THE VARIABILITY OF VERTICAL GROUND REACTION FORCES DURING UNLOADED AND LOADED DROP JUMPING

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INTRODUCTION

Drop jumping as a plyometric exercise engaging muscle in a stretch-shortening cycle is widely used in athletic training. The purpose of this type of training is to give the muscle through the pre-stretching mechanism (eccentric-concentric contraction) more forceful shortening using the stored elastic energy and the stretch reflex.

In drop jumping, the vertical impulse $F_Y \cdot t$ is of utmost importance in changing the (vertical) momentum of the body which, in turn, depends on the body's mass and (vertical) velocity at touchdown. On the basis of the impulse-momentum relationship, $F \cdot t = \Delta mV$, it is possible to equally increase the (vertical) impulse by increasing either the drop velocity (which depends on the drop height), or the body mass (by adding a weighted vest).

Different aspects of drop jumping have been already studied (Bosco, 1979,1990, Schmidtbleicher 1983). However, the effect that systematic changes in mass and velocity has on the impulse has not yet been investigated. It was therefore the purpose of this study to examine the effect that variations in mass and velocity has on the force-time parameters (Impulse).

METHODS

Five top track and field and diving athletes, 3 males and 2 females, participated in the study. The age range of the subjects was 17-24 years. All subjects included drop jumping drills in their training routines. Subjects were instructed to perform two unloaded drop jumps from each height of 0.45 (condition A) and 0.55 (condition B) meters. In addition, each athlete performed two loaded drop jumps from a standard height of 0.30 meters where, in each case, the additional load was such as to result in momentum equal to the momentum of unloaded jumps from 0.45 and 0.55 meters, respectively.

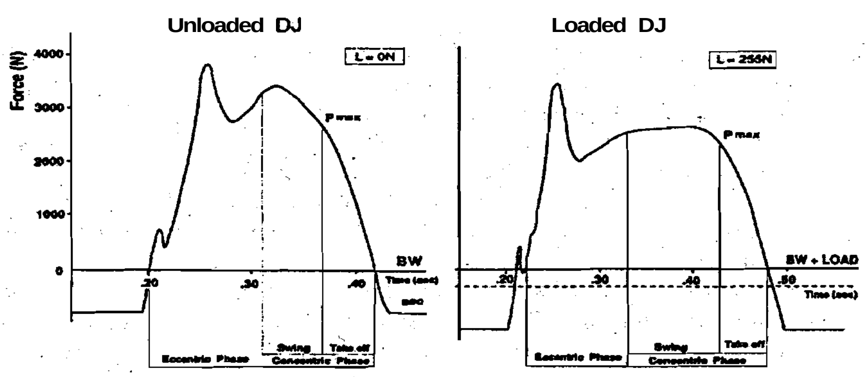

Figure 1. Sample of force time curves of a loaded and an unloaded drop jump

Subjects were asked to perform maximally, attempting to obtain maximal heights with short contact times. A 9281B Kistler force plate was used to collect force data at a sampling rate of 500 Hz. Sample of force time curves of loaded and unloaded drop jumps is presented in Figure 1. Average forces at selected phases, peak power, net height jumped and take-off velocities were subsequently calculated. Loaded and unloaded mechanical parameters were compared via t-tests. All trials were simultaneously recorded by two 30 Hz video cameras. Video data, however, is presently analysed and will be presented at a later time.

RESULTS AND DISCUSSION

Take off velocities (V), jumped heights (h) and peak power (P) are presented in Table 1. As expected, unloaded velocities and heights were significantly larger than the loaded ones. being 20% and 31% higher. respectively. Peak power was also significantly higher in the unloaded drop jumps. The difference in peak power should be attributed to the difference in take-off velocity and not to the additional load.

Table 1. Kinematic results of the loaded and unloaded drop jump

	Jumping Condition	Unloaded DJ	Loaded DJ	t	P
$V_{take\ off}$ (m/s)	A	3.09±0.8	2.80±0.28	12.0	0.0002
	B	3.17±0.3	2.61±0.19	9.7	0.0006
h_{max} (cm)	A	49± 9	40±8	9.5	0.0006
	B	52±10	35±5	7.4	0.002
V_{pmax} (m/s)	A	2.36±0.24	2.25±0.23	4.4	0.01
	B	2.42±0.23	2.11±0.10	3.7	0.02
P_{max} (w)	A	3830±1659	3196±1344	3.3	0.03
	B	3802±1748	2784±1217	3.9	0.017

Table 2 shows temporal results. With the exception of the time from peak power to take off, which was found to be the same in both types of jumps, all temporal measurements were significantly longer in the loaded jumps. The fact that the time of the concentric phase (end of eccentric phase to take-off) is made up from the time from the end of the eccentric phase to peak power (swing phase) and the time from peak power to take-off (take-off phase), combined with the fact that no temporal differences were found in the latter, indicate that the significantly larger duration of the concentric phase of the loaded jumps were solely due to differences in the swing phase and not the take-off one. In turn, the fact that no significant differences in the duration of the take-off phase were found may be of practical value in evaluating performance and talent identification. However additianal data is needed to verify and further investigate this statement.

Forces were compared by considering "zero" force to be the one of just the body weight (BW) (unloaded jumps), or BW plus load (loaded jumps). It was found that the average forces during both the eccentric and concentric phases to be higher in the unloaded jumps (Table 3). When, however, the force due to additional load was added. the recorded forces were not significantly different between the jumps. No significant differences between jumps were also found in the average forces during the take off phase.

Table2 Temporal results of the loaded and unloaded drop jump.

Jumping condition		Unloaded DJ	Loaded DJ	t	P
$t_{eccentr.}$ (ms)	A	108±16	130±12	3.4	0.03
	B	118±13	141±16	8.8	0.0008
$t_{concentr.}$ (ms)	A	137±22	164±26	4.2	0.01
	B	146±31	188±41	5.1	0.007
t_{swing} (ms)	A	85±15	112±21	5.5	0.005
	B	93±30	135±43	3.6	0.02
$t_{take\ off}$ (ms)	A	52±9	52±9	0.0	1.0
	B	53±9	53±6	0.2	0.88

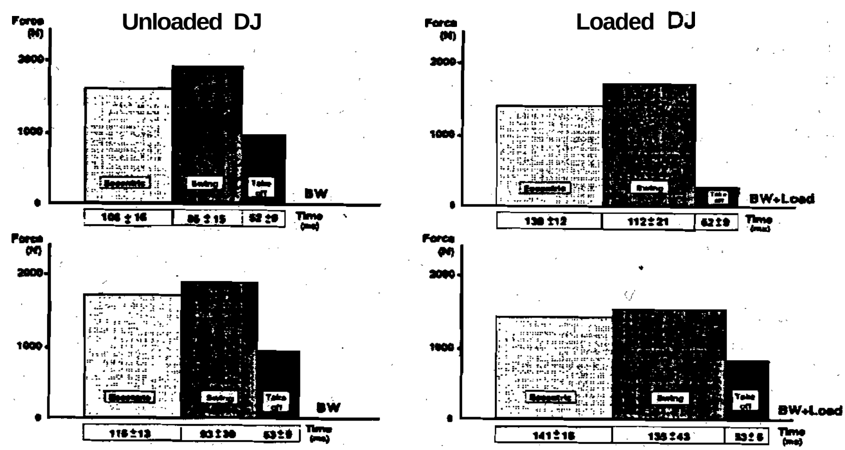

Figure 2. Force and temporal results of the different phases of the jumps

Force and temporal results of the different phases of the jumps are also presented graphically in figure 2.

Table 3. Kinetic results of the loaded and unloaded drop jump.

	Jumping condition	Unloaded DJ	Loaded DJ	t	P
$F_{ave\ eccentric}$ (N)	A	1620±298	1401±166	3.1	0.04
	B	1721±354	1430±293	8.5	0.001
$F_{ave\ concentric}$ (N)	A	1558f479	1437±448	2.9	0.04
	B	1537±547	1308±432	3.6	0.03
$F_{ave\ swing}$ (N)	A	1903±536	1709±565	3.8	0.018
	B	1881±745	1548±581	1.0	0.38
$F_{ave\ take\text{-}off}$ (N)	A	987±370	866±254	0.9	0.42
	B	967±368	853±356	0.7	0.56
F_{pmax} (N)	A	1594±575	1383±475	2.8	0.05
	B	1554±669	1321±593	3.2	0.03

CONCLUSION

The results indicate that in loaded and unloaded drop jumps where mass and (drop) velocity is systematically varied, there are differences in average forces and temporal measurements at selected phases of the jumps. At the end, however, the total effort (impulse) given by the athlete may be the same. Therefore in loaded and unloaded drop jumps performed with maximal effort, the performance level depends on the athletes physical conditioning.

Since the loaded drop jumps are necessarily performed slower than the unloaded ones it might be beneficial for athletes to use them during the preparatory and learning training period and to use the unloaded drop jumps closer to competition time.

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