[Relationship between drop vertical jump heights and isokinetic measures utilizing the stretch-shortening cycle]

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Abstract:
The purpose of this study was to determine how isokinetic eccentric and concentric peak torque/body weight ratios and time to peak torque values relate to drop vertical jump heights in 30 healthy subjects (12 men and 18 women, age = 22.7±2.2 yr, ht =169.6±8.0 cm, wt =67.2f11.9 kg). Drop vertical jumps were performed from a box 50 cm high. Subjects were tested isokinetically on each leg for the motions of knee extension and ankle plantar flexion. Eccentric and concentric peak torque (PT)/body weight ratios along with time (s) to eccentric and concentric peak torque were extracted from the Kin Com II computer. A stepwise multiple regression analysis was conducted to determine the relationship between the eight predictor variables and drop vertical jump height. Knee extension concentric PT/body weight ratio was the most significant predictor of drop vertical jump height, accounting for 23% of-the variance. This finding suggests that the stretch-shortening cycle can be simulated using isokinetic strength measurements and that drop vertical jump height can be attributed in part to concentric knee extension strength.

Article:
1. INTRODUCTION
The muscle stretch-shortening cycle (SSC) plays an important role in physical activity. The stretch-shortening cycle is based on the concept that a muscle can exhibit a stronger concentric contraction by immediately preceding it with a strong, quick eccentric contraction [6,11-13]. This physiologic sequence occurs in a variety of sport activities, such as the long jump in track and the basketball lay-up.

Early studies by Cavagna et al. [4,5] focused on examining the amount of force a muscle could produce when preceded by several different loading environments. One of these conditions included prestretching an isolated frog gastrocnemius muscle at different speeds and then measure the resulting force production. In addition, they measured muscle force production after human subjects performed small vertical jumps onto a force platform [3-5]. Through this series of experiments, it was shown that when a concentric contraction is immediately preceded with a prestretch, a stronger concentric contraction results.

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More recently, vertical jump height has been used as a standard measure to assess the efficiency of the stretch-shortening cycle. Two research reports [1,8] have indicated that vertical jumps preceded by an eccentric contraction result in greater vertical jump heights. The jumps were initiated while standing on top of a box, jumping to the ground, and upon hitting the ground proceeding into a forceful vertical jump.

The stretch-shortening cycle has also been examined using isokinetic dynamometry. Helgeson and Gajdosik [6] studied knee extension torque production using the Biodex (Biodex Medical Systems, Inc., Shirley, NY, USA). Knee extension occurred under three different loading protocols; a concentric contraction preceded by a passive stretch, a concentric contraction preceded by an isometric load, and a concentric contraction preceded by an eccentric load. Velocity was set at 60° .5-1. The results showed that the greatest concentric peak torque (PT) production occurred when the contraction was preceded by an eccentric load. Time to peak torque was also found to be faster in both the isometric and eccentric preload conditions [6]. Earlier work by Svantesson et al. [10] produced similar findings when studying ankle plantar flexion peak torque using the Kin Corn II (Chattecx Corporation, Hixson, TN, USA) isokinetic dynamometer.

Plyometric exercises which incorporate the stretch-shortening cycle principles, have been used as both a strength training tool and as a way to improve functional progression during the rehabilitative process. The- purpose of this study was to examine the relationship between isokinetic eccentric and concentric peak torque/body weight ratios and time to peak torque values and drop vertical jump heights.

2. METHODS

The study was reviewed and approved by a University Committee for the Protection of Human Subjects. Twelve males and 18 females subjects (age = 22.7±2.2 yr, ht = 169.6±8.9 cm, wt = 67.2±11.9 kg) agreed to participate. All subjects read and signed a consent form before participating in the study. Subjects reported for testing wearing running shorts and shoes.

2.1. ***Drop vertical jumps***

Each test session commenced with the subjects performing a 5 minute stationary bi cycle warm-up. This was followed by having the subjects perform a series of general lower body flexibility exercises. Subjects were then instructed to perform a sequence of three drop vertical jumps. For this, subjects stood next to a wall while standing on a box 50 centimeters in height. The feet were parallel and shoulder width apart, while the knees were extended. Subjects initiated the maneuver by jumping off the box and landing on the floor, thus creating an eccentric contraction. From this position, the subjects immediately produced a forceful concentric quadriceps contraction by jumping upward. As the subjects jumped, they extended their arm to mark the highest point reached on the wall. The total jump height was calculated from the difference between the initial height, calculated while the subject reached up while standing on the floor, and the drop vertical jump height. A total of three practice jumps were provided prior to the three maximal efforts. A one minute rest was included between each jump.

2.2. ***Isokinetic testing***

Following a brief rest, subjects were tested for strength on the Kin Corn II isokinetic dynamometer. Knee extension and ankle plantar flexion strength were tested on each leg. A velocity of 120° s-1 was used for all tests. Knee extension was performed with the subjects seated on the dynamometer, the arms folded over the chest and stabilizing straps placed around the waist and thigh. The shin pad was placed distally approximately two finger breadths above the lateral malleolus. The knee extension motion was performed through a range of 80°, with the start and stop angles set at 90° (flexion) and 10° (from full extension), respectively. Ankle plantar flexion was executed with the subjects positioned prone. Stabilizing straps were placed around the thigh, ankle, and forefoot. Ankle plantar flexion motion was performed through a range of 30°, with the start and stop angles set at 0° (subtalar joint neutral) and 30° (plantar flexion) respectively. Gravity correction was performed according to manufacturers' guidelines for both isokinetic test procedures.

The subjects performed a series of five sub- maximal warm-up contractions to familiarize themselves with the isokinetic dynamometer. Subjects were instructed to resist the downward force during the eccentric phase, and then, without any pause, immediately follow with a forceful concentric contraction. Following a one minute rest, a total of three maximal contractions were performed.

2.3. ***Statistical analysis***

An average score for peak torque and time to peak torque was determined for each trial of the right and left legs. Because the subject pool contained a mix of genders, peak torque values were normalized for body weight. A stepwise multiple regression analysis was conducted using the SPSS for Macintosh Release 6.1.1 (SPSS Inc., Chicago, IL, USA) statistical package. The criterion variable was drop vertical jump height, while the eight predictor variables included eccentric and concentric knee extension peak torque/body weight ratios, eccentric and concentric ankle plantar flexion peak torque/body weight ratios, knee extension time to peak torque, and ankle plantar flexion time to peak torque. Criterion for entry into the regression prediction equation was PIN 0.49 and tolerance < 0.0001. The Pearson Product Moment correlation was also used to determine the correlation between drop vertical jump heights and the eight predictor variables.

3. RESULTS

Peak torque/body weight ratios and time to peak torque values for knee extension and ankle plantar flexion are found in Table 1. The average drop vertical jump height was 37.49 cm. A total of 30 subjects completed testing.

The knee extension concentric peak torque/ body weight ratio was a significant ($p < 0.001$) predictor of drop vertical jump height, accounting for 23% of the variance in the regression equation. The Pearson Product Moment correlation coefficient for the knee extension concentric peak torque/body weight ratio with drop vertical jump height was $r= 0.48$ ($p = 0.003$). In addition, time to peak torque for eccentric knee extension and the ankle plantar flexion peak torque/body weight ratio contributed significantly to the regression prediction equation. The two predictor variables accounted for 10% and 11% of the variance, respectively. However, neither variable formed a significant Pearson Product Moment correlation ($p > 0.05$) with drop vertical jump height. A summary of the regression coefficients (predictor variables) is presented in Table 2.

4. DISCUSSION

The primary finding of this study was that knee extension peak torque/body weight ratio was a significant predictor of drop vertical jump height. Taylor et al. [11] demonstrated similar results when they examined the correlation between vertical jumps and knee and ankle concentric peak torque. They showed a positive correlation ($r = 0.90$, $p = 0.01$) between vertical jump power output assessed using the Sargent Jump test and concentric knee extension [11].

A number of factors may have contributed to the lack of correlation with the remaining predictor variables. Komi [7,8] reported that the physiological basis of the stretch-shortening cycle depends on the muscles' ability to use the elastic energy that is stored during the eccentric phase of the cycle. When a person lands on the ground following a jump off a box, the knee extensor and ankle plantar flexor musculature stores the energy resulting from this eccentric muscle action. This energy is quickly converted and used during the concentric muscle contraction that occurs as the person jumps upward from the ground performing a vertical jump. However, there appears to be an optimal box height that will produce maximal vertical jump heights. Several reports [1,2,9] have

Table 1
Peak torque/body weight ratios and time to peak torque values for knee extension and ankle plantar flexion (Mean±SD)

Type of contraction	Peak torque (Nm)/body weight (kg) ratios	Time to peak torque (s)
Concentric knee extension	2.10±0.45	0.12±0.10
Eccentric knee extension	2.31±0.45	0.47±0.11
Concentric ankle plantar flexion	1.26±0.41	0.02±0.01
Eccentric ankle plantar flexion	1.35±0.39	0.42±0.15

Table 2
Stepwise multiple regression analysis summary of predictors of drop vertical jump height and Pearson product moment correlation coefficients

Predictor variable	n	R^2	R^2 change	p	Pearson r
Knee Ext Con PT/BW	30	0.23	0.23	>0.001	0.48
Knee Ext Ecc time to PT	30	0.33	0.10	0.001	−0.25
Ankle PF Con PT/BW	30	0.44	0.11	0.007	−0.01
Ankle PF Con time to PT	30	0.51	0.07	0.64	−0.22
Ankle PF Ecc time to PT	30	0.54	0.03	0.07	−0.07
Knee Ext Con time to PT	30	0.56	0.02	0.07	−0.04
Knee Ext Ecc PT/BW	30	DNE*	N/A	N/A	0.27
Ankle PF Ecc PT/BW	30	DNE*	N/A	N/A	−0.001

*DNE = did not enter the regression prediction equation!

suggested that box heights above this optimal level will result in decreased vertical jump performance.

The box height in the current study may have been a confounding factor producing time to peak torque values that did not significantly correlate with vertical jump performance. Komi and Bosco [8] determined that the ideal box height for depth jumps was as high as 62 cm for males and 50 cm for females. Because our subjects consisted of both males and females, a box height of 50 cm was chosen for this study. Interestingly, Asmussen et al. [1] suggested that the ideal box height be set at 41 cm, while Radcliffe and Osternig [9] found a box height of 30 cm resulted in optimal storage and usage of the elastic energy. Further research is indicated to examine the box height issue more closely.

Helgeson and Gajdosik demonstrated that concentric time to peak torque values were faster when the concentric muscle contraction was immediately preceded by an isometric or eccentric muscle action [6]. The results of this study are difficult to compare because each subject was allowed to begin the isokinetic test maneuver whenever they felt comfortable, which did not always correspond to the examiners start command. This created difficulty in determining the exact time the contraction was initiated, which in turn lead to discrepancies in determining the exact time to peak torque. It is recommended that future studies include only those isokinetic test repetitions that begin at the time of the verbal start command.

When conditioning or rehabilitating an athlete following an injury, it is important to progress the work towards the functional activity the athlete participates in. This helps to insure that the athlete is both physically and mentally prepared to return to the rigors of athletic competition. Isokinetic imitation of the stretch-shortening cycle can be a useful progression in the functional rehabilitation of an athlete who may utilize the stretch- shortening cycle in their respective sporting activity. An athlete may not be physically ready to perform plyometric or other stretch-shortening related activities, however may be able to perform these activities imitated using isokinetic dynamometry. In fact, this would

allow these athletes to combine both concentric and eccentric muscle actions into a more functional activity, rather than having to work them separately. This study suggests that isokinetic imitation of the stretch-shortening cycle may be an important quantitative tool to use in the rehabilitation and conditioning of athletes.
This study was able to show a relationship between open (isokinetic exercise testing) and closed (drop vertical jump) chain activities. The results of this study seem to show that concentric knee extension strength as assessed via isokinetic dynamometry, is an important factor in drop vertical jump performance. This information may prove to be valuable to the clinician or strength coordinator in the rehabilitation of athletes who require jumping maneuvers as part of the respective sport activities.

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