to get the squatting jump without any preparatory (downward) movement. Although the knee flexion is very small, it can influence the small, statistically nonsignificant, differences between SJ and CMJ. This difference is less than 2 cm while Bosco and Komi (1982) reported for group of students about 5 cm. The arms movement does not influence significantly on other biomechanical variables except F_{min} in SJ and CMJ.

On the basis of correlation coefficients (see Table 4) it can be said, that reaction force is proportional to body mass in each case. The same relation exists between body height and maximal ground reaction force. The jumping height is influenced by body height to the same degree in spite of the way of performing the jump.

INTERPRETATION AND CONCLUSION

In the analytical paper Hay et al. (1981) reported that the downward torque at the shoulder joint in the lowest position of the CMJ and upward

TABLE 4
Correlation coefficients

		SJ	SJA	CMJ	CMJA
Body mass	— F_{min}	0.71	—	0.38	0.66
	— F_{max}	0.68	0.82	0.63	0.70
Body height	— F_{max}	0.38	0.56	0.42	0.51
	— jumping height	0.52	0.56	0.56	0.52

Statistically significant at 0.05 level when $r > 0.35$.

torque at elbow joint in the subsequent phase, correlate significantly with height of jump. Bober (1964) wrote that also angular velocity of upper extremity swing has positive correlation with end velocity of take-off. The mean angular velocity of the arms of the propulsive phase can be over 1000°/sec. It can really influence the ground reaction force and improve the stretch-shortening cycle of leg muscles, which in turn provide the opportunity for re-utilization of their potential elastic energy (Bosco and Komi, 1982). This is probably the main source of gain in jumping height when upper extremity is applied and explains why there are no differences in mechanical parameters of take-off between jumps in question. The difference in jumps with or without upper extremities swing is rather due to higher strain done on leg extensors than due to kinematical changes in movement executed by lower extremities.

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