THE EFFECTS OF BOX HEIGHT ON

DROP JUMP PERFORMANCE

by

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ABSTRACT

THE EFFECT OF BOX HEIGHT ON DROP JUMP PERFORMANCE

Cameron Douglas Addie

Depth jumps (DJ) are commonly implemented in plyometric training programs in an attempt to enhance lower extremity jump performance. However, it is unknown how different box heights affect jump height (JH) and ground contact time (GCT). **PURPOSE:** The purpose of this study was to assess jump heights and ground contact time of depth jumps from various box heights. **METHODS:** Twenty college students who engaged in plyometric training (M = 13, F = 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). A 16 camera Vicon system was used to track reflective markers bilaterally to calculate JH (ASIS, PSIS), while a Kistler force plate was used to record GCT. JH and GCT were compared using a 2x5 (sex x box height) repeated measures ANOVA. **RESULTS:** There was no interaction but there was a main effect for sex where both JH (M>F) and GCT (F>M) showed a significant M bias. There was no box height main effect for JH DJ30 (.4934 ± .1126 m), DJ45 (.5003 ± .1134m), DJ60 (.4936 ± .1195 m), DJ76 (.4957 ± .1105 m), DJ91 (.4783 ± .1162 m) but there was for GCT where DJ30 (.3584 ± .0971 s), DJ45 (.3605 ± .10528 s) and DJ 60 (.3723 ± .1049) were not significantly different from each other but were all less than DJ76 (.3962 ± .1161) and DJ91 (.4209 ± .1154). **CONCLUSIONS:** Increasing box height beyond 60cm increased GCT but did not affect JH. Therefore, practitioners designing plyometric training programs that implement DJs in order to increase JH may stop at a box height of 60cm. This would keep GCT minimal which might play a role in other power and speed events.

CHAPTER I

INTRODUCTION

Background

The ability to jump high is important in sports such as basketball and volleyball. A common assessment used in these sports is vertical jump, an indicator of lower body power that transcends to all other sports. One method of training to increase vertical jump performance is plyometric exercises. Plyometric exercise utilizes 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. Drop jumps require an individual to drop from a designated height then immediately perform a vertical jump (Byrne, Moran, Rankin, & Kinsella, 2010; Flanagan, Ebben, & Jensen, 2008; Stieg et al,. 2011; Suchomel, Bailey, Sole, Grazer, & Beckham, 2015; Taube, Leukel, Lauber, & Gollhofer, 2012; Young et al., 1995). Drop jumps are frequently used train the SSC and can also be used to assess reactive strength of athletes (Flanagan et al., 2008).

Reactive strength index (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. Flanagan, Ebben, and Jensen (2008) calculated RSI using jump height divided by ground contact time. Previous research suggested that determining an individual's optimal drop jump box height can be difficult; for example, if the box is too low or too high the SSC stimulus will not be maximized (Byrne et al., 2010). RSI is utilized as a coaching and laboratory tool to measure the ability to change quickly from an eccentric to concentric muscle action. RSI is one way to measure optimal drop jump box height (Beattie, Carson, Lyons, & Kenny, 2017; Flanagan & Comyns, 2008; Flanagan et al., 2008). Walsh, Arampatzis, Schade, and Bruggemann (2004) stated that optimal jump height has minimal purpose without paying attention to ground contact time, while Peng (2011) does not recommend drop heights over 60 cm due to increased potential injury risk. However, little is known about drop jump box heights above 60 cm. Young et al. (1995) revealed that as drop height increases, jump height decreases and ground contact time increases, while Bobbert, Huijing, and Van Ingen Schenau (1987) postulated that increasing drop height above 20 cm will increase hip and knee extensors which could lead to increased jump height. On the contrary, an increase in drop height can decrease lower leg stiffness, which could lead to a decrease in jump performance (Taube et al., 2012). Therefore, the hypothesis is that as box height increases jump height would also increase. This study aimed to answer the following question: will there be a significant difference in jump height, ground contact time, and reactive strength as box height increases.

Purpose

Therefore, the purpose of this research was to investigate whether an increase in box height would result in an increase in various performance related variables

Research Question

What is the effect of increased box height on ground contact time, jump height, and reactive strength?

Hypothesis

The research hypotheses of this investigation were as follows:

H1: There is a no significant relationship between box height and ground contact time.

H2: There is a significant relationship between box height and jump height.

H3: There is a significant relationship between box height and RSI.

Basic Assumptions

The following assumptions were made for this investigation: (a) all participants gave maximal effort during training sessions, and (b) variables were accurately recorded via the Vicon Nexus software system, Kistler force plate, Visual 3D software.

Delimitations

The following delimitations for this study are as follows: (a) participants were right footed dominant, and (b) participants had no lower limb pathology within the last year.

Limitations

The following limitations for this study were as follows: (a) participants were volunteers from the University of West Florida, and (b) participants had heterogeneity of prior training experience.

CHAPTER II

REVIEW OF THE LITERATURE

To better understand the effects of drop height on reactive strength index (RSI) in recreational athletes, it is necessary to discuss the factors that influence reactive strength index. The review of literature will cover reactive strength index, effect of box height on jump height, and the effect of box height on ground contact time. The following section will introduce the neuromuscular differences in drop jump training and its effects on RSI.

Neuromuscular Differences

Taube, Leukel, Lauber, and Gollhofer (2012) studied the influence of drop height on jump performance. Thirty-three subjects were randomly assigned into two training groups: stretch-shortening cycle group 1, where they performed drop jumps from 3 different heights (30 cm, 50 cm, and 75 cm), while stretch-shortening cycle group 2 performed drop jumps from only 30 cm. All participants were free of neuromuscular disabilities and had not performed plyometric exercises in the past. Additionally, none of the subjects participated in any other systematic training during the experiment. Training was performed three times per week for four weeks. Group 1 performed 12 jumps from 30 cm and 50 cm. The number of drops from 75 cm increased from six jumps for the first week, eight jumps for the second week, ten jumps the third week, and twelve jumps the final week. Group 2 jumped the same number of jumps as group 1 but solely from 30 cm. All participants were encouraged to jump as high as they could while having minimal ground contact time. A repeated measures ANOVA was used to test for differences between rebound height and duration of ground contact time. Group 2 had significantly decreased ground contact time compared to group 1 ($p = 0.00$). For jump height, group 1 significantly increased height compared to group 2 ($p = 0.01$). Overall, the stretch-shortening cycle for both groups showed statistically significant neuromuscular differences ($p = 0.03$). Taube et al., (2012) suggested lower heights will elicit shorter ground contact times while higher heights will elicit greater rebound effect.

Stieg, Faulkinbury, Tran, Brown, Coburn, and Judelson (2011) examined the effects of post-activation potentiation to improve vertical jump height in collegiate women soccer players (mean ± SD: age = 18.94 ± 0.74 yr, weight = 66.07 ± 6.42 kg, height = 169.35 ± 5.25 cm). Seventeen collegiate women soccer players performed drop jumps from their knee height. All subjects performed zero, three, six, nine, and twelve drop jumps with rebound in randomized order. Subjects were asked to give maximal effort and the vertex was set up as a motivation tool. Results indicated no significant change in jump height with the warm-up of zero, three, six, nine, and twelve drop jumps ($p > 0.05$). Overall, there was a decrease in jump height across the board. The researchers suggested that these results could mean the stimulus of box height or volume of jumps did not reach the individual's necessary stimulus to elicit post-activation potentiation. Stieg et al. (2011) suggested that strength coaches should avoid drop jumps with collegiate women soccer players as a warm-up protocol due to its inability to activate post-activation potentiation.

Ball, Stock, and Scurr (2010) compared vertical ground reaction force between left and right legs to assess the symmetry of training. Ten recreational males were randomly assigned (mean ± SD: age = 27.0 ± 6.48 yr, weight = 82.26 ± 6.82 kg, height = 1.86 ± 0.08 m) to jump from 0.2, 0.4, and 0.6 meters. Subjects were instructed to step off the platform and required to land on the force plate and jump as high and as quick as possible. Results indicated a significant difference in vertical ground force in the subjects preferred limb ($p < 0.00$). There was also a significant difference in maximal vertical force as box height increased ($p = 0.02$). Ball et al.

(2010) indicated that as box height increases, eccentric forces increased through the lower limbs but jump height or force produced decreased. The researchers speculated that this result could be due to lack of drop jump experience, as well as a decrease in muscle and limb stiffness causing the decrease in force production. Secondly, ground contact time was increased as box height increased ($p = 0.04$). Ball et al. (2010) indicated that the optimal contact time of 0.26 seconds will elicit the greatest power output. Finally, the researchers indicated that box heights less than 0.4 meters will elicit the greatest ground reaction forces with the shortest amount of ground contact time. In addition, low box heights will not cause asymmetry between lower body limbs. If an individual has no jumping experience, Ball et al. (2010) suggested that there is an increased chance in bilateral differences in box heights greater than 0.4 meters.

Bobbert et al. (1987) studied kinematics, kinetics, and electromyography data. The researchers compared two different types of drop jumps, the first a bounce drop jump and the second one being a countermovement drop jump. Ten trained male volleyball players (mean ± SD: age = 23.0 ± 4.0 yr, weight = 84.8 ± 9.5 kg, height = 1.95 ± 0.06 m) preformed these drop jumps from 20 cm. Results indicated that bounce drop jumps (3500 ± 120.82 N) have a significantly greater vertical ground reaction force compared to countermovement drop jumps (1750 ± 278.87 N). The researches postulated that the increase in vertical ground reaction force during the bounce drop jump was due to greater muscle and tendon stiffness in the ankle, hip, and knee joints, as well as a greater vertical acceleration in the take-off phase. Bobbert et al. (1987) also suggested that bounce drop jumps have significantly lower ground contact times ($p < 0.05$). The researchers suggested that the bounce drop jump should be performed as quickly as possible, while the countermovement drop jump should use a more controlled eccentric phase before jumping. Bobbert et al. (1987) indicated that more power is generated if an individual utilizes a bounce drop jump technique due to the increase in potentiation. Researchers recommended that strength coaches utilize the bounce drop jump technique with box heights set at 20 cm to provide greater stimulus, due to bounce drop jumps utilizing minimal ground contact while achieving the greatest jump heights, to increase standing countermovement jumps.

Hoffren, Ishikawa, and Kom (2007) investigated age related effects on drop jumps. Both young and elderly populations were compared. Twelve young (5 men and 7 women; mean ± SD: age = 25.2 ± 2.5 yr, weight = 66.8 ± 10.7 kg, height = 171.4 ± 7.4 cm) subjects and thirteen elderly subjects (5 men and 8 women; mean ± SD: age = 69.0 ± 3.8 yr, weight = 67.8 ± 9.8 kg, height = 168.0 ± 6.7 cm) performed drop jumps from 10, 15, and 20 centimeters. Take-off speed and ground contact time were evaluated. Results indicated that elderly subjects (DJ10cm = 439 ± 61 ms, DJ15cm = 430 ± 71 ms, DJ20cm = 418 ± 56 ms) spent significantly more time on the ground compared to younger subjects (DJ10cm = 365 ± 42 ms, DJ15cm = 348 ± 30 ms, DJ20cm = 335 ± 30 ms). As box height increased no significant increase in ground contact time was observed ($p > 0.5$). Take-off time was significantly lower in the elderly subjects (DJ10cm = 1.05 ± 0.21 ms, DJ15cm = 1.11 ± 0.23 ms, DJ20cm = 1.13 ± 0.22 ms) compared to the younger subjects (DJ10cm = 1.38 ± 0.23 ms, DJ15cm = 1.42 ± 0.24 ms, DJ20cm = 1.46 ± 0.24 ms), meaning that younger subjects produced greater lower body power output. The researchers suggested that younger subjects demonstrate greater joint stiffness and the ability to absorb force and utilize elastic energy better than elderly subjects. Hoffren et al. (2007) speculated that joint stiffness is a necessary component to have an efficient stretch-shortening cycle. The researchers concluded that elderly populations use different mechanics for drop jumps compared to younger populations resulting in differences in take-off time and ground contact time.

Makaruk and Sacewicz (2011) investigated the role of drop height and body mass in determining exercise intensity through ground reaction forces. Nine elite male track athletes volunteered to serve as subjects for the study (mean ± SD: age = 20.4 ± 2.8 yr, weight = 78.8 ± 5.0 kg, height = 1.81 ± 0.7 m); each athlete preformed a drop jump from 0.2, 0.4 and 0.6 meters. Participants also performed the same jumps with weighted vests that were five and 10% of their body mass. A significant increase ($p < 0.01$) from the 0.2 m drop jump to the 0.4 m drop jump in ground reaction forces was observed as box height increased. Additionally, no significant increase in ground reaction forces ($p > 0.05$) was observed with the addition of weight vest compared to their unloaded forces at the same height. Makaruk and Sacewicz (2011) suggested that box height is a greater indicator in determining exercise intensity than body mass because of the increase in ground reaction force. Makaruk and Sacewicz (2011) recommended not performing drop jumps over 0.6 meters. Makaruk and Sacewicz (2011) suggested that athletes need to able to control these increased ground reaction forces as box height increases. If the athlete fails to absorb these high eccentric loads, an increase in injury risk will occur and failure to reach an appropriate overload of the body.

Laffaye and Choukou (2010) examined gender differences in jumping parameters. The researchers hypothesized that males would jump higher than females, but eccentric forces will be greater for females than males. Moreover, males and females would demonstrate different drop jumping technique. Nine female volleyball athletes (mean ± SD: age = 22.6 ± 3.6 yr, weight = 63.4 ± 8.6 kg, height = 171.3 ± 5.3 cm), and nine male volleyball athletes (mean ± SD: age = 21.8 ± 3.0 yr, weight = 73.2 ± 6.7 kg, height = 184.35 ± 4.9 cm) performed drop jumps from 30 and 60 centimeters. The results of this study showed that males jumped significantly higher than females ($p < 0.05$), but there was no difference between jump height and box height ($p = 0.58$).

Leg stiffness did not show a gender effect or jumping effect ($p = 0.27$), but for mean power a gender effect was observed. Males produced more power than females ($p < 0.05$). Lastly, there was a main effect of jumping condition where the 60-centimeter box produced more vertical ground reaction forces compared to the 30-centimeter box ($p < 0.05$). Results indicated that males jump higher than females and have the ability to produce more power after landing. Males having superior jumping performance over females can also be attributed to shorter ground contact times. Laffaye and Choukou (2010) suggested that optimal box height for drop jumps are between 30 and 60 centimeters because vertical performance does not change. The researchers suggested that coaches might take into consideration the gender of the athlete to address the appropriate techniques to facilitate optimal performance.

Neuromuscular differences occur in drop jump training due to box height. Training at a lower box height will reduce the athlete's ground contact time, while training at higher box heights will increase the athletes jump height (Makaruk & Sacewicz, 2011). Researchers recommended not performing drop jumps above 60 centimeters because vertical performance does not change (Laffaye & Choukou, 2010). However, research on the effects of box height on reactive strength remains equivocal.

Reactive Strength Index

Byrne, Moran, Rankin, and Kinsella (2010) investigated two popular jumps to find an optimal drop height. The first jump being the maximum jump height method (MJH) which will only account for maximum jump height. The second jump was the reactive strength index method (RSI) which accounts for both jump height and ground contact time. These methods were tested to find out which one would improve performance in a countermovement jump after eight weeks of drop jump training. Twenty-two physically active males (mean ± SD: age = 20.8

± 4.4 yr, weight = 82.6 ± 9.9 kg, height = 1.80 ± 0.06 m) were randomly assigned into two groups, the maximum jump height group and the reactive strength index group. They performed two sessions per week for eight weeks. The results of the study showed that both the MJH and RSI methods identify drop heights, but the MJH method resulted in a 0.10 m greater median drop height than the RSI method. Both methods were effective in improving countermovement jumps. The reactive strength was increased across the board for both methods; however, the MJH method only increased jump height compared to the control group at the heights of 0.30-0.60 meters. The findings of this study indicated that both MJH and RSI methods are effective in improving reactive strength and countermovement jump performance over an eight-week training period of drop jumps. However, the MJH was better at increasing jump height in the countermovement jump while the RSI methods decreased ground contact time. According to the researchers, finding the optimal height for an athlete is important to improve neuromuscular capacity to help improve jumping performance.

It is well known that plyometric training improves lower body power and utilizes the stretch-shortening cycle. Depth jumps are one of the most common forms of plyometric exercise. Reactive strength has been used to monitor stress on the musculotendinous. Flanagan et al. (2008) defined reactive strength as how well an individual can change from an eccentric to concentric contraction and can be described as an individual's explosiveness. Several reactive strength equations are currently used by coaches and trainers. One equation divides jump height by ground contact time. Reactive strength is a reliable and valid score to determine optimal box height. Time to stabilization is a new method used to measure neuromuscular control. Time to stabilization is calculated by measuring the time taken for vertical ground reaction forces to stabilize within five percent of the subject's body weight after landing from a jump. Flanagan et al. (2008) studied the test reliability of the reactive strength and time to stabilization in plyometric exercises. Twenty-two NCAA division 1 athletes (mean ± SD: age = 20.43 ± 2.43 yr, weight = 92.80 ± 17.19 kg, height = 175.6 ± 9.1 cm) who participated in track and field were recruited to complete three jumps from 0.30 m in a non-fatigue state. A repeated measure experimental design was conducted to test the reliability of jump height, ground contact time, reactive strength, and time to stabilization. For the depth jumps, subjects were instructed to land and jump as high and as quickly as possible. For both the reactive strength jumps and time to stabilization jumps, subjects were instructed to stick the landing and remain still for seven seconds. The results of this study indicated that jump height and ground contact time were shown to be highly reliable for reactive strength index (>0.9), and time to stabilization was not reliable (<0.7). The researchers suggested that reactive strength could be a quick and efficient method to monitor individual progress and optimize drop jump training. Flanagan et al. (2008) suggested that practitioners needing a quick and reliable one trial score may benefit by using the reactive index score compared to the time to stabilization method.

Ebben and Petushek (2010) examined the reliability of the reactive strength index, which takes jump height divided by ground contact time, and its counterpart the reactive strength index modifier that uses time to take off divided by jump height. Twenty-six men (mean ± SD: age = 20.23 ± 1.63 yr, weight = 79.41 ± 9.03 kg, height = 180.98 ± 6.13 cm) and twenty-three women (mean ± SD: age = 20.39 ± 1.50 yr, weight = 65.35 ± 9.81 kg, height = 171.01 ± 7.07 cm) who participated in club or recreational sports performed drop jumps from boxes normalized to their vertical jump ability. The results indicated that the reactive strength modifier is as reliable ($p < 0.00$) as the original method to find reactive strength in determining optimal box height of an individual. Ebben and Petushek (2010) suggested that reactive strength modifier can also be used for other plyometric jumps since it takes into account time to take off and is not confounded by box height. Gender did not play a role on reactive ability ($p > 0.05$): both men and women achieved similar results with different magnitudes. The researchers suggested that both the original reactive strength method and the reactive strength modification are both reliable in determining reactive strength for men and women.

Kipp, Kiely, Giordanelli, Malloy, and Geiser (2018) investigated the drop jump performance parameters and the effects of drop-height on jump height, ground contact time, and reactive strength. Twelve male division 1 basketball players (mean ± SD: age = 21.6 ± 1.8 yr, weight = 80.5 ± 10.5 kg, height = 1.93 ± 0.10 m) performed three drop jumps from 30, 45, and 60 centimeters. All subjects were instructed to jump as high and as fast as they could. Results indicated that as box height increased eccentric work increased ($p = 0.01$), but concentric work remained consistent. Results also indicated no significant differences in reactive strength, jump height, and ground contact time (reactive strength index: 30 = 0.957, 45 = 0.986, 60 = 0.967; jump height: 30 = 0.971 m, 45 = 0.853 m, 60 = 0.85 m; Ground contact time: 30 = 0.940 s, 45= 0.969 s, 60 = 0.978 s). Kipp et al. (2018) concluded that elite basketball players do not alter their landing mechanics allowing them to produce the similar reactive strength as box height increase. Reactive strength has a high correlation with vertical stiffness allowing male basketball players to produce greater forces without sacrificing jump height or increasing ground contact time. Reactive strength shows the ability of basketball players to absorb these large eccentric loads. Finally, the reactive strength profile gives strength and conditioning coaches' information on vertical stiffness. The authors concluded that strength coaches should utilize reactive strength profiles to determine optimal drop-height that will allow athletes to maximize lower body power.

Beattie, Carson, Lyons, and Kenny (2017) investigated the relationship between maximum strength variables and reactive strength variables by performing drop jumps from 0.3, 0.4, 0.5, and 0.6 meters. Secondly, they investigated if stronger or weaker athletes would have a greater reactive strength index. Forty-five college athletes (age: 23.70 ± 4.00 yr; weight: 87.50 ± 16.10 kg; height: 1.80 ± 0.08 m) across various sports (rugby union, n = 20; weightlifting, n = 8; distance running, n = 8; powerlifting, n = 4; recreational, n = 5) determined their maximal strength by preforming a mid-thigh pull test using a force plate. Results indicated that there was no significant difference ($p > .05$) in RSI as box height increased. Researchers suspected this was due to no significant changes in ground contact time and jump height. However, differences were seen in the strong versus weak group ($p \leq .01$), where the strong group had an increase in reactive strength at every height compared to the weak group. Beattie et al. (2017) suggested that relatively stronger athletes have greater reactive strength, showing the importance of having a balance between strength training and polymeric training to enhance reactive strength. Beattie et al. (2017) suggested that a well-rounded strength program should aim to increase reactive strength and that drop jumps are optimal for most individuals between 0.3-0.6 meters.

Struzik, Juras, Pietraszewski, and Rokita (2016) compared the values of reactive strength for countermovement drop jumps and bounce drop jumps. Countermovement drop jumps aim to achieve the highest jumps, while bounce drop jumps aimed to use downward velocity to convert to upward velocity as soon as possible after landing. Eight youth basketball players (mean ± SD: age = 17.70 ± 0.2 yr, weight = 79.6 ± 7.4 kg, height = 188.4 ± 6.4 cm) performed the countermovement drop jumps and bounce drop jumps twice from 15, 30, 45, and 60 centimeters. The results of the study indicate that there is a significant difference ($p < 0.05$) in jumps at 30, 45, and 60 centimeters. Jumps heights were significantly increased ($p < 0.05$) in the countermovement drop jump compared to the bounce drop jump. Results were significantly shorter ($p < 0.05$) in the bounce drop jumps for time of contact, amortization, and take-off. Researchers indicated that different types of depth jumps elicit different reactive strength scores. Differences in scores can be explained by the increase in amortization and upward velocity that the countermovement drop jump demonstrated. Struzik et al. (2016) suggested that the athlete's needs will decide jumping technique for improving jumping performance.

Suchomel, Bailey, Sole, Grazer, and Beckham (2015) investigated the reliability of the reactive strength by creating their own method of reactive strength. Their new formula uses time to take off divided by flight time. This new formula measures jump height and ground contact time. One hundred and six college students male (n = 61; mean ± SD: age = 20.5 ± 2.2 yr, weight = 82.6 ± 10.4 kg, height = 180.4 ± 6.9 cm) and female (n = 45; mean ± SD: age = 20.5 ± 2.2 yr, weight = 67.0 ± 9.7 kg, height = 168.8 ± 7.4 cm) participated in the study. Each participant performed 25 countermovement jumps with thirty-second rest between each jump. Every jump was performed on a force plate. The results indicate that reactive strength modifier is a reliable ($p < 0.01$) test of reactive strength for other jumps besides drop jumps. Suchomel et al. (2015) indicated that the modifier is a reliable equation that can be used for both men and women. Suchomel et al. (2015) demonstrated that the reactive strength modifier can also be used to measure an individual's explosiveness, as well as monitoring their progress.

Reactive strength index is a reliable measurement that can be applied to both male and female athletes to determine reactive strength and monitor progress (Suchomel, Bailey, Sole, Grazer, & Beckham, 2015). Research reveals that reactive strength has shown a positive correlation with overall strength and greater reactive strength scores (Beattie, Carson, Lyons, &

Kenny, 2017). However, less is known on how different jumping techniques will affect reactive strength.

Markwick, Bird, Tufano, Seitz, and Haff (2015) investigated the reliability of the reactive strength index from a drop jump with professional male basketball players. Thirteen male basketball players (mean ± SD: age = 25.8 ± 3.5 yr, weight = 94.8 ± 8.2 kg, height = 1.96 ± 0.07 m) performed three drop jumps from 20, 30, 40, and 50 centimeters. Jump height and reactive strength were observed from these jumps. No significant differences ($p > 0.05$) were observed in jump height or reactive strength as box height increased. There was also no difference ($p > 0.05$) in jump height or reactive strength between trails. The researchers suggested that coaches should measure jump height as it appears to be the most useful variable for creating a reactive strength profile, as well as when dealing with large groups, it appears that only one trial is required when assessing reactive strength.

Jump height is a critical factor in assessing reactive strength and is one of the variables strength coaches monitor and try to increase. Earp et al. (2010) suggested that drop jumps produce greater pre-stretch which will increase force production. While Peng (2011) recommended not performing drop jumps from heights greater than 50 centimeters due to the increase potential of injuries. However, less is known on how drop height will affect ground reaction time.

Jump Height

Plyometric exercises involve the stretch-shortening cycle which controls an eccentric muscle action to a rapid concentric muscle action. Plyometric training involves the ability of a muscle to store elastic energy and utilize it as explosive energy. Plyometric training can enhance lower body power. Two common exercises that increase vertical jump height are the standard countermovement jump and the depth jump. Gehri, Ricard, Kleiner, and Kirkendall (1998) compared both plyometric exercises to determine which is superior. Fourteen males (mean ± SD: age = 20.33 ± 1.43 yr, weight = 67.23 ± 6.12 kg, height = 178.33 ± 9.01 cm) and 14 females (mean ± SD: age = 19.63 ± 1.43 yr, weight = 53.23 ± 7.82 kg, height = 166.33 ± 3.91 cm) participated in a 12-week training program designed to improve vertical jumping ability. For the first two weeks subjects performed two sets of eight reps; for the remaining 10 weeks both training groups performed four sets of eight reps. Each group received five seconds of rest between each repetition and 1-minute rest between each set. A height of 40cm was chosen for the depth jump height. A two-factor ANOVA was used to test for differences in training group pre-test and post-test. The results indicate that both training groups increased vertical jump height; however, the depth jump group (pre: 26.50 ± 9.11 cm, post: 28.63 ± 5.23 cm, change: 2.13 ± 1.86 cm), proved to be superior to increase power compared to the countermovement jump group (pre: 30.50 ± 7.20 cm, post: 32.15 ± 7.59 cm, change: 1.65 ± 0.97 cm). Gehri et al. (1998) believed this occurred due to a greater positive energy production in the concentric phase of the jump. The researchers suggested that training depth jumps is more sports-specific compared to countermovement jumps. The researchers concluded that plyometric depth jump exercises should be used with a resistance program to improve lower body power and jumping performance.

According to Earp et al. (2010) muscle architecture and number of cross-bridge formations are highly associated with the ability to produce force. Muscle architectures have been studied during running but are unknown in jump performance. Countermovement jumps utilize the stretch-shortening cycle and redirect energy in the concentric movement to create more power. Compared to a squat jump, drop jumps have been shown to be superior in producing lower body power and jump height to a certain degree. Earp et al. (2010) predicted that jump performance is based on the muscular structure of the lower body; secondly the authors' aim was to determine if certain structures will allow an individual to increase performance with an increased loading pre-stretch. Twenty-five men (mean ± SD: age = 23.3 ± 3.2 yr, weight = 86.2 ± 11.6 kg, height = 176.1 ± 7.4 cm) performed three jumps each of countermovement jumps, squat jumps, and drop jumps for two sets. There was a 3-minute rest between sets and all jumps were completed with hands on the hips. Countermovement jumps were defined as subjects started in an upright position then dropped to their own selective depth and jump as high as possible. Squat jumps were defined as subjects drop down to their selective depth and paused for 1-2 seconds then jumping as high as possible. Depth jumps were described as subjects falling off the box with one foot, landing on both feet, and immediately jumping as high as possible. Results indicated that both countermovement jumps (Jump height: $p = .02$, Peak power: $p = .03$) and drop jumps (Jump height: $p = .00$, Peak power: $p = .04$) produced greater jump height and peak power compared to squat jumps. Earp et al. (2010) suggested that drop jumps produce greater pre-stretch which will produce more force. The researchers suggest that a more efficient stretch-shortening cycle or greater cross-bridge formation can lead to an increase in vertical jump height and lower body peak power.

Mirzaei, Norasteh, de Villarreal, and Asadi (2014) investigated the effects of drop jumps compared to countermovement jump training on sand. The purpose of this study was to investigate jumping performance through the standing vertical jump and broad jump. Thirty untrained males (mean ± SD: age = 20.7 ± 0.8 yr, weight = 75.2 ± 8.9 kg, height = 180.4 ± 6.6 cm) participated. Participants were spilt into either the drop jump group or the sand group. The drop jump group completed five sets of five reps at a 45-centimeter box while the sand group completed five sets of five reps in the sand. Results revealed a significant ($p < .05$) increase with both groups in standing vertical jump ($p = .00$) and broad jump ($p = .00$). Mirzaei et al. (2014) suggested that both drop jump and plyometric training in the sand will increase jumping performance. The researchers suggested that plyometrics on sand will demonstrate a reduction in elastic energy and a loss of energy from the ground, making the concentric phase of the vertical jump much more important for energy production.

Ramirez-Campillo et al. (2018) investigated the accuracy of an individual athlete's reactive strength profile compared to a strength and conditioning coach choosing a fixed box height for all athletes to drop off. Seventy-three national level youth male soccer players (mean ± SD: age = 13.8 ± 1.2 yr, weight = 47.23 ± 9.98 kg, height = 1.53 ± 0.1 m) were randomly assigned to either the fixed group that dropped from a box height of 30 centimeters, or the second group which found their own optimal box height by performing a reactive strength index test and performed the jumps at that height. The control group did not perform any drop jumps. A training regime was conducted for both groups for seven weeks. Results from the training intervention revealed no significant ($p > .50$) difference between groups. However, the optimal group did increase in jump height (CMJ (cm) OPT pre: 27.6 ± 5.6, OPT post: 31.8 ± 5.4) and reactive strength (RSI OPT pre: 1.1 ± 0.5, RSI OPT post: 1.5 ± 0.5) compared to the fixed group (CMJ (cm) Fixed pre: 27.9 ± 5.4, Fixed post: 29.9 ± 5.7; RSI Fixed pre 1.1 ± 0.5, RSI Fixed post 1.3 ± 0.5). The researchers suggested that in order to best optimize youth national soccer players, lower body power should be based of individual parameters.

Peng (2011) examined the kinematic and kinetic data of drop jumps from heights of 20, 30, 40, 50, and 60 centimeters. Peng (2011) investigated impulse, power, work, and stiffness between box heights. Sixteen active college students, 11 men (mean ± SD: age = 21.8 ± 1.8 yr, weight = 73.6 ± 15.5 kg, height = 172.8 ± 8.1 cm) and five women (mean ± SD: age = 21.2 ± 1.1 yr, weight = 57.2 ± 7.2 kg, height = 162.4 ± 3.8 cm), completed all jumps three times in randomized order. Subjects were asked to jump as high and as fast as possible. Results revealed a significant increase in ground reaction forces ($p < 0.05$) at box heights 50 centimeters or higher. Peng (2011) proclaimed that approximately three times the subject body weight is being used when landing from heights higher than 50 centimeters, which results in an increased risk for injuries. Additionally, as box height increased jump height decreases (DJ(cm): DJ20 = 23.7 ± 5.1, DJ30 = 23.3 ± 4.6. DJ40 = 22.1 ± 4.0, DJ50 = 21.9 ± 5.1, DJ60 = 20.8 ± 4.7). Peng (2011) suggested that with the increase in box height and the resulted increase in ground reaction force demonstrated that active college students do not have the ability to absorb high eccentric forces. The researcher concluded that strength and conditioning coaches should be aware that box height can be used as an indicator for intensity, and when writing training programs coaches should not have drop-heights exceeding over 50 centimeters, due to the inability of most individuals overcoming their high eccentric forces.

Matavulj, Kukolj, Ugarkovic, Tihanyi, and Jaric (2001) investigated if limited drop jump training can lead to an increase in jumping performance. Thirty-three junior male basketball players performed drop jumps from 50 and 100 centimeters. Results revealed that dropping from 50- or 100-centimeters increased countermovement jump performance (4.8 cm; 5.6 cm) due to the increased rate of force development. The researchers saw no significant difference between the groups ($p > 0.05$); both groups increased their jump height due to an increased hip extensor. Matavulj et al. (2001) cannot attribute the increases in vertical performance to the training protocol since the researchers did not stop the subjects from participating in other jumping activities, such as basketball practice and games. Matavulj et al. (2001) suggested that coaches looking to increase jumping performance with junior basketball players may benefit from adding drop jumps at 50-100 centimeters. Additionally the researchers suggested that this improvement could be associated with increased production of the leg extensor muscles and increased rate of force development.

Barr and Nolte (2014) examined the relationship between maximal leg strength and drop jump performance. Fifteen female rugby players (mean ± SD: age = 20.3 ± 0.5 yr, weight = 71.6 ± 9.9 kg, height = 1.71 ± 0.5 m) performed drop jumps from 0.24, 0.36, 0.48, 0.60, 0.72, and 0.84 meters. Participants also performed a maximal front squat to determine leg strength. Pearson's correlation was used to split the group into strong and weak based on the subject's body mass. Results revealed a significant difference ($p = 0.01$) in the strong group. Subjects showed increased jumped height, reactive index score, and decrease ground contact time compared to the weaker group. Barr and Nolte (2014) suggested that relative strength does play a partial role in predictive drop jump performance with female soccer players. Bar and Nolte (2014) attributed the results to the weaker group having to absorb eccentric forces almost eight times their body mass, while the stronger group showed an increased ability to absorb these eccentric forces. The researchers concluded that strength and conditioning coaches could consider athletes increasing their lower body strength before performing drop jumps over 0.24 meters.

Ground Contact Time

Deliceoğlu et al. (2017) studied 13 youth Turkish national volleyball players to examine the effects of drop height on ground contact time, jump height, and lower body power outputs. Thirteen male volleyball players (mean ± SD: age = 15.9 ± 0.5 yr, weight = 80.2 ± 5.2 kg, height = 1.93 ± 4.6 m) performed drop jumps from 10, 20, 30, 40, 50, and 60 centimeters. Results revealed no significant increase ($p > 0.05$) in ground contact time as box height increased, but there was a significant increase ($p > 0.05$) as drop height increased, absolute and relative power also increased. The researchers suggested that there was no change in ground contact time as drop height increased due to the level of athletes being tested. Deliceoğlu et al. (2017) postulated that elite athletes demonstrated the ability to absorb these high eccentric forces, whereas recreational athletes do not normally demonstrate these same results. Deliceoğlu et al. (2017) suggest that to increase power, strength coaches should focus on decreasing or keeping ground contact time to a minimal in order to produce the greatest power outputs.

Walsh, Arampatzis, Schade, and Bruggemann (2004) examined the effects of drop height on ground contact time. Fifteen decathletes (mean ± SD: weight = 78.94 ± 5.86 kg, height = 1.83 ± 0.06 m) performed three drop jumps from 20, 40, and 60 centimeters. The subjects where encouraged to jump as high and as fast as possible. Results indicated that there was no significant difference ($p > 0.05$) in ground contact time with an increase in drop height. According to the researchers, the findings indicated that strength coaches should train their athletes based off the rule of specificity, in addition to what the athletes' individual needs are. Walsh et al. (2004) suggested that coaches should decide on box height based on other jump performance parameters, such as jump height or reactive strength, to determine optimal box height for each individual athlete.

Young et al. (1995) investigated verbal coaching techniques to influence jump performance. Seventeen male college students (mean ± SD: age = 23.6 ± 4.4 yr, weight = 78.3 ± 10.8 kg, height = 179.2 ± 7.0 cm) performed three drop jumps from 30, 45, and 60 centimeters. With each trial jump, different instructions on how to jump were given. The first instruction was to jump "high as you can." The second jump was to jump "soon as your feet hit the ground."

Lastly, they were instructed to jump “as high and as fast as possible.” Results showed that ground contact was significantly shorter ($p < 0.01$) when instructing subjects to keep ground contact minimal compared to the other groups. Similar results were also seen as box height increased. Jump height was significantly increased ($p < 0.05$) in the group that stressed jump height the most; additionally, as box height increased jump height decreased and ground contact time increased. The researchers suggested that jumping results will depend on the motivational cues for the jump. Young et al. (1995) suggested that strength and conditioning coaches whose sport involves long stretch-shortening cycles should perform drop jumps with the intention to maximize jump height and mimic the movements of a countermovement jump, while athletes whose sport involves fast stretch-shortening cycles should perform drop jumps with the goal of keeping ground contact time minimal.

CHAPTER III

METHODS

Participants

A total of 20 participants (13 males and 7 females; age: 22.80 ± 2.69 yr; height: 175.65 ± 11.81 cm; weight: 78.32 ± 13.50 kg) volunteered to participate. In this study all participants were right foot dominant and had no lower limb pathology within the last year. This study was approved by the university IRB and all participants read and signed an informed consent prior to participation (Appendix A).

Instrumentation

Sixteen high-speed VICON cameras collecting at 250 Hz were used to track reflective markers located on the participants' left and right anterior superior iliac spine and posterior superior iliac spine. Sixteen-channel Delsys Trigno Electromyography (EMG) system collecting at 2000 Hz was used to collect peak muscle activation in seven leg muscles (rectus femoris, vastus medialis, vastus lateralis, biceps femoris, semitendinosis, gluteus maximus, and gluteus medius). A Kistler force plate collecting at 2000 Hz was used to determine ground contact time. Vicon Nexus software (ver. 1.8.5) and Visual 3D software (ver. 5.02.27) were used to process raw data. IBM SPSS statistics (version 20) was used to analyze all data

Procedures

Subjects were requited by word of mouth. Subjects were required to read and sign an informed consent prior to participation (Appendix B). Subjects also filled out a questionnaire requiring anthropometric information and drop jump history (Appendix C). The National Strength and Conditioning Association (NSCA) recommends that a subject should be able to squat 1.5 times their body weight (Baechle & Earle, 2008, p. 423). Subject weight was not an exclusion criterion due to the fact that many athletes can still preform drop jumps with proper mechanics at weights exceeding 220 pounds. Subjects were tested on their maximum jump height and reactive strength index. Subjects were prepped with reflective markers on their anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS) bilaterally. These markers were used to track jump height. After subjects were prepped, they were required to complete a 5-minute warm-up on a Monark exercise bike at their desired pace. After the warm-up, the primary investigator demonstrated correct mechanics of countermovement jumps and drop jumps for the subjects. Subjects were required to reenact these same jumping mechanics. Subjects were not permitted to continue until proper jumping and landing mechanics were demonstrated. Once jumping and landing mechanics were accepted by the primary investigator, the subjects preformed three submaximal countermovement jumps with 30 seconds between each jump. Once all three jumps were completed a 2-minute break was allotted for rest. Subjects continued their warm-up performing three submaximal drop jumps at three different drop heights (30 cm, 45 cm, and 60 cm), subjects were also allotted 30 seconds of rest between jumps and 2-minutes of rest between the different drop heights. These same rest periods were standard throughout all testing.

After completing all warm-up jumps, subjects were instructed to preform three maximal countermovement jumps. Subjects were instructed to stand on the force plate and jump up as high as possible on the primary investigator's command. Once the three jumps were completed the primary investigator brought out five drop jump boxes (30 cm, 45 cm, 60 cm, 76 cm, and 92 cm). For the drop jumps the primary investigator instructed the subjects to fall off the box by hanging their right leg off the box and waiting for the primary investigator commands to start. The primary investigator instructed the subject to land on the force plate when falling off the box prior to performing the vertical jump. The primary investigator instructed the subjects to jump as high and as quickly as possible, this command was repeated before every jump. Subjects started with the lowest box and completed one drop jump for each height for three sets. To add counterbalance sets 2 and 3 were to be randomized by the primary investigator. There were 30 second breaks in-between jumps and a 2-minute rest between sets. Maximal jump height and ground contact time were recorded. To find reactive strength, maximum jump height was divided by ground contact time.

Statistical Analysis

Raw data was entered into IBM SPSS statistics (version 20) and reviewed for any errors or missing values. Once screened the researcher performed a 1 x 5 ANOVA (RSI by drop height) 1 x 6 ANOVA (jump height by drop height), and 1 x 5 ANOVA (ground contact time by drop height) was performed to determine if there was a statistical difference between variables.

CHAPTER IV

RESULTS

Jump Height

The research rejects the null hypothesis for jump height, there was no significant interaction or main effect ($p > 0.05$) for box height (Table 1). There was a significant main effect for sex ($p = 0.038$) where men (0.55 ± 0.02 m) jumped higher than women (0.39 ± 0.03 m) (Appendix D, E).

RSI

The research accepts the null hypothesis for RSI, there was no significant interaction ($p > 0.05$), but there was a significant main effect for box height ($p < 0.05$) where 30cm was greater than 91cm, while 45cm and 60cm were both greater than 76cm and 91cm (Figure 1). There was also a main effect ($p = 0.002$) for sex where males (1.73 ± 0.14) were greater than females (0.90 ± 0.19) (Appendix F).

Ground Contact Time

The research rejects the null hypothesis for ground contact time there was no significant interaction ($p > 0.05$), but there was a significant main effect for box height ($p < 0.05$) where 91cm and 76cm were longer than 30cm, 45cm, and 60cm (Figure 2). There was also a main effect ($p = 0.020$) of sex where females (0.45 ± 0.04 s) spent a longer time on the ground than males (0.34 ± 0.03 s) (Appendix G).

Table 1

Mean and SD for Jump Height for each Box Height

Box Height (cm)	0	30	45	60	76	91
Mean&Std.	0.48±0.01	0.46±0.01	0.47±0.02	0.46±0.02	0.46±0.01	0.45±0.02

N = 20

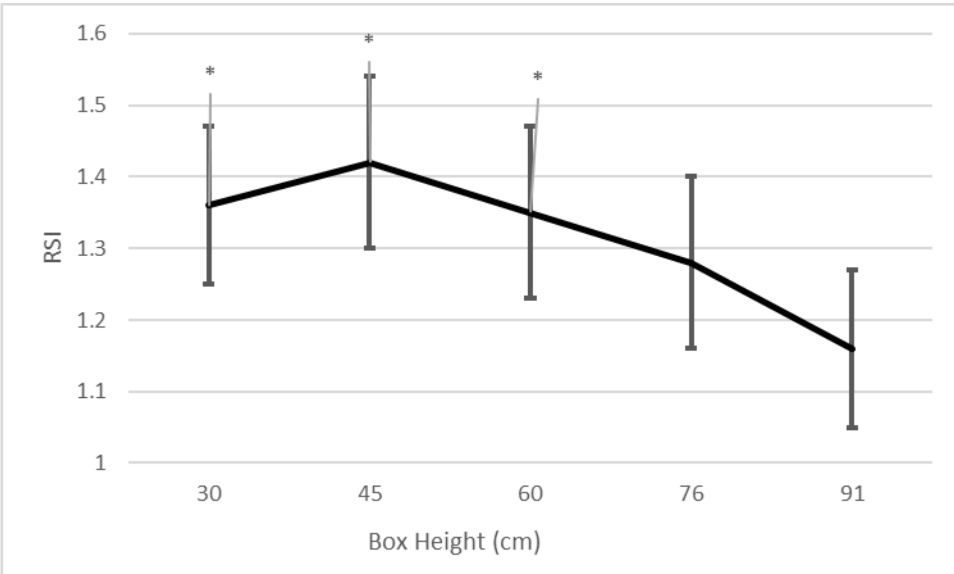

Figure 1. Mean and SD for RSI score for box height

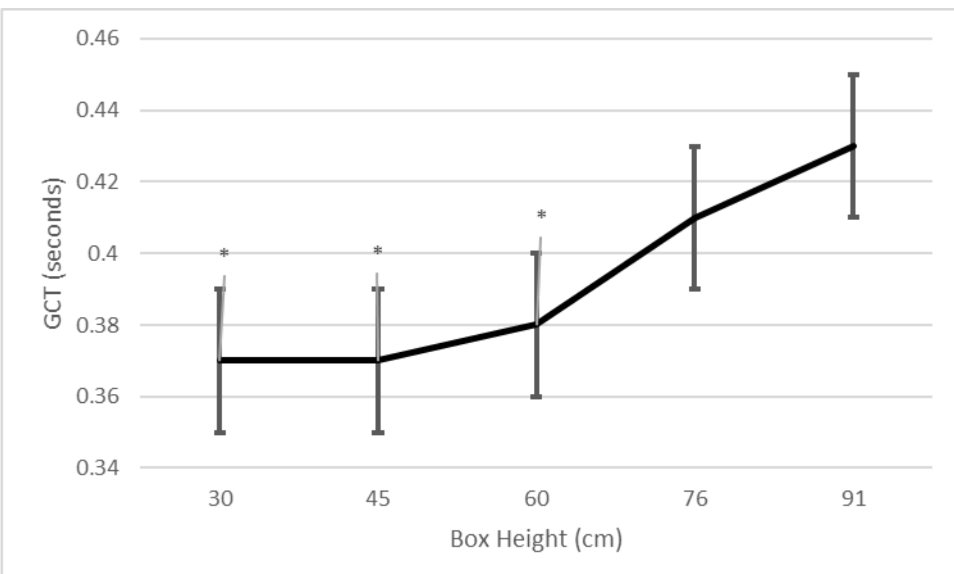

Figure 2. Mean and SD for GCT for box height

CHAPTER V

DISCUSSION

The purpose of this study was to examine the effect of box height on drop jump GCT, jump height, and RSI. The main findings of this research demonstrated that as box height increased, GCT also increased but jump height did not change, which resulted in a decrease in RSI.

Finding the optimal box height is critical to achieving the best training results. A method of determining optimal box height is RSI, which is a valid and reliable measure of jumping performance (Flanagan et al., 2008). Ramirez-Campillo et al. (2018) found that when seventy-three national level, young male soccer players performed drop jumps from their optimal height, there was a significant increase ($p < 0.05$) in RSI and jump height with an increase in box height. Compared to the fixed group that performed drop jumps from a fixed height, the second group did not see increase in jump height or RSI. This could be due to the training protocol allowing the athletes to train at their individualized drop height. Specific training via drop jumps may elicit different outcomes; as box heights greater than 60 cm have been shown to promote increases in jump height, whereas box heights less than 60 cm show a decrease in GCT (Gehri, Ricard, Kleiner, & Kirkendall 1998; Taube et al., 2012).

GCT is an important variable related to the stretch-shortening cycle (SSC). The SSC can be broken into either fast (< 0.25 seconds) or (slow > 0.25 seconds) (Flanagan & Comyns, 2008). A study conducted by Walsh et al. (2004) demonstrated that fast GCT is related to acceleration, while slow GCT is related to force production. Taube et al. (2012) revealed that shorter drop heights maximize power output with the least amount of GCT. Peng (2011) revealed that increasing box heights over 50 cm decreased performance due to an increase in GCT, which was supported by the findings of the current study. Research conducted by Young et al. (1995) showed that as box height increased above 30 cm, GCT also increased due to an inability for subjects to overcome the high eccentric forces. Similar results by Ball et al. (2010) were observed in which box heights over 40 cm, increased GCT when compared to box heights lower than 40 cm. Ball et al. (2010) concluded that the optimal GCT for drop jumps is less than 0.26 seconds, postulating a decrease in power output with GCT greater than 0.25 seconds. Results differ from the current study due to differences in participants.

Deliceoğlu et al. (2017) results contradicted the present findings where thirteen youth Turkish national volleyball players performing drop jumps at 20, 40, and 60 cm showed no increase in GCT as box height increased. These results may differ from the present study due to the different populations and different box heights used. Hoffren, Ishikawa, and Komi (2007) had young subjects perform drop jumps from 10, 15, and 20 cm; results showed no increase in GCT as box height increased.

The present study results also indicated that as drop height increased rebound height did not change. Similar findings were seen by Barr and Nolte (2014) who had female high school athletes perform drop jumps from 0.24, 0.36, 0.48, 0.6, 0.72, and 0.84 m and found no significant increase ($p > 0.05$) in jump height between box heights. It can be hypothesized that the box heights were too high for the young athletes to overcome the high eccentric forces. Similar findings were seen by Stieg et al. (2011) who had collegiate women soccer players perform depth jumps from the level of the lateral femoral condyle and found no increase in vertical jump height, which could be due to the box height being too low. Similar to the present study, Earp et al. (2010) found that drop jumps from 40 cm resulted in no significant difference ($p > 0.05$) in jump height compared to the normal countermovement jump. This could be due to the level of conditioning or the subjects not being at an elite level. Markwick, Bird, Tufano, Seitz, and Haff (2015) conducted a study were thirteen professional National Basketball League players (mean ± SD: age = 25.8 ± 3.5 yr, weight = 94.8 ± 8.2 kg, height = 1.96 ± 0.07 m) performed drop jumps from 20, 30, 40, and 50 cm. No changes in jump height were observed; however, there was an increase seen compared to the countermovement jump. This could be due to the subjects being well-trained athletes who have highly developed SSCs. Similar findings were observed by Bobbert et al. (1987) who reported that there was no increase in jump height with an increase in box height. Taube et al. (2012) contradicted the present study's findings, reporting drop jumps from 40 cm or higher increased subjects rebound jump height; this could be due to increased force in the eccentric phase due to greater drop heights. A study done by Young et al. (1995) also contradicted the present study findings, showing that subjects performing drop jumps form 30, 45, and 60 cm experienced a decrease in jump height as box height increased. Similar findings were observed by Peng (2011) suggesting that the SSC may decrease with drop heights greater than 40 cm.

The present study results revealed a decrease in RSI as box height increased, this is due to an increase in GCT with no difference in jump height; these results are mixed compared to previous studies. Markwick et al. (2015) had professional basketball players (mean ± SD: age = 25.8 ± 3.5 yr, weight = 94.8 ± 8.2 kg, height = 1.96 ± 0.07 m) perform drop jumps from 20, 30, 40, and 50 cm and observed no significant changes ($p > 0.05$) in RSI. Similar results were seen by Kipp, Kiely, Giordanelli, Malloy, and Geiser (2018) where 12 NCAA division 1 basketball players (mean ± SD: age = 21.6 ± 1.8 yr, weight = 80.5 ± 10.5 kg, height = 1.93 ± 0.10 m) performed drop jumps from 30, 45, and 60 cm. Results indicated no changes in RSI as box height increased. Struzik et al. (2016) observed similar findings as the previous authors with eight youth male basketball players (mean ± SD: age = 17.70 ± 0.2 yr, weight = 79.6 ± 7.4 kg, height = 188.4 ± 6.4 cm); no changes in RSI were observed with an increase in box height from 15, 30, 45, and 60 cm. Beattie et al. (2017) saw the same mixed results as the current study, where 45 college athletes (age: 23.70 ± 4.00 yr; mass: 87.50 ± 16.10 kg; height: 1.80 ± 0.08 m) across various sports (rugby union, n = 20; weightlifting, n = 8; distance running, n = 8; powerlifting, n = 4; recreational, n = 5) were assigned into weak and strong groups based on relative mid-thigh pull strength. Each participant performed drop jumps from 0.3, 0.4, 0.5, and 0.6 meters. The strong group did not decrease RSI with an increase in box height, while the weaker group saw a significant decrease ($p \leq .01$) in RSI as box height increased. The authors suggested that this could be due to the higher eccentric load with the increase in box height.

Conclusion

The results of this study show a parabolic curve in RSI which increases with box height. This was due to an increase in GCT while jump height remained constant. Box heights between 30 and 45 cm demonstrated the greatest RSI, while greater box heights decreased RSI. Therefore, it is recommended that strength and conditioning coaches emphasize minimal ground contact time and utilize box heights no greater than 45 cm to maximize RSI. Future research should be focused on using RSI to develop a strength profile for an athlete and should be used in order to maximize jump training. The present study indicated that as box height increased, jump height remained constant while GCT increased; this will cause a decrease in RSI as box height increases. The present study demonstrated mixed results compared to previous research. One reason could be due to the inability of the participants to absorb the load on the eccentric phase leading to the increase in GCT.

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APPENDIX

APPENDIX A

Institutional Review Board Approval

University of West Florida

Research and Sponsored Programs
11000 University Parkway, Bldg. 11
Pensacola, FL 32514-5750

Mr. Cameron Addie

April 05, 2018

Dear Mr. Addie:

The Institutional Review Board (IRB) for Human Research Participants Protection has completed its review of your proposal number IRB 2018-163 titled, "Effects of Drop Height on Depth Jumps," as it relates to the protection of human participants used in research, and granted approval for you to proceed with your study on 04-04-2018. As a research investigator, please be aware of the following:

* You will immediately report to the IRB any injuries or other unanticipated problems involving risks to human participants.
* You acknowledge and accept your responsibility for protecting the rights and welfare of human research participants and for complying with all parts of 45 CFR Part 46, the UWF IRB Policy and Procedures, and the decisions of the IRB. You may view these documents on the Research and Sponsored Programs web page at http://research.uwf.edu. You acknowledge completion of the IRB ethical training requirements for researchers as attested in the IRB application.
* You will ensure that legally effective informed consent is obtained and documented. If written consent is required, the consent form must be signed by the participant or the participant's legally authorized representative. A copy is to be given to the person signing the form and a copy kept for your file.
* You will promptly report any proposed changes in previously approved human participant research activities to Research and Sponsored Programs. The proposed changes will not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the participants.
* **You are responsible for reporting progress of approved research to Research and Sponsored Programs at the end of the project period 03-20-2019. If the data phase of your project continues beyond the approved end date, you must receive an extension approval from the IRB.**
* If using electronic communication for your study, you will first obtain approval from the authority listed on the following web page: https://uwf.edu/offices/institutional-communications/resources/broadcast-distribution-standards/.

Good luck in your research endeavors. If you have any questions or need assistance, please contact Research and Sponsored Programs at 850-474-2824 or 850-474-2609 or irb@uwf.edu.

Sincerely,

Dr. Mark Roltsch, Assistant Vice President for Research and Director of the Office of Research and Sponsored Programs

Dr. Ludmila Cosio-Lima, Chair, IRB for Human Research Participant Protection

Phone 850.474.2824 Fax 850.474.2802
Web research.uwf.edu

APPENDIX B

Informed Consent Form for Subject Participation

TITLE OF STUDY
Effects Of Drop Height on Depth Jumps
PRINCIPAL INVESTIGATOR
Cameron Addie
Exercise Science Department
Bldg. 72, Biomechanics Lab 213 11000 University Pkwy. Pensacola, FL 32514
(859) 630-8588
Cda24@studnets.uwf.edu

PURPOSE OF STUDY

You are being asked to take part in a research study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. Please read the following information carefully. Please ask the researcher if there is anything that is not clear or if you need more information.

The purpose of this study is to determine if a greater drop height for depth jumps will elicit a greater muscle activation in the quadriceps, hamstring and glutes. As well will a greater drop height increase vertical jump performance. Secondly we will examine if there is an increase in amortization phase with an increase in drop height. Lastly we will be examining if a greater drop high decrease reactive strength.

STUDY PROCEDURES

You will be prep with markers on Anterior Superior Iliac Spine and Posterior Superior Iliac spine, and EMG will be placed on quads, hamstring, and glute muscles. Afterwards you will have a 5 minutes to warm-up on a stationary bike at your choice of intensity. You will then perform 3 submaxim countermovement jumps followed by 3 max countermovement jumps. Following your countermovement jump you will perform 3 sub max depth jumps from (12in, 18in, 24in),you will then perform 3 max depth jumps from (12in, 18in, 24in, 30in, 36in) in a random order. You will receive 30 second rest per jump and 2 minute rest per set Trails should take a total of 90 minutes

RISKS

The potential risks to yourself in this study include ankle sprains, knee injury, muscle pain, and muscle soreness. Ankle sprains can be compared as stepping off the curb, while muscle pain and muscle soreness can be compared as the same sensation you might have after workout. The researcher will minimize these risks by providing clear directions on how to perform each athletic task. Participants could also experience muscle injury, inappropriate changes in blood pressure or heart rhythm during the exercise tests. The risk of these events is very low in individuals who are physically active and apparently

Participant's Initials: ________

healthy, such as the target population. As this is a controlled study being performed by a knowledgeable researcher, the risk is likely less than what the participant experiences during their normal training. An automated external defibrillator (AED) is located in the hallway adjoining the laboratory, and available for use if needed. Phone access to EMS is available in the testing lab.

BENEFITS

You will be coached and shown how to properly perform a depth jump.

CONFIDENTIALITY

Your responses and data to this study will be anonymous. Every effort will be made by the researcher to preserve your confidentiality including the following:

- Identification code names/numbers for participants that will be used on all research notes and documents
- Keeping notes, and any other identifying participant information in a locked file cabinet in the personal possession of the researcher.

Your data will be kept confidential except in cases where the researcher is legally obligated to report specific incidents. These incidents include, but may not be limited to, incidents of abuse and suicide risk.

CONTACT INFORMATION

If you have questions at any time about this study, or you experience adverse effects as the result of participating in this study, you may contact the researcher whose contact information is provided on the first page. If you have questions regarding your rights as a research participant, or if problems arise which you do not feel you can discuss with the Primary Investigator, please contact the Institutional Review Board at (850) 857-6203

VOLUNTARY PARTICIPATION

Your participation in this study is voluntary. It is up to you to decide whether or not to take part in this study. If you decide to take part in this study, you will be asked to sign a consent form. After you sign the consent form, you are still free to withdraw at any time and without giving a reason. Withdrawing from this study will not affect the relationship you have, if any, with the researcher. If you withdraw from the study before data collection is completed, your data will be returned to you or destroyed

CONSENT

I have read and I understand the provided information and have had the opportunity to

Participant's Initials: ________

ask questions. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and without cost. I understand that I will be given a copy of this consent form. I voluntarily agree to take part in this study.

Participant's signature ______________________________ Date __________

Investigator's signature _____________________________ Date __________

Participant's Initials: ________

APPENDIX C

Subject Anthropometric Data

	AGE	SEX	HEIGHT (m)	MASS (kg)
SUBJECT 01	21	F	1.75	65.77
SUBJECT 02	21	M	1.85	94.35
SUBJECT 03	22	M	1.75	76.66
SUBJECT 04	22	M	1.91	74.84
SUBJECT 05	23	M	1.93	95.25
SUBJECT 06	24	M	1.95	88.50
SUBJECT 07	21	M	1.80	79.40
SUBJECT 08	22	M	1.76	84.20
SUBJECT 09	23	M	1.85	92.99
SUBJECT 10	21	M	1.73	70.31
SUBJECT 11	24	M	1.88	104.33
SUBJECT 12	20	F	1.52	60.90
SUBJECT 13	24	M	1.67	92.00
SUBJECT 14	21	F	1.67	73.90
SUBJECT 15	28	F	1.72	76.00
SUBJECT 16	20	F	1.63	52.16
SUBJECT 17	24	M	1.78	76.66
SUBJECT 18	31	M	1.78	81.19
SUBJECT 19	23	F	1.60	63.50
SUBJECT 20	21	F	1.60	63.50

APPENDIX D

Max Jump Height Performance Testing Data

	MAX_JUMP_HT_CALC_AVG12_MEAN (cm)	MAX_JUMP_HT_CALC_AVG18_MEAN (cm)	MAX_JUMP_HT_CALC_AVG24_MEAN (cm)	MAX_JUMP_HT_CALC_AVG30_MEAN (cm)	MAX_JUMP_HT_CALC_AVG36_MEAN (cm)
SUBJECT 01	0.35	0.38	0.31	0.35	0.31
SUBJECT 02	0.62	0.63	0.60	0.60	0.58
SUBJECT 03	0.73	0.74	0.74	0.71	0.66
SUBJECT 04	0.58	0.60	0.60	0.61	0.61
SUBJECT 05	0.47	0.49	0.49	0.52	0.56
SUBJECT 06	0.50	0.47	0.51	0.49	0.48
SUBJECT 07	0.56	0.57	0.55	0.58	0.49
SUBJECT 08	0.54	0.52	0.55	0.57	0.57
SUBJECT 09	0.46	0.50	0.50	0.50	0.51
SUBJECT 10	0.60	0.62	0.60	0.59	0.45
SUBJECT 11	0.58	0.60	0.57	0.58	0.55
SUBJECT 12	0.38	0.39	0.40	0.41	0.39
SUBJECT 13	0.58	0.58	0.59	0.56	0.60
SUBJECT 14	0.41	0.40	0.42	0.37	0.38
SUBJECT 15	0.36	0.37	0.33	0.37	0.35
SUBJECT 16	0.50	0.52	0.51	0.51	0.51
SUBJECT 17	0.41	0.39	0.36	0.34	0.36

SUB JECT 18	0.52	0.54	0.56	0.52	0.56
SUB JECT 19	0.46	0.44	0.45	0.45	0.44
SUB JECT 20	0.25	0.27	0.25	0.28	0.21

APPENDIX E

Mean Counter Movement Jump Performance Testing Data

	CMJ MEAN (cm)
SUBJECT 01	.42
SUBJECT 02	.70
SUBJECT 03	.60
SUBJECT 04	.58
SUBJECT 05	.58
SUBJECT 06	.56
SUBJECT 07	.59
SUBJECT 08	.64
SUBJECT 09	.47
SUBJECT 10	.57
SUBJECT 11	.64
SUBJECT 12	.44
SUBJECT 13	.58
SUBJECT 14	.41
SUBJECT 15	.38
SUBJECT 16	.48
SUBJECT 17	.37
SUBJECT 18	.56
SUBJECT 19	.42
SUBJECT 20	.29

APPENDIX F

Reactive Strength Index Performance Testing Data

	RSI_AVG12 _MEAN	RSI_AVG18 _MEAN	RSI_AVG24 _MEAN	RSI_AVG30 _MEAN	RSI_AVG36 _MEAN
SUBJECT 01	1.27	1.47	1.18	1.13	1.05
SUBJECT 02	2.18	2.00	1.84	1.85	1.53
SUBJECT 03	2.86	3.03	3.05	3.10	2.60
SUBJECT 04	2.28	2.84	3.05	2.73	2.85
SUBJECT 05	1.81	1.73	1.63	1.65	1.66
SUBJECT 06	1.41	1.31	1.36	1.29	1.02
SUBJECT 07	2.08	2.13	1.81	1.99	1.43
SUBJECT 08	2.11	2.04	1.62	1.63	1.48
SUBJECT 09	1.10	1.27	1.36	1.18	1.22
SUBJECT 10	1.24	1.76	1.87	1.62	1.26
SUBJECT 11	0.99	0.98	0.95	0.93	0.87
SUBJECT 12	1.13	1.04	1.05	0.87	0.74
SUBJECT 13	1.77	1.88	1.72	1.68	1.54
SUBJECT 14	0.86	0.84	0.79	0.63	0.62
SUBJECT 15	0.76	0.76	0.71	0.70	0.73
SUBJECT 16	1.29	1.29	1.31	1.14	1.18
SUBJECT 17	1.17	1.28	1.24	1.10	1.01
SUBJECT 18	1.78	1.87	1.87	1.68	1.58
SUBJECT 19	1.05	0.91	0.87	0.88	0.84
SUBJECT 20	0.51	0.59	0.48	0.53	0.36

APPENDIX G

Ground Contact Time Performance Testing Data

	MAX_JUMP_HT_CALC_AVG12_MEAN (cm)	MAX_JUMP_HT_CALC_AVG18_MEAN (cm)	MAX_JUMP_HT_CALC_AVG24_MEAN (cm)	MAX_JUMP_HT_CALC_AVG30_MEAN (cm)	MAX_JUMP_HT_CALC_AVG36_MEAN (cm)
SUBJECT 01	0.35	0.38	0.31	0.35	0.31
SUBJECT 02	0.62	0.63	0.60	0.60	0.58
SUBJECT 03	0.73	0.74	0.74	0.71	0.66
SUBJECT 04	0.58	0.60	0.60	0.61	0.61
SUBJECT 05	0.47	0.49	0.49	0.52	0.56
SUBJECT 06	0.50	0.47	0.51	0.49	0.48
SUBJECT 07	0.56	0.57	0.55	0.58	0.49
SUBJECT 08	0.54	0.52	0.55	0.57	0.57
SUBJECT 09	0.46	0.50	0.50	0.50	0.51
SUBJECT 10	0.60	0.62	0.60	0.59	0.45
SUBJECT 11	0.58	0.60	0.57	0.58	0.55
SUBJECT 12	0.38	0.39	0.40	0.41	0.39
SUBJECT 13	0.58	0.58	0.59	0.56	0.60
SUBJECT 14	0.41	0.40	0.42	0.37	0.38
SUBJECT 15	0.36	0.37	0.33	0.37	0.35
SUBJECT 16	0.50	0.52	0.51	0.51	0.51
SUBJECT 17	0.41	0.39	0.36	0.34	0.36
SUBJECT 18	0.52	0.54	0.56	0.52	0.56
SUBJECT 19	0.46	0.44	0.45	0.45	0.44
SUBJECT 20	0.25	0.27	0.25	0.28	0.21