Parameters that Influence Vertical Jump Height

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Abstract

Plyometric activities utilize rapid switches from eccentric to concentric contractions in order to increase the speed or force of muscle contractions. Training the stretch-shortening cycle through jumping has been shown to enhance athletic performance. The purpose of this study was to determine the optimal box heights from which to drop from for athletes to achieve a maximal rebound height. Division III collegiate football players (n=55) that met the inclusion criteria (>18 years old, no previous lower extremity injury, <100 kg) were participants in this study. Initial data collection included height, weight, leg length, age, standing vertical jump, and quadriceps muscle strength measured on a Biodex Isokinetic Dynamometer. Peak torque and work per repetition were calculated for eccentric and concentric quadriceps activity. Participants completed 3 box drops from each of 4 different box heights with the vertical rebound heights being measured on a Vertec System®. An ANOVA revealed no statistically significant difference in vertical rebound between box heights as well as standing vertical jump and the vertical rebound height from any of the box drop heights. There was also little to no correlation (Pearson R<0.25) between vertical rebound from any box drop heights and concentric work per repetition, eccentric peak torque, and eccentric work per repetition. There was a fair correlation (Pearson R=0.29-0.33) between concentric peak torque and vertical rebound from all box drop heights. Leg length correlated moderately (Pearson R= 0.56-0.61) with vertical rebound from all box drop heights. This study indicates that increased box drop height does not result in
statistically significant greater vertical rebounds. Thus, given no increase in vertical rebound height, increasing box drop jump beyond the lowest box height (0.12m) tested simply increases the risk of injury without any benefits. A limitation of this study was that jumping technique was not a variable assessed. It would be a serious oversight to not acknowledge that technique may also be a critical component of achieving a maximal box drop rebound height.

**Introduction**

Jumping is a simple plyometric task that is performed in a variety of athletic activities.

Plyometric exercise utilizes the stretch-shortening cycle to train muscles to do more work in a short amount of time (Holcomb, Lander, Rutland, & Wilson, 1996; Komi, 1978). In plyometric activities, muscles rapidly switch from an eccentric action to a concentric contraction, essentially leaving no time for the muscle to relax. The stored elastic energy of the muscle and stretch reflex summate to permit the muscle to create greater force (Hedrick & Anderson, 1996; Holcomb et al., 1996; Komi, 1988; Wagner & Kocak, 1997; McNeely, 2005).

In a recent survey of training preferences, 94% of college strength and conditioning coaches reported using plyometric training (Durell, Pujol, & Barnes, 2003). Tasks such as vertical jumps, hops, and/or bounding movements are often used to increase explosiveness and strength of the lower extremities (Ebben, 2005; McNeely, 2005). Research has attempted to identify the optimal height for drop jumping to achieve the greatest gains in vertical jump (Walsh et al, 2004; Lees & Fahmi, 1994; Bobbert, 1990). Lees and Fahmi (1994) reported maximal rebound height occurred at drops of 0.12m, maximal vertical forces occurred at 0.36m, and maximal vertical velocity occurred at 0.12m. Asmussen and Bonde-Peterson (1974) reported optimal drop height
was 0.4m. Voigt et al (1995) found a 0.3m drop height produced significantly higher jump heights than 0.6 or 0.9m. In 1978, Komi and Bosco reported that rebound height continued to increase up to a drop height of 0.6m for males and 0.5m for females. Conversely, Bobbert and associates (1987) found no significant difference between 0.2, 0.4, and 0.6m rebound height with peak force increasing as drop height increased.

Although many athletes believe that large drop heights are needed to achieve maximal gains in rebound vertical jump, increasing drop height can produce a deterioration of the rebounding technique. This, in turn, can lead to an increase in impact forces thereby increasing the risk of injury (Bobbert, 1990). The purpose of this study was to determine the relationship of optimal drop height and physical characteristics on the rebound height of a vertical jump.

Hypotheses

It was hypothesized that 1) concentric and eccentric quadriceps strength would be highly correlated to vertical jump and 2) stronger athletes would achieve higher maximal rebound jump heights from higher drop heights.

Methods

Participants

Recruitment of Division 3 collegiate football players was approved by the Widener University Institutional Review Board for the protection of human subjects. Fifty-five participants (age 19.1 ± 1.4 yrs; height 180.5 ± 5.2 cm; weight 87.3 ± 9.1 kg) who met the inclusion criteria of being greater than 18 years of age and free of lower extremity injury were included in the study.
Athletes weighing more than 100 kg (220 lbs) were excluded from data collection as recommended by the National Strength and Conditioning Association (Baechle, 1994).

**Procedures**

Data collected from each participant included age (years), leg length (cm), height (cm), weight (kg), standing vertical jump (1-step approach), and quadriceps muscle strength. Leg length was assessed using a meter stick. The athlete was instructed to place one end of the meter stick in the most proximal aspect of the groin and the measurement was taken at the most distal aspect of the heel. Height and weight were assessed on a standard scale. The Vertec System ® (Power Systems, Knoxville, TN) was used to measure standing vertical jump with a one-step approach. A Biodex Isokinetic Dynamometer (Biodex Corporation, Shirley, NY) was used to assess concentric and eccentric quadriceps muscle strength. The participant’s dominant lower extremity was tested with the trunk stabilized in a seated position and the arms folded across the chest. The participant performed five concentric repetitions at 240°/sec with the maximal peak torque and maximal work per repetition used for data analysis. After a 1-minute rest, five eccentric repetitions were performed at 120°/sec with the maximal peak torque and maximal work per repetition used for data analysis.

Each participant was instructed in the proper box drop technique and given the opportunity to practice while receiving feedback. The standardized technique used required the athletes to step off the drop box platform, land with both feet simultaneously on the floor, and immediately rebound up with a maximal effort as high as possible (Figure 1). Participants completed three box drops from each of the four box heights (0.12, 0.24, 0.36, 0.48m), with a 10-second
minimum rest interval between jumps (Ebben, 2005). All vertical rebound heights were measured via the Vertec System®.

Analysis

Analysis of variance (ANOVA) was performed on data generated from the standing vertical jump and rebound jumps from the various box drop heights. Correlations were performed between the mean of each box drop jump height and the following independent variables: leg length, vertical jump, concentric peak torque, concentric work per repetition, eccentric peak torque, and eccentric work per repetition.

Results

The mean and standard deviation rebound jump heights were 2.88 ± 1.02m, 2.89 ± 1.21m, 2.89 ± 1.04m, and 2.89 ± 1.08m for the 0.12m, 0.24m, 0.36m, and 0.48m box drop heights, respectively (Figure 2). An ANOVA revealed no significant difference (p=0.72) in vertical jump heights among the four box drop rebound heights (Table 1). There was also no significant difference (p=0.17) among standing vertical jump (2.91 ± 1.07m) and any of the box drop rebound heights (Table 2). An excellent Pearson correlation (R> 0.75) was calculated between standing vertical jump and all box drop rebound heights (Table 3). Moderate correlations were evident between leg length and all box drop rebound heights (Pearson R= 0.56-0.61) but only fair correlations existed between concentric peak torque and all box drop rebound heights (Pearson R=0.29-0.33). Finally, there were little to no correlations between concentric work per repetition, eccentric peak torque, and eccentric work per repetition and all box drop rebound heights (Pearson R<0.25). (Portney & Watkins, 2000)
Discussion

In the current study, vertical rebound height was reported to be slightly greater with the increasing box drop heights, although this increase was not statistically significant (p=0.72). These results are consistent with a previous study by Lees and Fahmi (1994) who studied 30 male athletes who performed drops from six different box heights (0.12, 0.24, 0.36, 0.46, 0.58, and 0.68m) and reported the optimal drop height for all measured parameters (maximum rebound height, maximum vertical force, maximum vertical velocity, height rise of the center of gravity, and instantaneous power output) to be 0.12m.

Although prior researchers (Walsh et al, 2004; Bobbert, 1990) have emphasized the influence of jumping technique on the resultant height of the rebound vertical jump, the present study did not attempt to alter the athlete’s self-selected rebound technique. Athletes were simply told to “drop off each box by stepping forward, landing simultaneously on both feet, and immediately rebound upward as high and as fast as possible.” Walsh et al (2004) studied the responses of 15 male athlete to drop heights of 0.2, 0.4, and 0.6m. The researchers reported that contact time of the feet with the floor had a greater effect on rebound height when compared to the starting drop height. In drops with moderate contact times (161-166ms), the quadriceps of the knee was found to contribute 37% of the total power. However, the quadriceps was reported to generate only 28% of the total power with shorter contact times (136-152ms). Therefore, despite not assessing contact time in the current research, it was confounding that quadriceps muscle strength did not display a higher correlation to rebound height.
Neither concentric or eccentric peak torque, nor work per repetition demonstrated more than a fair correlation to rebound jump height. The current investigators anticipated that eccentric quadriceps strength would be important in accumulating the potential energy upon landing and subsequently converting to kinetic energy for a maximal vertical jump. It was theorized that if one athlete possessed greater eccentric quadriceps strength than another, the stronger athlete would be able to absorb more force on landing and translate that to a higher rebound height. No such relationship was identified in the current study.

It has been demonstrated that forces on the lower extremities can reach levels of 15 times an individual’s body weight with plyometric tasks (Perttunen, Kyrolainen, Komi, & Heinonen, 2000). Since maximal power is generally achieved when working with loads between 30 and 70% of maximum, it follows that athletes with the greater quadriceps muscle strength would more likely be able to work within this recommended range to achieve optimal plyometric results (Warpeha, 2005).

Lephart et al (2002) examined the influence of kinematics, vertical ground reaction forces, and strength during the landing of plyometric tasks. They concluded that weak quadriceps musculature may be insufficient to decelerate the body when landing. As a result, landing may occur on a more extended knee with greater hip internal rotation. These alterations of landing posture may place the lower extremity in a poor biomechanical position to appropriately distribute and absorb the impact forces.
A limitation of this study included the absence of assessing contact (amortization) time with the floor via force plate instrumentation. Consequently, the authors of the current study were unable to determine if contact time was a more significant factor than box drop height. Another limitation of the current study was the lack of training sessions with regard to specific jumping and landing techniques. Research has shown that athletes skilled in jumping activities demonstrated increased ankle plantarflexion (McKinley & Pedotti, 1992; McNitt-Gray, 1993), increased knee flexion (McNitt-Gray, 1993; Viitasalo, Salo, & Lahtinen, 1998) and decreased ground reaction forces (Prapavessis & McNair, 1999; Viitasalo, Salo, & Lahtinen, 1998).

In summary, this study revealed that the increased height of the box drops did not result in significantly greater vertical jumps. Optimal rebound jump height occurred from the lowest drop height tested (0.12m). Technique may be a critical component of achieving a maximal box drop. Thus, the risk of injury may be increased with increasing height of the box drops without a concurrent benefit in vertical jump height.

References


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