Mechanical comparison of eight vertical jump exercices.

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1 Introduction

Vertical jump exercises are widely used in sport training and may differ by a couple of variables that could significantly influence muscle work and neuromuscular activity. Three decades of literature have documented the influence of counter-movement, drop jump, range of motion and external load on mechanical parameters during vertical jump exercices. Most studies have investigated these variables separately. In most cases, only a few mechanical parameters are reported. So the aim of this study was to compare in a single paradigm, several mechanical variables calculated from the data measured by a force platform during eight common vertical jump exercises.

2 Methods

Ten healthy male subjects (age: 26±4yr; height: 1.80±0.05m; weight: 77±9kg), participated in this study. After a standardized warm-up, they performed, in a randomized order eight kinds of vertical jumps on a force platform. The tests were (1) Squat jump (SJ); (2) Short counter-movement jump (S-CMJ); (3) Natural counter-movement jump (N-CMJ); (4) Deep counter-movement jump (D-CMJ); (5) Loaded (20kg) counter-movement jump (20-CMJ); (6) Short drop jump (S-DJ); (7) Deep drop jump (D-DJ); (8) Six consecutive jump test (6CJ). Prior to each test a specific instrucion was given to the subject.

A force platform (Kistler, type 928A11) was used to measure the vertical component of the ground reaction force during each test (F). This signal was thereafter analysed using Labview applications (Labview 8.5, National Instrument) specifically developed for each jumping exercise and allowing the calculation of the subject's center of mass vertical acceleration (*A*), velocity (*V*), displacement (*D*) and power (*P*) during the jumps. Power was calculated as the product of ground reaction force and vertical velocity. Ground contact time (*T*) was also measured. Peak values of each parameter were calculated during both eccentric (*ec*) and concentric (*co*) phases of the jump. Stiffness, calculated as the ratio between the force at the lowest position and the center of mass displacement at this position (*Dmin*), was also analysed. ANOVA and classical t-tests were used for comparison between jump tests.

3 Results and Discussion

Means and standard deviations for each variable and for each jump modality are presented in Table 1. These results provide an overview of the similarities and differences between different types of vertical jump exercises frequently utilised during plyometric training. According to the litterature the counter-movement significantly improves jump height, concentric velocity and peak power but, surprisingly, not peak force. Moreover, a recent study has provided no evidence that peak force is higher in the CMJ than in the SJ [1].

All the deep jumps (N-CMJ, D-CMJ and D-DJ) produced superior jump heights and concentric velocities as compared to the shallow jumps (S-CMJ, S-DJ and 6CJ), confirming that an insufficient center of mass lowering reduces the velocity development and consequently the jumping performance [2]. An unnatural jumping strategy (D-CMJ) produced the same jump height as the N-CMJ. In agreement with a recent study [2] the use of a deeper flexion (D-CMJ) did not reduce jump height in comparison with self selected flexion (N-CMJ).

As expected, loading a counter-movement jump with 20kg (20-CMJ) reduced jump height and *Vco*, and increased ground contact time but did not produce a greater peak force than unloaded jumps : the increase in load is counter-balanced by a decrease in acceleration. In the 20-CMJ lower velocity and acceleration were observed during the eccentric phase : such a strategy may be used to preserve muscles from any extreme eccentric loading and potential risk of injury.

Interestingly, the more powerful exercises were the S-DJ and 6CJ that involved short impulse durations and very high acceleration levels. In contrast, a large range of motion (*Dmin*) seemed to decrease power development. It appears that vertical jump performance and power development are not necessarily linked. Power output is influenced by the jumping modality and could not be accurately predicted from a single assessment of vertical jump height.

Table 1 shows that eccentric loading (*Fec*) is emphasized by short impulse jumps (S-CMJ, S-DJ and 6CJ), confirming that these exercises are very usefull for improving rate of eccentric force development. Results show that shallow knee flexion favour higher *Fec*, but at the same time lead to lower jumping performance, reinforcing the theory that peak force and power are not directly linked to the jump height.

Stiffness, reported to be determinant in some high power tasks like jumping and sprinting, appears to be highly dependent on the jumping strategy. Interestingly, greatest stiffness values were not recorded during the highest vertical jumps, meaning that stiffness is not critical for jumping high. These findings are not surprising as the highest jumps are the deepest ones. In fact, stiffness appears to be critical to the rate of eccentric force development and in the maintaining of a positive energy balance [1] which are key points for short duration and high impulse activities like sprinting, bounding or changing direction.

4 Conclusions

The present study demonstrated that mechanical parameters are largely influenced by the style of jump. In the light of these results, there is an evidence that jumping modality has to be pertinently selected according to the sport context and training objective.

References

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Table1. Means and standard deviations of each variable and for each jump modality. Significant differences between jumping modalities ($p<0.05$) were found between all variables unless denoted by a letter, which means that all variables with the same letter were not statistically different.

	SJ	***S-CMJ***	***N-CMJ***	***D-CMJ***	***20kg CMJ***	***D-DJ***	***S-DJ***	***6-CJ***
Dmin (cm)	-0.27 (0.02) [a]	-0.18 (0.03)	-0.3 (0.05) [a]	-0.37 (0.04) [c]	-0.31 (0.08) [ad]	-0.34 (0.07) [cd]	-0.13 (0.04) [b]	-0.12 (0.02) [b]
Jump Height (cm)	0.36 (0.05) [cd]	0.36 (0.06) [c]	0.42 (0.06) [a]	0.43 (0.05) [a]	0.32 (0.05) [db]	0.42 (0.06) [a]	0.32 (0.06) [b]	0.31 (0.06) [b]
Tec (s)	0 (0)	0.09 (0.01) [b]	0.15 (0.03) [a]	0.17 (0.04) [a]	0.19 (0.03)	0.25 (0.06)	0.1 (0.03) [b]	0.07 (0.01)
Tco (s)	0.3 (0.1) [b]	0.15 (0.02)	0.22 (0.04) [ac]	0.26 (0.02) [bc]	0.27 (0.05) [b]	0.23 (0.04) [a]	0.1 (0.02)	0.08 (0.01)
Fec (N)	876 (219)	2462 (313)	1973 (325) [a]	1869 (270) [a]	1959 (273) [a]	2036 (439) [a]	4076 (941)	4840 (821)
Fco (N)	1819 (250) [b]	2586 (346)	2022 (269) [ab]	1883 (252) [b]	2048 (246) [a]	1999 (344) [ab]	3910 (751)	4731 (802)
Aec ($m.s^{-2}$)	0 (0)	22.5 (4)	16.2 (5.1) [a]	14.6 (2.8) [a]	10.5 (2.7)	16.9 (5.5) [a]	43.9 (12.8)	53.5 (8.8)
Aco ($m.s^{-2}$)	14 (2.4)	24.1 (4.4)	16.8 (4.3) [a]	14.8 (2.4) [a]	11.5 (2.6)	16.4 (4.3) [a]	41.8 (10.8)	52 (8.6)
Vec ($m.s^{-1}$)	0 (0)	-1.15 (0.17) [b]	-1.29 (0.18) [a]	-1.44 (0.22) [a]	-1.14 (0.21) [b]	-1.9 (0.35) [c]	-1.85 (0.23) [c]	-2.39 (0.18)
Vco ($m.s^{-1}$)	2.57 (0.18) [bc]	2.59 (0.2) [b]	2.79 (0.19) [a]	2.8 (0.17) [a]	2.41 (0.19) [de]	2.78 (0.17) [a]	2.49 (0.22) [cd]	2.35 (0.29) [e]
Pec (w)	0 (0)	-1719 (512) [a]	-1434 (311) [a]	-1651 (541) [a]	-1404 (345) [a]	-3073 (631)	-4954 (1416)	-6354 (1126)
Pco (w)	3662 (723) [b]	4291 (876) [a]	4121 (640) [ad]	3727 (678) [be]	3862 (702) [be]	3951 (671) [de]	5386 (1095) [c]	5795 (1365) [c]
Stiffness ($N.m^{-1}$)	0 (0)	14264 (3448)	6784 (2027) [a]	4926 (1020)	6697 (2702) [a]	6132 (2029) [a]	31143 (11215)	40646 (11158)