INFLUENCE OF THE ANKLE JOINT DORSIFLEXION ON THE EXECUTION OF VERTICAL JUMPS

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The purpose of the present study was to investigate the differences in the execution of vertical jumps between individuals with good and poor ankle dorsiflexion ability. Thirty (30) males and thirty (30) female P.E. students, after being evaluated for ankle dorsiflexion, formatted the flexible and inflexible groups (FG and IFG) and executed vertical jumps. In the SQJs the IFG exhibited more inclination of the trunk at the beginning of the jump, while in the CMJs and the DJs they applied greater forces and produced greater peak angular accelerations in all joints. The IFG, by leaning forward the trunk, underwent a greater injury risk for the low back while executing the SQJs. On the other hand, they underwent an increased injury risk for the achilles tendon by raising the heels off the ground and applying greater forces during the DJs.

KEY WORDS: ankle joint flexibility, dorsi flexion, vertical jump, kinematics, kinetics, injury risk.

INTRODUCTION: A considerable amount of research has dealt with the mechanical output occuring during a vertical jump, as well as the factors influencing it. Findings suggest that a proximal to distal sequence of muscle activation exists, since hip extensors are activated first, followed by the knee flexors and finally the ankle plantar flexors (Pandy and Zajac, 1991). The importance of the ankle joint for achieving maximal jump height was reported by Luhtanen and Komi (1978) and by Hubley and Wells (1983), as they found that the contribution of the ankle plantar flexion to take-off velocity was around 23%. Ankle contribution to a vertical jump depends upon the magnitude of the force developed by the plantar flexors, from the differences in their stimulation onset times (Bobbert and van Zandwijk, 1999) and from its range of motion (Wilson, Elliot, & Wood, 1991). Subsequently, range of motion depends on the dorsiflexion and plantar flexion ability. However, it is still unclear how the ankle dorsi-flexion (ADF) affects the technical characteristics of a jump. Therefore, the purposes of the present study were to investigate: a) the effect of limited ADF on the position of the body at the lowest body centre of mass (BCM) position during vertical jumps and b) the effect of limited ADF on the kinetic and kinematic parameters of vertical jumps.

METHOD:

Subjects: The initial sample was 155 male and 197 female physical education students. After the conduction of a flexibility test for the determination of their passive ADF angle, fifteen male and female with ADF values less than 59.8^o were assigned to the flexible groups (FG), whereas fifteen male and female with ADF values over 71.8^o were assigned to the inflexible groups (IFG).

Data Collection: The selected subjects executed the jumping tests Squat jumps (SQJ), Countermovement jumps (CMJ) and Dropjump from 60cm height (DJ60). In the SQJs, the subjects (with the heels placed on the force plate) started with the knees bent in an approximate 90^o angle. In CMJs subjects were instructed to jump as high and as fast as possible, after lowering the torso from an upright body position. In DJ60, subjects were instructed to jump as high and as fast as possible. All jumps were performed barefooted, with a minimum 60-second interval. Ground reaction force data during the execution of the jumps were sampled at 500 Hz from an AMTI OR6-5-1 force plate (AMTI, Newton, MA). Concurrently, all jumps were recorded with a Panasonic NV-MS4E video camera (Matsushita Electric Industrial Company, Osaka, Japan), operating at 50 Hz.

Data Analysis: After the manual digitization of 22 anatomical points a 2-D DLT kinematic analysis was held through a custom build software. The derived data underwent a digital filtering process (2^{nd} order Butterworth filter, 5-7 Hz cutoff frequency) according to Winter (1990). From the position data linear and angular variables were derived with standard mathematical procedures. The synchronization of kinetic and kinematic data was accomplished with Lagrange interpolation. The kinetic and kinematic parameters underwent a statistical procedure using independent samples t-tests with the SPSS software (SPSS Incorporated, Chicago, Il, version 12). The level of significance was set at $p < 0.05$.

RESULTS: In the SQJs the horizontal distance between the center of mass of the upper body (torso and upper limbs) and the hip (*CMt-H*) was significantly different, while the jump height (*H*) was almost the same (Table 1). The other variables, Time impulse (Ti), Force to bodyweight ratio (F/bw), Rate of force development (RFD) and Vertical body centre of mass displacement (S_{BCM}) did not show any difference. In CMJs, significant difference was also observed for CMt-H (men).

Table 1. Kinematics and dynamic parameters for all the subjects in the three types of jumps (Mean ± standard deviation)

		Men			Women		
		Flexible (n=15)	**Inflexible (n=15)**	**p**	**Flexible (n=15)**	**Inflexible (n=15)**	**p**
SQJ							
H	cm	27.6±4.3	28.0±6.4	.85	19.2±2.8	17.6±2.4	.09
Ti	ms	457 ± 74	443 ± 72	.61	449 ± 46	463 ± 79	.54
F/bw		2.4 ± 0.2	2.5 ± 0.3	.79	2.2 ± 0.1	2.2 ± 0.2	.84
RFD	kN/s	10.7 ± 3.6	11.2 ± 3.4	.72	6.5 ± 2.1	7.6 ± 3.3	.30
S_{BCM}	cm	50 ± 6	49 ± 8	.74	43 ± 5	41 ± 4	.31
CMt-H	cm	21.8 ± 4.2	32.3 ± 5.1	.00*	19.1 ± 3.1	25.6 ± 4.7	.00*
CMJ							
H	cm	32.0 ± 4.0	30.2 ± 4.9	.27	20.2 ± 2.9	18.9 ± 3.0	.22
Ti	ms	644 ± 116	650 ± 112	.88	595 ± 82	577 ± 103	.61
F/bw		2.6 ± 0.3	2.5 ± 0.3	.23	2.3 ± 0.2	2.4 ± 0.2	.84
RFD	kN/s	12.3 ± 3.4	10.7 ± 4.5	.29	7.5 ± 2.2	9.1 ± 3.9	.16
S_{BCM}	cm	60 ± 9	54 ± 5	.03*	45 ± 7	44 ± 7	.60
CMt-H	cm	25.6 ± 3.4	30.9 ± 4.3	.00*	19.7 ± 2.6	22.7 ± 6.2	.08
DJ60							
H	cm	22.4 ± 5.9	19.5 ± 4.6	.14	12.7 ± 2.8	10.6 ± 3.7	.08
Ti	ms	523 ± 105	441 ± 96	.03*	527 ± 87	459 ± 100	.05
F/bw		3.4 ± 0.5	3.9 ± 0.7	.06	3.7 ± 0.4	4.1 ± 0.8	.12
RFD	kN/s	56.2±20.8	76.2±25.1	.02*	59.2±20.1	65.8±23.9	.41
S_{BCM}	cm	45 ± 1.1	36 ± 0.5	.01*	35 ± 0.8	29 ± 0.7	.02*
ω_{kn}	deg/s	11.1 ± 0.9	10.5 ± 0.7	.05	10.3 ± 0.6	10.0 ± 0.6	.25
ω_{hip}	deg/s	8.6 ± 0.9	8.4 ± 0.6	.47	7.6 ± 0.8	7.8 ± 1.0	.60
a_{kn}	deg/s	45.6 ± 7.5	54.7 ± 15.9	.05	43.2 ± 9.6	52.0 ± 17.1	.08
a_{hip}	deg/s	36.2 ± 5.3	41.7 ± 10.5	.07	33.0 ± 7.6	35.0 ± 5.5	.40
CMt-H	cm	19.4 ± 6.0	19.8 ± 6.4	.84	16.1 ± 3.5	15.8 ± 5.1	.86

For the DJ60, kinetic analysis (Table 1) showed that the FG exhibited larger vertical BCM displacement (S_{BCM}), larger impulse time (*Ti*) and lower rate of force development (*RFD*). Force to body weigth ratio (*F/bw*) was also found to be lower for the FG but not significantly different. Finally, kinematic analysis revealed that there was a tendency for the FG to have higher peak angular velocity (ω), but lower peak angular acceleration (a) in all joints.

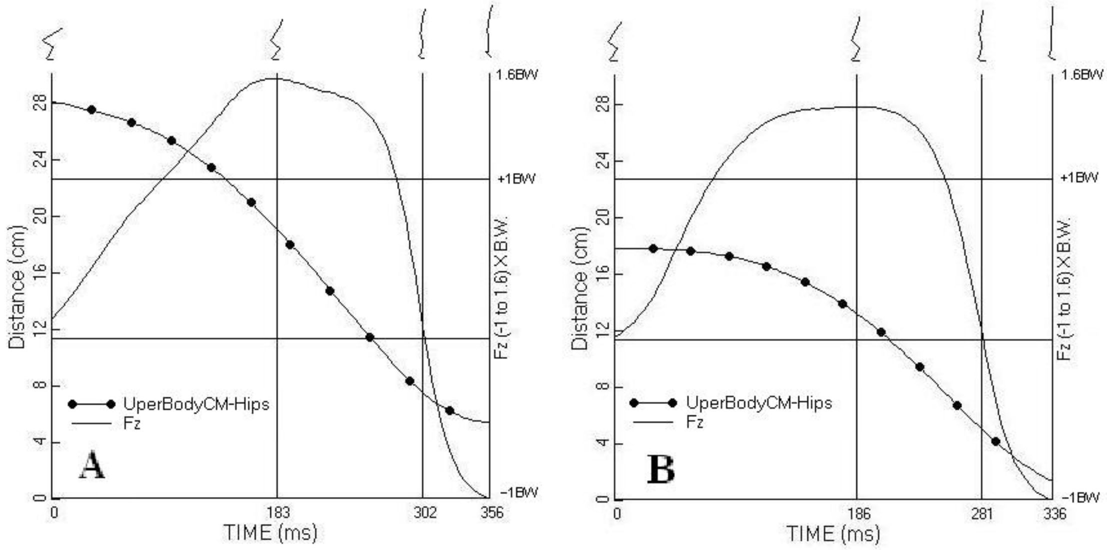

Figure 1. Representative, UpperBody centre of mass horizontal distance from Hips and force output during SQJ (A: IFG, B: FG).

DISCUSSION: In SQJs no significant differences between the FG and the IFG were observed, except for the inclination of the trunk, which caused a greater CMt-H (Figure 1). In the CMJs the FG had greater peak angular velocities in all joints, as well as shorter CMt-H. This shorter CMt-H might be important concerning low back injury prevention caused by rotational movements around the hip joint (Hollmann and Hettinger, 1980). By contrast, the IFG lifted the heels off the ground. Papaiakovou et al. (2003) found that inflexible individuals achieve less jump height when they executed a SQJ with their heels off the ground. A smoother ground reaction force (GRF) development in the DJ60 was exhibited from the FG, and lower peak vertical GRF values were recorded. This could have occurred as result of the larger joint range of motion, which in turn contributed to a larger BCM vertical displacement during the propulsive phase. The larger GRF and RFD values observed for the IFG may lead to greater peak angular accelerations. However, these greater peak acceleration values did not contribute to an enhancement in linear BCM velocity, perhaps due to smaller range of motion caused by the stiffness (Bobbert and van Soest, 2001).

CONCLUSION: Based on the findings of the present research, it could be proposed that the way someone jumps depends on the dorsiflexion ability. Although simulation studies have reported that heel contact is not required for an optimal jumping solution and different initial postures do not affect jumping performance (Selbie and Caldwell, 1996), we believe that these findings do not stand for people with limited ADF. Coaches should reconsider the technical issues of vertical jumps based on the flexibility of the ankle joint. For instance, it is unavoidable for an individual with limited ADF to perform a SQJ without leaning his trunk forward. In sports, where an upright posture is required during the execution of the jump (i.e. a rebound in basketball or a block in volleyball), an arrangement for an athlete with poor ADF can be achieved, such as supporting the anterior part of the sole with an implement. However, possible consequences of such an arrangement must be taken into consideration (i.e. high achilles tendon's tension, lack of stability, poorer performance).

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