

Effects of Drop Height on Drop Jump Performance

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ABSTRACT

Background: Drop jumps (DJ) are commonly implemented in plyometric training programs in an attempt to enhance jump performance. However, it is unknown how different drop heights (DH) affect reactive strength index (RSI), jump height (JH) and ground contact time (GCT). **Objectives:** The purpose of this study was to assess the effect of various DHs on RSI, JH, and GCT. **Methods:** Twenty volunteers with a history of plyometric training (Males = 13, Females = 7; age: 22.80 ± 2.69 yr, height: 175.65 ± 11.81 cm, mass: 78.32 ± 13.50 kg) performed DJs from 30 cm (DJ30), 45 cm (DJ45), 60 cm (DJ60), 76 cm (DJ76), and 91 cm (DJ91) and a countermovement jump (0 cm). A 16-camera Vicon system was used to track reflective markers to calculate JH; a Kistler force plate was used to record GCT. RSI was calculated by dividing JH by GCT. RSI and GCT were compared using a 2x5 (sex x DH) mixed factor repeated measures ANOVA, while JH was compared using a 2x6 (sex x DH) repeated measures ANOVA. **Results:** There were no interactions, but there was a main effect for sex for both JH (M>F) and GCT (F>M). JH demonstrated no main effect for DH: DJ30 (0.49 ± 0.11 m), DJ45 (0.50 ± 0.11 m), DJ60 (0.49 ± 0.12 m), DJ76 (0.50 ± 0.11 m), and DJ91 (0.48 ± 0.12 m). However, GCT showed a main effect where DJ30 (0.36 ± 0.10 s), DJ45 (0.36 ± 0.12 s), and DJ60 (0.37 ± 0.10 s) were not significantly different but were less than DJ76 (0.40 ± 0.12 s) and DJ91 (0.42 ± 0.12 s). **Conclusions:** Increasing DH beyond 60 cm increased GCT but did not affect JH, resulting in decreased RSI. Therefore, practitioners designing plyometric training programs that implement DJs may utilize DHs up to 60 cm, thereby minimizing GCT without compromising JH.

Key words: Plyometric Exercise, Athletes, Demography, Reflex

INTRODUCTION

Jump height (JH) is an important component in sports, such as basketball and volleyball, which require explosive lower body power (Archer et al, 2016). A common test to determine power is the vertical jump. One method of training to increase vertical jump performance is plyometric exercise, which utilize the stretch-shortening cycle (SSC), a reflex muscle function that occurs when a muscle is stretched immediately before being contracted (Young, Pryor, & Wilson, 1995). A commonly used plyometric exercise is the drop jump (DJ). DJs require an individual to drop from a designated height and immediately perform a rebound vertical jump (Byrne, Moran, Rankin, & Kinsella, 2010; Flanagan, Ebben, & Jensen, 2008; Stieg et al., 2011; Struzik, Pietraszewski, & Rokita, 2016; Suchomel, Bailey, Sole, Grazer, & Beckham, 2015; Taube, Leukel, Lauber, & Gollhofer, 2012; Young et al., 1995); DJs can also be used to assess the reactive strength index (RSI) (Flanagan et al., 2008). RSI is highly reliable and may be beneficial for strength and conditioning coaches or researchers as a tool to provide feedback

or determine intensity for plyometric exercises. RSI is utilized as a coaching and laboratory tool to measure the ability to quickly change from an eccentric to concentric muscle action and is calculated by dividing jump height by ground contact time (GCT) (Flanagan et al., 2008). Previous research suggests that determining an individual's optimal DJ height can be difficult, if the box is too low or too high the SSC stimulus will not be maximized (Byrne et al., 2010). RSI is one way to measure optimal DJ height, as optimal jump height has minimal purpose without paying attention to GCT (Beattie, Carson, Lyons, Kenny, 2017; Flanagan & Comyns, 2008; Flanagan et al., 2008; Young et al., 1995). While Peng (2011) does not recommend DHs over 60 cm due to increased injury risk, little is known about DHs above 60 cm. Young et al. (1995) demonstrated that as DH increases, JH decreases and GCT increases. It has been postulated that increasing DH above 20 cm could increase hip and knee extension and lead to increased JH (Bobbert, Huijting, & van Ingen Schenau, 1987; Young et al., 1995). While previous studies have examined RSI, there is limited research on RSI and DH above 60 cm. Examining DJs can aid in creating

individualized RSI profiles to enhance training programs. Therefore, the purpose of this study was to investigate the effects of DH on RSI, JH, and GCT. We hypothesized that as DH increased JH and GCT would also increase.

METHODS

Study Design

This was a quasi-experimental study that was approved by the University Institutional Review Board. Participants volunteered to participate and were required to read and sign an informed consent prior to participation. Participants also provided a history of plyometric training experience.

Participant Characteristics

A total of 20 participants, 13 males and 7 females (age: 22.80 ± 2.69 yr; height: 175.65 ± 11.81 cm; mass: 78.32 ± 13.50 kg), with a history of plyometric training participated. They were physically active, healthy, and free from musculoskeletal injuries within the past year. They were also required to be right foot dominant.

Materials and Procedures

Height and mass were measured prior to testing using a manual stadiometer (Detecto, Webb City, MO, USA). Retro-reflective markers were placed bilaterally on the anterior superior iliac spine and posterior superior iliac spine. Kinematic data were collected using a Vicon Bonita 16-camera motion capture system (Vicon Motion Systems Ltd., Oxford, UK) at 250 Hz. Force plate data was collected at 2,000 Hz using a Kistler force plate (Kistler Instrument Corp., Novi, MI, USA). Vicon Nexus software (Ver. 1.8.5; Vicon Motion Systems Ltd., Oxford, UK) was used to synchronize motion capture and force plate data at 2,000 Hz. Raw data was processed using Visual 3D software (Ver. 5.02.27; C-Motion, Inc., Germantown, MD, USA) to calculate JH and GCT. Participants were instructed to wear athletic clothing and footwear for testing. They completed a 5-minute warm-up on a Monark 874E cycle ergometer (Monark Exercise AB, Vansbro, Sweden) at a self-selected pace. They also performed three submaximal countermovement jumps with 30 seconds rest between jumps. Participants were then given a 2-minute rest prior to performing three submaximal drop jumps at 30 cm, 45 cm, and 60 cm with 30 seconds rest between jumps and 2-minutes rest between drop heights. All participants performed a total of 12 submaximal warm-up jumps. After completing the warm-up, they completed three maximal standing countermovement jumps with arm swing while standing on the force plate. Following the countermovement jumps, participants performed DJs at five different DHs (30 cm, 45 cm, 60 cm, 76 cm, and 91 cm) by stepping off the box with their right leg and immediately performing a maximal rebound vertical jump upon landing. The first set was completed in ascending order for participants to become familiar with the increasing eccentric forces. Sets two and three were completed in a counterbalanced order to eliminate

fatigue as a factor. Participants were given 30 seconds rest between jumps and 2-minutes rest between sets, one set included all five DHs (Read & Cisar, 2001). Each participant performed three maximal countermovement jumps and 15 drop jumps total. Maximal JH and GCT were recorded. RSI was calculated by dividing JH by GCT.

Statistical Analyses

RSI and GCT were analyzed with 2 x 5 ANOVAs (sex x drop height) while JH used a 2 x 6 ANOVA (sex x drop height), this includes the countermovement jump at 0 cm, to determine statistical differences. An alpha level of 0.05 was used to determine statistical significance ($p < 0.05$). The average of three jumps at each DH was used for statistical comparisons. Statistical analysis was performed using IBM SPSS Statistics software (version 20, IBM, Armonk, NY, USA).

RESULTS

Ground Contact Time

There was no significant interaction ($p > 0.05$). There was a significant main effect for drop height ($p < 0.05$) where 30 cm, 45 cm, and 60 cm were shorter than 91 cm and 76 cm (Figure 1). There was also a main effect ($p = 0.02$) for sex where females (0.45 ± 0.04 s) spent a longer time on the ground than males (0.34 ± 0.03 s).

Jump Height

There was no significant interaction or main effect ($p = 0.23$) for drop height (Table 1). There was a significant main effect for sex ($p = 0.03$) where males (0.55 ± 0.02 m) jumped higher than females (0.39 ± 0.03 m).

Reactive Strength Index

There was no significant interaction ($p > 0.05$). There was a significant main effect for drop height ($p = 0.00$) where 30 cm was greater than 91 cm, while 45 cm and 60 cm were both greater than 76 cm and 91 cm (Figure 2). There was also a significant main effect ($p = 0.00$) for sex where males (1.73 ± 0.14) had a greater RSI than females (0.90 ± 0.19).

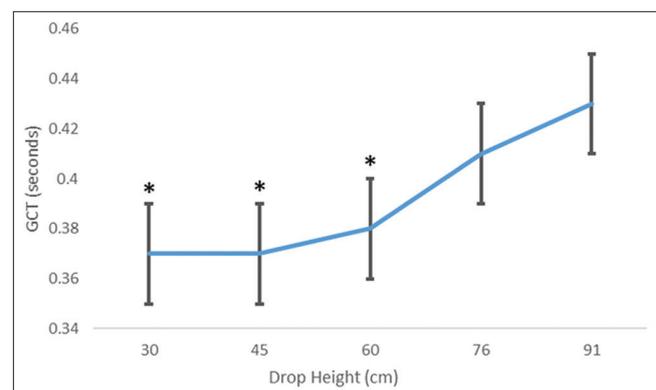
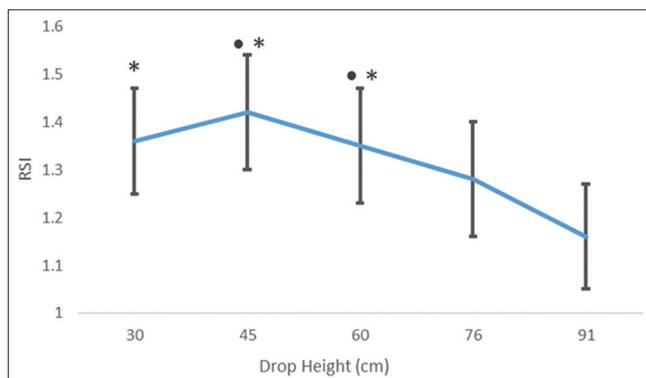


Figure 1. Mean and SD of ground contact time (GCT) by drop height. * significantly less than 76 and 91

Table 1. Jump height (meters) by drop height (0=standing)

Drop Height (cm)	0	30	45	60	76	91
Mean±SD	0.48±0.01	0.46±0.01	0.47±0.02	0.46±0.02	0.46±0.01	0.45±0.02

**Figure 2.** Mean and SD of reactive strength index (RSI) by drop height. * significantly greater than 91 • significantly greater than 76

DISCUSSION

The purpose of this study was to examine the effect of drop height on drop jump GCT, JH, and RSI. The main findings were that as drop height increased, GCT also increased but jump height did not change. This resulted in a decrease in RSI after 60 cm.

Finding the optimal drop height is critical to achieving maximum training results. A method of determining optimal box height is RSI (Flanagan et al., 2008). Ramirez-Campillo et al. (2018) found that when young male soccer players trained with drop jumps from their optimal drop height, they significantly increased RSI and jump height. In contrast, a fixed group performed drop jumps from a fixed height and saw no increases (Ramirez-Campillo et al., 2018). This could be due to the protocol allowing the athletes to train at their individualized drop heights resulting in increased RSI scores. Specific training via drop jumps may elicit different outcomes; as drop heights greater than 60 cm have been shown to promote increases in jump height, whereas drop heights less than 60 cm show a decrease in GCT (Gehri, Kleiner, & Kirkendall, 1998; Suchomel et al., 2015). Results of the present study indicate that GCT plays a more significant role in RSI than JH since JH was not affected by DH (Ramirez-Campillo et al., 2018; Walsh, Arampatzis, Schade, & Brüggemann, 2004).

GCT is an important variable related to the stretch-shortening cycle (SSC). The SSC and GCT can be broken into fast (< 0.25 seconds) or slow (> 0.25 seconds) (Ball, Stock, & Scurr, 2010; Ramirez-Campillo et al., 2018). Research shows that slow GCT is related to force and power production, while fast GCT is related to acceleration (Ball et al., 2010; Taube et al., 2012; Walsh et al., 2004). Drop heights over 30 cm causes decreases in fast SSC performance, this decrease is due to an inability to overcome high eccentric forces causing increases in GCT (Ball, Stock, & Scurr, 2010; Peng, 2011; Taube et al., 2012; Walsh et al., 2004; Young et al., 1995). Some previous research contradicts the current findings where they showed no increase in GCT as drop

height increased (Deliceoğlu et al., 2017; Hoffren, Ishikawa, & Komi, 2007). This conflict may be due to participant training experience and demographics, as individuals who are able to overcome high eccentric forces may not see an increase in GCT as drop height increases (Deliceoğlu et al., 2017; Hoffren, Ishikawa, & Komi, 2007).

The present study indicated that as drop height increased, rebound jump height did not change. Similar findings were seen in previous research using recreational, high school, and collegiate males and females; where no changes were seen in jump height from heights ranging from 20 to 60 cm compared to countermovement jumps (Barr & Nolte, 2014; Bobbert et al., 1987; Earp et al., 2010; Stieg et al., 2011). Markwick, Bird, Tufano, Seitz, and Haff (2015) observed similar findings as the present study, however, there was an increase in jump height compared to the standing countermovement jump. However, Taube et al. (2012) found that drop jumps from heights of 30, 40, 50, and 60 cm increased participants' rebound jump height; their findings could be due to increased force during the eccentric phase at greater drop heights. Peng (2011) and Young et al. (1995) contradict the present study's findings, demonstrating a decrease in jump height as drop height increased. Peng (2011) suggests that the SSC may decrease with drop heights greater than 40 cm due to increasing eccentric forces.

The present study revealed a parabolic curve in RSI as drop height increased, which was due to an increase in GCT with no difference in jump height. This contradicts previous research where males and females (high school, collegiate, and professional athletes) performed drop jumps from 20, 30, 40, 50, and 60 cm and showed no significant changes in RSI across heights (Kipp, Kiely, Giordanelli, Malloy, & Geiser, 2018; Markwick et al., 2015; Struzik, Pietraszewski, & Rokita, 2016). Beattie et al. (2017) observed the same results as the current study, where college athletes across various sports were assigned to weak and strong groups based on relative mid-thigh pull strength. The weak group observed a significant decrease in RSI with an increase in drop height while the strong group saw no change (Beattie et al., 2017). They suggested that the stronger group was able to overcome the high eccentric load due to greater strength (Beattie et al., 2017). The present study did not directly assess strength but found similar results as the weak group, demonstrating a parabolic curve in RSI which was probably due to weak lower body strength. Limitations to the study include sample size and different levels of participant training experience. Future research should focus on using RSI to develop strength profiles for athletes in order to maximize jump training.

CONCLUSION

The results of the current study showed a parabolic curve in RSI, which increased with drop heights between 30 and

60 cm. Drop heights above 60 cm decreased RSI due to an increase in GCT, while rebound jump height remained constant. Therefore, it is recommended that strength and conditioning coaches emphasize minimal GCT and utilize drop heights no greater than 60 cm in order to maximize RSI.

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