2014-12-01

Ground Forces Impact on Release of Rotational Shot Put Technique

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A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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December 2014

ABSTRACT

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In the shot put throw, the primary power is generated in the form of ground reaction forces as a result of action of the lower extremities (Coh, Stuhec, & Supej, 2008). The purpose of this study was to determine how the ground reaction force and ground contact time during the delivery phase of rotational shot put relates to the predicted distance of the throw. This will allow us to determine the optimal approach of force application for maximum throwing distance (Linthorne, 2001). Eight male subjects were used in this study (age 23 ± 4 y; body mass 123 ± 14 kg; height 190 ± 4 cm; all right handed). Subjects threw three attempts in a custom-built shot put ring where two force plates were located where both feet were expected to land in the delivery. The throws were also filmed using two high-speed cameras at 120 frames/s. These videos gave us the speed, angle and height of release for predicting distance thrown. Results: Peak right leg force during delivery was correlated with throwing distance ($R^2 = 0.450$, $p = 0.001$). Also, left leg ground time was significant with predicted throwing distance ($R^2 = 0.516$, $p < 0.001$). Because increased strength leads to greater throwing distances (Zaras et al., 2013) and peak right leg force was significant, it would be useful to perform proper strength training exercises that can increase a thrower's ability to increase the peak ground forces during a throw. If the thrower can produce greater peak force into the ground with the right leg during the delivery phase, this should cause the thrower to come off their left leg sooner, resulting in greater speed of release and thus distance thrown.

Keywords: shot put, forces, release

ACKNOWLEDGMENTS

I would like to thank and acknowledge my committee chair, Dr. Iain Hunter, for the mentoring and guidance he has given me through the last five years. He has shown great patience during my time working with him allowing me to work full-time as a coach and compete professionally in track and field. Dr. Hunter has become a lifetime friend to myself and my family. Additionally, my committee, Dr. Philip Allsen and Dr. Allen Parcell, have always given me insightful ideas and recommendations that I truly appreciate. I love their ability to take knowledge from their specific areas of expertise and apply it to my research. I would like to thank my wife who has been so supportive throughout my time in graduate school. Also, my parents need to be recognized for instilling in me a desire to obtain a post-bachelor's degree and the importance of education.

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Introduction

The four components of throwing a shot put that contribute to the overall distance are release angle, height, velocity, and horizontal starting position of the shot at release. Of these four components, release velocity has the greatest impact on the distance thrown. Increasing the velocity lengthens flight time and increases the horizontal velocity (Hubbard, deMestre, & Scott, 2001; Young, 2004; Frohlich, 1981).

Ground reaction forces must be optimized in order to maximize release velocity. Release velocity greatly overshadows any other consideration of the distance (Frohlich 1981). Even though the velocity of release is so important, the ground forces that help produce this release velocity still have a large impact on the distance thrown (Coh, Stuhec, & Supej, 2008).

In the shot put event there are two different techniques used to compete. The traditional glide technique, used since the late 1950's, and the rotational technique which borrowed a spinning movement from the discus throw and applied it to the shot put. During the last 20 y, the rotational shot put technique has been used by most elite male shot putters. Despite the small amount of research on ground forces in the rotational shot put, only a few studies have shown the differences between the rotational and glide techniques (Bartonietz, 1994a, 1994b; Bosen 1985). The maximum ground reaction forces in the rotational technique are larger than the glide technique but directed steeper (Bartonietz, 1994a). This means that athletes using the rotational technique attain their maximum ground reaction force in a shorter amount of time compared to athletes using the glide technique. Only a few of these studies have captured the ground forces in elite shot putters. Of those studies, none has been done on multiple shot putters ranging from amateur level to elite level athletes (Coh, Stuhec, 2005). The primary power is generated in the form of ground reaction forces as a result of the action of the lower extremities (Coh, Stuhec, &

Supej, 2008). Bartonietz (1994a) showed that one of the difficulties of the rotational technique is to produce accelerating power output from the right leg during the delivery phase. This portion of the throw starts when the right leg touches the ground in the middle of the throw until the shot has been released (Linthorne, 2001). Because most successful male shot putters use the rotational technique, this will be the focus of this study.

The rotational technique displays tendency of a long–short timing of phases, which means that of the entire throw, the delivery takes a proportionally short time (Figure 1). Data from Bartonietz (1994b) suggests that athletes using the glide technique spend 56% of their total throwing time in the delivery phase as opposed to athletes using the rotational technique who spend 41% of their total throwing time in the delivery phase. This shorter delivery-phase time gives the vertical component of the ground reaction forces greater importance compared to the glide technique because it must be obtained in a shorter amount of time. That study (Bartonietz, 1994a), however, only discussed the ground reaction forces in the vertical or Y direction. Our study included the X and Z directions along with Y.

For our study, we also looked at the horizontal components of force along with the vertical components. The ideal forces in these directions have not been analyzed previous to this study. If we understand what forces seem to be created by elite throwers compared to amateur throwers, we can possibly either change training exercises or technique in order to optimize these forces.

The purpose of this study was to determine how the ground reaction force direction, time and peak magnitude during the delivery phase of rotational shot put among selected male shot putters relates to the predicted distance of the throw. This allowed us to determine the optimal approach of force application for maximum throwing distance (Linthorne, 2001).

Methods

Subjects

Eight male subjects (see Table 2) were used in this study (age 23 ± 4 years; body mass 123 ± 14 kg; height 190 ± 4cm). These athletes were either attending a university or competing professionally at the time of data collection. In order to qualify for the study subjects had to have a personal record farther than 15 m and must have been using the rotational shot put technique. We wanted a range of subjects from elite to novice so that we could better understand what ground reaction forces elite athletes have compared to novice athletes. This project was approved by the Brigham Young University Institutional Review Board for Human Subjects.

Each subject was informed of the possible risks and hazards of participating in this study prior to giving their written consent to participate. All subjects self-reported their height, and their weight was measured on the force plates. The subjects were allowed to warm-up like they would for any other practice.

Testing Procedures

All subjects in the group threw at least three trials that would have been considered legal throws in a competition (such as staying in the ring and not fouling). The throws were filmed using two Casio FH100 high-speed cameras at 120 frames/s. The cameras were positioned to the side of the thrower with 45° between them. These videos gave us the speed, angle and height of release following digitizing in Vicon Motus 9.2 (Colorado Springs, CO). The digitized points were filtered with a Butterworth low-pass filter at 6 Hz. A Vicon calibration structure was used to calibrate the area around the shot release. This information was used to determine the predicted distance of each throw. The shot put ring and toe board are of regulation size (Figure 2).

Subjects performed the throws like they would in an official track meet, meaning they had to stay in the circle without fouling (touching outside the circle until the throw is complete). The athletes completed at least three throws without fouling out of a total of 30 maximal attempts if needed. They were allowed to recover physically as much as they felt they needed before the next attempt.

Subjects threw in a custom-built shot put ring where two AMTI force plates (OR-6, Watertown, MA, USA) were used for collecting ground reaction force data at 960 Hz. They were located where both feet were expected to land in the delivery.

Time of foot contact during the delivery phase and the angle of the resultant force relative to the horizontal plane at the time of peak force were recorded with a threshold of 20 N.

Data Analysis

A forward selection linear regression was used to correlate ground reaction force data (impulse and time of contact on plate) with predicted distance thrown (using release velocity, angle and height from the eight frames before and after release digitized by Vicon Motus). The parameters we tested were left leg time on plate, right leg time on plate, flight time between right and left leg touchdown, impulse and peak forces of left and right legs, and throwing direction impulse of left and right legs.

Results

Peak right leg force during delivery was correlated with throwing distance ($R^2 = 0.450$, $p = 0.001$, Figure 3). However, peak left leg force was not quite significant ($p = 0.085$). A second regression looked at the timing of events, including right and left foot time on the ground and flight time (the time between right foot contact with the force plate and left foot time on the force plate), found only left leg ground time significant with predicted throwing distance ($R^2 = 0.516$, $p < 0.001$, Figure 4).

Discussion

Higher peak forces of the legs were expected to correlate with predicted distance thrown. In our study, however, the right leg was the only leg that was a significant predictor. A positive trend fell short of significance for left leg peak force with distance thrown. While peak force from the right leg was correlated with throwing distance, without force plate data from the pre-delivery phase of the throw, we could not determine if the peak right leg force correlation may be influenced by technique earlier in the throw.

During the delivery phase, we believe the right leg peak force must be of greater importance than the left leg peak force because it seems to be the leg out of the two that produced force in the direction of delivery at some point during touchdown. Because of the momentum the thrower has from the pre-delivery phase in the direction of the throw along with the right leg force in delivery, the left leg's primary purpose appears to be producing an opposite force in order to help the athlete stay within the ring. We believe the peak right leg correlation was better than the left leg correlation because of this reason.

Even though right foot contact time and flight time were good predictors of estimated distance thrown, left foot contact time was the other parameter we tested that was a significant predictor. McCoy, Gregor, Whiting and Rich (1984) stated that elite shot putters are often off the ground at release. The explosive lifting of the body out of the delivery position contributes to the shot's vertical velocity during the delivery phase. The possible detrimental effect of being off the ground at release is more than adequately compensated for by the explosive lifting prior to release. In their study, 66% of the athletes had their left foot off the ground prior to release

(McCoy et al., 1984). We don't believe a thrower would purposely try to take the left leg off the ground as fast as possible, but a better thrower transfers the force to the implement faster by quickly applying vertical forces against the ground causing the left foot to come off the ground faster.

Even though our study showed two parameters that were significant with throwing distance compared to other parameters we tested, the correlations are still quite weak. Potentially some of the nonsignificant factors could be correlated with performance. Future studies with a greater number of subjects could determine if this is the case. Because peak right leg force was significant, it would be useful to perform proper strength training exercises that can increase a thrower's ability to increase peak ground forces during a throw. Increased strength leads to greater throwing distances (Zaras et al., 2013). Our study shows the importance of the lower body in producing forces related to improved shot performance.

Conclusion

Realizing that right leg peak force and left leg ground time were correlated with performance, we believe the optimal approach of a rotational shot putter to be: If the thrower can produce greater peak force into the ground with the right leg during the delivery phase, this should cause that ground force to transfer up the thrower/implement system and if this force is applied rapidly, the thrower will come off their left leg sooner resulting in greater speed of release and thus distance thrown.

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Table 1. The mean of our measured ground force data along with standard deviation

Measured Characteristics	Mean	SD
Predicted Distance Thrown (m)	16.11	2.11
Left time (s)	0.25	0.11
Right time (s)	0.44	0.05
Flight time (s)	0.22	0.03
Impulse Left (Ns)	245.9	102.6
Impulse Right (Ns)	513.6	221.8
Peak Force Left (N)	1572.9	836.1
Peak Force Right (N)	1475.4	681.2
Peak Force Left (BW)	1.28	0.38
Peak Force Right (BW)	1.14	0.58
Throwing Direction Impulse Left (deg)	-59.33	36.95
Throwing Direction Impulse Right (deg)	-21.31	53.20

Table 2. Subject Demographics

Subject	Mass (kg)	Height (m)	Age (y)
1	126	1.92	29
2	111	1.83	23
3	133	1.96	18
4	104	1.88	21
5	120	1.91	25
6	114	1.91	21
7	139	1.93	22
8	141	1.91	27

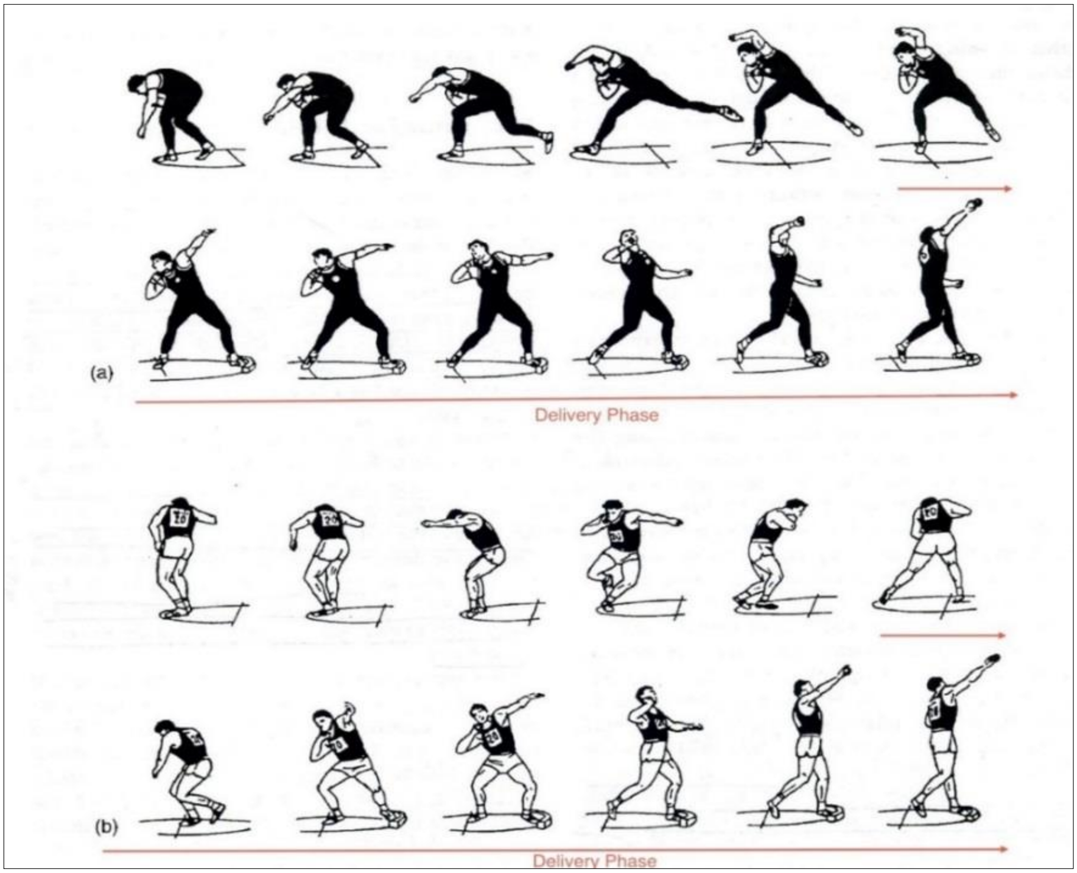

Figure 1. Illustration of the different time of the delivery phase between the glide and rotational shot put techniques

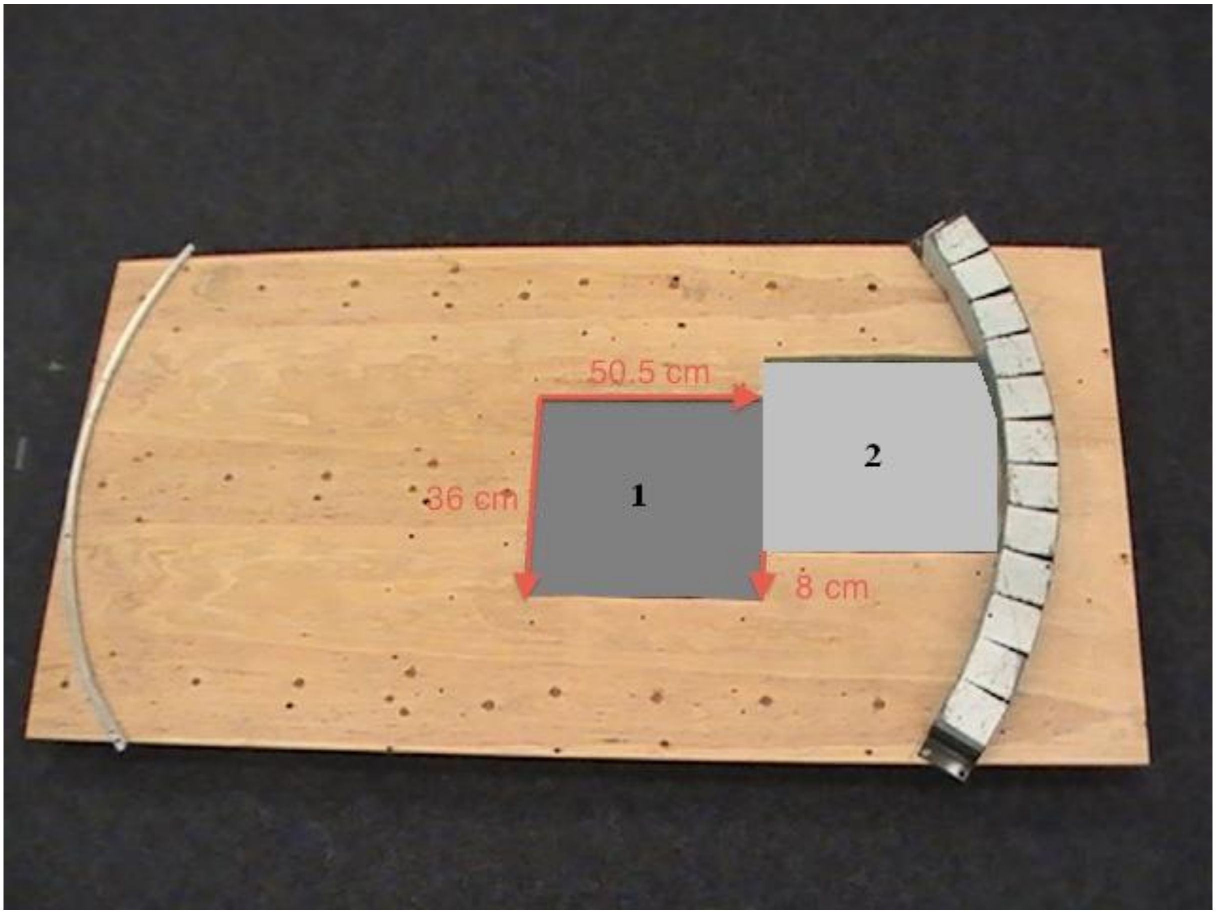

Figure 2. Lay out of the shot put ring and the placement of the two force plates.

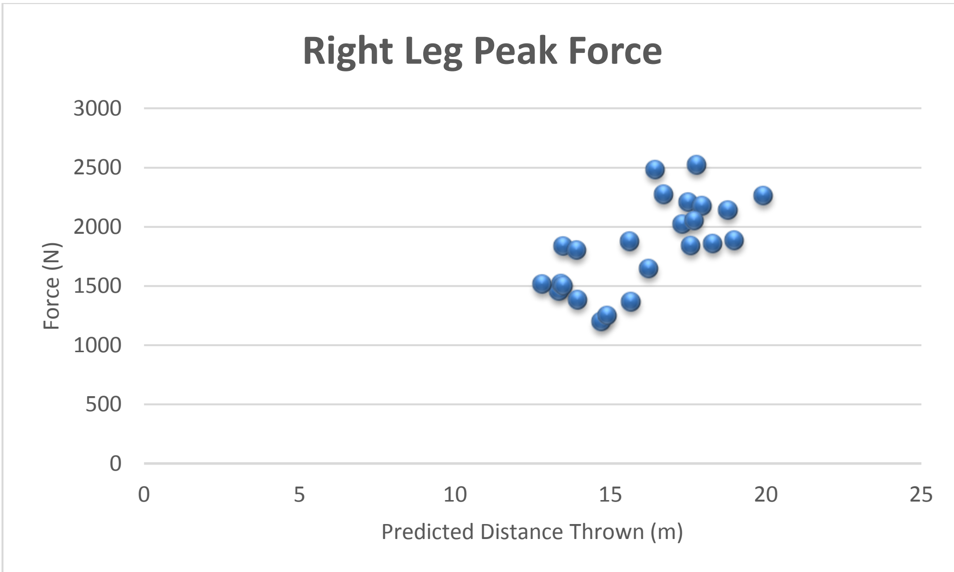

Figure 3. Graph of Peak Right Leg Force with Distance Thrown

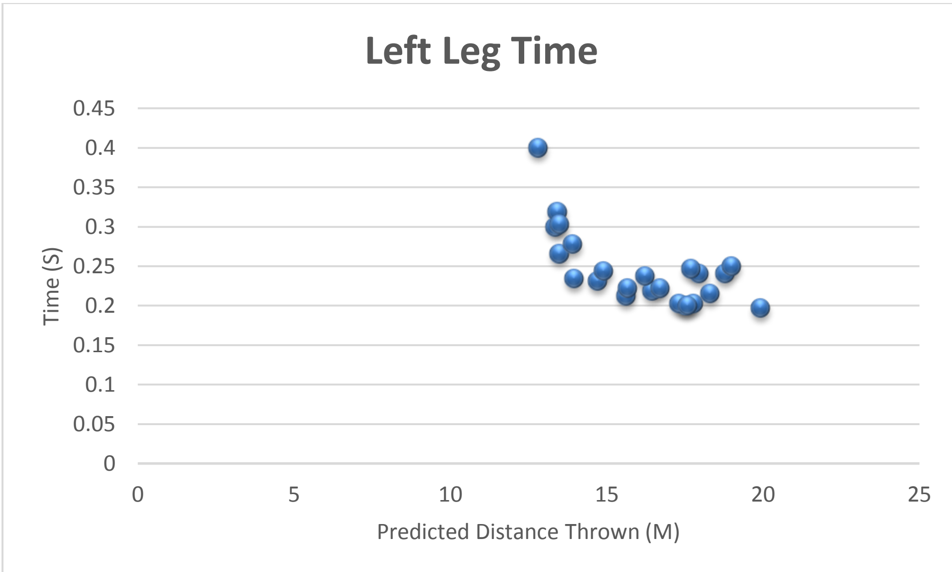

Figure 4. Graph of Left Leg Time on Force Plate with Distance Thrown

Appendix: Subjects

Subjects and Distance Thrown

Subject	Distance (m)
1	16.46
1	16.72
1	17.79
2	17.52
2	17.96
2	19.93
3	17.32
3	17.60
3	18.31
4	13.96
4	14.72
4	14.91
5	17.71
5	18.79
5	19.00
6	15.63
6	15.67
6	16.24
7	13.36
7	13.43
7	13.49
8	12.82
8	13.49
8	13.92