The effects of differing drop heights on maximum vertical jump performance in Division II women's basketball players

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FINAL APPROVAL OF SCHOLARLY PROJECT
Master of Science in Biomedical Sciences
Concentration in Physical Therapy

Optimal Height for Lower Extremity Depth Jumping

Submitted by

Joseph Fisher

In partial fulfillment of the requirements for the degree of Master of Science in Biomedical Sciences

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Date of Presentation: June 22, 2004

Date of Approval: 12-14-04
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November 4, 2004

Conducted in Cooperation with
Medical College of Ohio
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Toledo, OH 43614

To meet the requirements of
Master of Science in Biomedical Sciences with a concentration in
Physical Therapy

Advisors: Reid Elam, Ph.D, P.T.
Dan Cipriani, Ph.D, P.T.

ACKNOWLEDGEMENTS
I would like to thank Reid Elam for his assistance with the development of this research study. I would also like to thank Dan Cipriani for his time and guidance that he generously offered for the completion of this article.
ABSTRACT

This study was done to determine the differences in maximum vertical jump performances following a drop from the set heights of 0, 45, and 75cm. Data for each subject was collected following a maximum vertical jump effort at each height, which was preceded by a single trial jump. Data were analyzed with a one-way repeated measures ANOVA followed by planned simple contrasts and a post hoc pairwise comparison using SPSS with p <.05. Subjects (N=14) involved in this study were volunteer participants from a Division II women’s basketball team. Subjects performed the 0cm jump prior to the randomly ordered subsequent drop jumps from 45cm and 75cm heights. The differing drop heights resulted in significant differences in maximum vertical jump between the 0 & 45cm drops and the 0 & 75cm drops. There were no significant differences between the 45 & 75cm drop heights. These results indicate that a higher maximum vertical jump can be achieved following a greater eccentric load than that produced from a countermovement (0cm).
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INTRODUCTION

Today, many training methods are used to enhance sport performance of athletes at every experience level. Plyometrics, one of these utilized methods, involves an eccentric overload to muscles for a large force production over a short period of time. In this study, as well as others frequently found in the literature, a drop jump and a counter-movement jump are the modes of plyometric testing or training for lower extremity muscle function. These jumps involve a passive downward displacement of body mass from a predetermined height followed by a change in direction in the form of a maximum vertical jump upon ground contact. Negative work, the eccentric phase beginning at initial contact, involves an elongation of the active lower extremity musculature to decelerate the downward displacing center of mass. Positive work, the concentric contraction, involves the anti-gravity musculature displacing the center of mass upward to produce the maximum vertical jump (13).

Prospective Benefits to Athletes

Wilson and Murphy (15) compared plyometric and weight training effects on concentric and eccentric force production. Using the drop jump, the authors assessed the magnitude and rate of developed lower extremity muscular force preceding and following an 8-week training period. Findings included that even though concentric muscle function was not enhanced, the rate of force development and vertical jump height were significantly increased from the control sample. The authors concluded that drop jump plyometric training would be appropriate for jumping sports that have this eccentric component due to these benefits.

With the high incidence of ACL tears and the jumping or cutting mode of injury, there
has been positive research supporting the use of plyometric jump training for its preventative benefits of ACL injury when incorporated into a female athlete’s workout. In a study by Baratta et al. (2), it was concluded that coactivation of the hamstrings and quadriceps muscles plays a major role in the stabilizing the knee for the prevention of ligament injury. The hamstrings act as the compressive force to distribute equal pressure of the articular surface and restrain the anterior translation of the tibia in relation to the femur, reducing the risk of injury in the athletic population (2,6). Therefore, it was concluded that athletes susceptible to injury secondary to imbalances in the hamstrings-to-quadriceps ratio would benefit from hamstring strengthening to decrease risk.

Hewett et al. (6) followed by conducting a study for the effects of a plyometric jump training program on hamstring torque and landing forces of eleven female high school volleyball players compared to a control male sample. Prior to training, the female group exhibited a significant less hamstring-to-quadriceps ratio compared to the male group. Following the 6-week plyometric program, the females increased hamstring peak muscle torque and brought the ratio to an equivalent value to that of the male group. The authors reported that ten of the eleven females tested effectively decreased landing forces following the program. The benefits of decreased landing forces correlates with decreased forces exerted on the lower extremity joints, suggesting the decrease in incidence of injury. In addition, subjects decreased adduction and abduction moments at the knee by 50% at landing when pre- and post-program comparisons were made.

With the increased participation of females in athletics and a significantly higher proportion of females suffering knee injuries than males, it is viable to use plyometrics for enhancement of neuromuscular properties for injury prevention. Hewett et al. (7) did a prospective study of female high school athletes involved in jumping or cutting sports. A neuromuscular training program incorporating weight training, plyometric jump training, and flexibility training was prescribed to 15 teams of athletes that represented the trained group. Representing the untrained group, 15 teams refused to incorporate this
program into preseason sport training. Each team member was monitored through the entire season to determine the effects of the neuromuscular training on the prevention of knee injuries. Results that were produced from this study revealed that the incidence of serious knee injury for the untrained group was 2.4 - 3.6 times higher than trained female athletes.

With the increase of female involvement in competitive sports, the demand for research outlining the most effective training for performance enhancement is growing. Upon review of the available studies pertaining to plyometric training, a large gap is revealed for research which focuses on the female athlete. With a higher female incidence of ACL injury than males due to reported factors such as hamstrings-to-quadriceps imbalances, estrogen levels, and anatomical Q-angle differences, research is needed for safe training techniques to enhance and optimize sport performance. A need has been established for the optimal drop height for female athletes that balances the gains of training and the risks of injury. Therefore, using drop jumps as the mode of plyometric activity, the aim of this study was to determine the effects of differing drop heights on the resulting maximum vertical jump of fourteen Division II women’s basketball players.

**METHODS**

Fourteen women’s basketball players from a Division II college volunteered to be the subjects for this study. In this study, drop jumps were used as the form of plyometric activity to define the enhancement of force production as a maximum vertical jump. Each subject signed an informed consent sheet, which was approved by the Institutional Review Board. Exclusion criteria for subject involvement was 1) if a current lower extremity condition existed, 2) current spine injuries or conditions existed, and 3) if a past medical history of any of the afore mentioned occurred in the last six months that would limit participation. Age, height, and weight were recorded for each subject prior to testing.
A Sony VHS recorder with a tripod was set at 30 feet from the jumping area to measure the vertical jump of each subject (1). A 16-pound shot put was dropped from one meter to define temporal reference. Time was calculated to correspond to the camera speed of 32 frames/second. Spatial references were calibrated from an individual holding a meter stick in the jumping area.

Testing took place in one day. Subjects were placed on a stationary bike for a five minute warm-up, followed by 10 minutes of stretching. Subjects were educated on the technique of dropping from the platform at a set height, landing, and then perform a maximum vertical jump. A single trial jump at each height of 0, 45, and 75cm drops was performed.

The first jump of each subject was at 0cm with the instruction of attaining maximum vertical height. The remaining two jumps were then randomly assigned for order by a coin flip. The “heads” coin flip represented the 45cm drop jump to be first, and a “tails” was for the 75 cm drop jump to be first. Data was then analyzed following collection from the video.

The null hypothesis for the study was stated that there will be no significant difference in the maximum vertical jump performance between the 0, 45, and 75 cm drop heights. The alternate hypothesis was stated that there will be a significant difference of maximum vertical jump performance from the heights of 0, 45, and 75 cm drops.

**Statistical Analysis**

For each subject, height and weight measurements were converted into the metric variables of centimeters (cm) and kilograms (kg) to determine BMI (kg/m²). The variables of height, weight, and BMI were tested as covariates on the effects of drop jump height using a repeated measures ANCOVA. A one-way repeated measures ANOVA was used to determine a possible difference occurring between 0, 45, and 75 cm drop heights on maximum vertical jump. Planned simple contrasts were run to compare drop heights of 0cm with 45cm and 0cm with 75cm. A post hoc pairwise comparison was run to determine differences that may have existed between 45cm with 75cm. All data
were analyzed using SPSS with significance set at $p < .05$.

RESULTS

A total of 14 female subjects with the average age of 20.43 (sd = 1.22) years participated in this study. Table 1 provides the relevant data pertaining to each subject.

Table 1

<table>
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<th>WT(LB.)</th>
<th>O(CM)</th>
<th>45(CM)</th>
<th>75(CM)</th>
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<th>GAIN 75</th>
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Mean (Standard Deviation) 20.43 (1.22) 68.71 (3.17) 146.00 (15.24) 7.76 (0.55) 11.76 (0.81) 11.62 (0.95) 4.00 (0.62) 3.86 (0.67)

The variables of height, weight, and BMI were not significant in affecting the maximum vertical jump performance outcomes from differing drop heights. The one-way repeated measures ANOVA revealed a significant difference ($p < .05$) across drop jumps of 0, 45, and 75cm on the resulting maximum vertical jump height among subjects. From the planned simple contrasts, significant differences ($p < .05$) were produced between the 0cm and 45cm drop heights, as with the compared 0cm and 75cm drop heights. No significant difference ($p > .05$) was revealed following assessment of the 45cm drop
height with the 75cm drop height using the post hoc pairwise comparison.

*Figure 1*

The effects of different drop heights on maximum vertical

<table>
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<tr>
<th>Maximum height</th>
<th>0cm</th>
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</table>

* 0cm significantly less than 45cm and 75cm drop heights at p < .05

**DISCUSSION**

In review of available research, most authors recognize that the concentric contraction following an eccentric pre-stretch load produces a greater force than solely a concentric contraction. The mechanisms underlying the increased force production are controversial in the literature, yet they must be discussed for a better understanding of outcomes. The significant increase of resulting vertical jump height produced by subjects in the trials of 45cm and 75cm drops compared to 0cm can be explained by the different mechanisms of muscle function during the plyometric activity.

First, the passive stretch experienced by the musculotendinous tissues enables the storage of elastic strain energy as potential energy for release during the subsequent
concentric contraction (3,12,13,14,15). The elastic strain energy increases with the increased intensity of the drop, resulting in its utilization as recoil energy for increased force production. The increased force results in the elevated maximum vertical jump performance.

Second, every muscle contains spindles responsible for monitoring the amount of stretch tension placed on a muscle. This safety mechanism that causes a reflexive contraction allows the muscles to maintain an appropriate length-tension relationship while adding to the elastic strain energy within the tendon fibers for future recoil (3,15). The suitable length that is maintained within the muscle allows for optimal cross-bridging of the myosin heads with the actin filaments. As the intensity of the drop increases, there is an increase in tendinous tissue stretch which relates to the increase in force production for maximum vertical jump in this study (9).

Third, considering the use of skilled collegiate athletes for subjects in this study, the adaptations that follow plyometric activity should be discussed. The muscle components opposing the golgi tendon organ are believed to undergo a greater stretch due to the desensitization of the GTO following plyometric training (4). This, coupled with the other neural adaptations, allow for increased force production on subsequent vertical jumps. In addition, the recruitment of muscle activation in a vertical jump has shown differences in achieved height between the experienced and inexperienced athlete. The experienced athlete presents with a more proximal-to-distal coordination of muscle activation to enhance the transfer of energy for linear translation (13,14). A co-activation of mono-articular and bi-articular muscles allows for a harnessing of rotational energies to be transferred as a linear translation from the ground reaction force at push-off in the maximum vertical jump.
Where as the 45cm and 75cm drop heights of the subjects produced significantly higher vertical jumps when compared to the 0cm height, the 45cm compared to 75cm heights were not significant. To account for this lacking difference, a study by Ishikawa and Komi (9) describes the effects of different dropping intensities on fascicle and tendon tissues of individuals. Comparable to the 30cm increase between the two jumps, the authors found that a maximum drop intensity before rebound did not produce an increased lengthening of tendinous tissues followed by an increased shortening of these tissues during ground contact of a drop jump. They concluded that protective inhibition of muscle activation occurred when the drop height was too high for the individual. In addition, the authors explain that too high of a drop height corresponding to an exceeding force for the individual results in the detachment of the actin-myosin cross bridges. Related to the current study, these conditions may have been present with the observed lower mean vertical jump height of the subjects resulting from the 75 cm drop. This suggests that the 30cm drop difference was, on average, beginning to exceed height for optimal muscle function for maximum vertical jump.

**Clinical Relevance**

With over 2.8 million females involved in high school sports (10) and the addition of 79 NCAA women’s teams since 1990 (11), it is evident that the trend of female participation in competitive sports is on the incline. For this reason, a greater importance must be placed on the treatment and prevention of associated injuries sustained from competition, as well as the enhancement of athletic performance to excel in sport activities. Hewett et al. (6) produced evidence supporting the use of plyometrics for the female athlete, showing significant decreases in adduction/abduction moments at the knee, decreased landing forces, decreased incidence of ACL injuries, and increased hamstrings-to-quadriceps ratio. Recognizing the physiological and anatomical differences that exist between males and females, it is important that an optimal range of drop heights be recognized for safe and effective training and treatment programs. From the results of the current study, the drop heights of 45 and 75cm did not produce significant differences.
According to the data, a 45cm drop would be just as effective for athletic enhancement and injury prevention without submitting the athlete to higher compressive loads at the knee upon landing.

The significance of this research study is that it pertains to sport-specific training for the female athlete. Sports such as volleyball and basketball involve maximal vertical jump efforts that are preceded by eccentric loading phases. Training with the use of an optimal drop height will offer maximum power production, which can be associated with effective sport performance. A study by Gehri et al. (5) compared different plyometric jump training methods for improving vertical jump and positive energy production following a 12-week program. The authors concluded that drop jump training most closely related sport-specific activities, resulting in improved vertical jump height and muscle contractile performance.

CONCLUSION
This study was performed on women collegiate athletes with previous jump and strength training. The results of the study suggest that an increase in drop height above the countermovement jump of 0cm will produce an increase in resulting maximum vertical jump. The data suggests that an inhibition of muscle activity began to occur at the 75cm height when compared to 45cm, revealing a decrease in the mean maximum vertical jump at the higher intensity. Due to physiological and anatomical gender differences, there is a need for further research in this area of plyometrics to better define the optimal drop height for injury prevention and sport enhancement training.

REFERENCES


