AN INVESTIGATION INTO THE RELEASE FACTOR EFFECTS OF HAMMER THROW

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This study aimed to determine the relationship of release factors on the final hammer throw distance of American throwers as well to determine where differences in release factors between the years and throw distance groups (TDG). The video from 94 hammer throws (52 female throws and 42 male throws) were analysed using 2-D to 3-D coordinates via DLT procedures. Analysis of the release factors of a throw revealed correlations with release velocity but not height and angle. Further analysis revealed that release height has decreased while vertical velocity and release angle have increased since 2016.

KEYWORDS: hammer throw, technique changes, comparison

INTRODUCTION: The ability of a hammer thrower to achieve the distance thrown is based upon the positions the thrower utilizes. Traditionally, the greatest distances are achieved through the optimal use of projectile-based release factors. Release factors include release velocity, release angle, and release height. The importance of release factors has been cited in sports science literature (Konz, 2006; Konz & Hunter, 2015; Leigh, Gross, Li, & Yu, 2008; Linthorne, 2001; Young & Li, 2005). The distance thrown is affected by athlete strength, athlete anthropometrics, and technique (Konz, 2006).

Athlete and coach attitude towards the optimal use of critical release factors continues to evolve as athletes become faster, stronger, and larger. Training protocols are adjusted to focus on the critical factors deemed the most important by the coach and athlete. Hammer throw research has not investigated how release factor outcomes and hammer throw technique change over time as athletes evolve. Specifically, no research has investigated when changes to the release factors occurred and which of these factors is the focus of training as athletes evolve. This study investigated 1) the differences in release variables of American hammer throwers between throw distance groups and sex; and 2) the differences (changes) in release variables over time of American hammer throwers. The goal was to determine when technique changes to provide insight into the current technique and the effectiveness of training methods used by American throwers.

METHODS: The video from 94 hammer throws (52 female throws and 42 male throws) were analyzed. The footage was captured at the 2016-2019 USA Track and Field Olympic Trials and USA Track and Field National Championships. Two high-speed cameras (Sony, Tokyo, Japan) capturing at 59.94 fps were used to record every throw. One camera was placed on the right side of the capture volume, and one camera was placed behind the capture volume. A calibration frame was used to calibrate the high-speed camera positions and orientations in reference to the capture volume. The calibration frame consisted of four poles with nine points on each pole, with a total of 36 points. Each point on the pole was a known 0.305 meters apart. A rectangle was formed around the activity area of interest. The video with the poles around the capture volume was collected.

The calibration video and the selected throwing videos were imported and trimmed in the Contemplas Templo software (Contemplas, Kempten, Germany). For the calibration videos, two frames with no movement or view obstructions were trimmed. For the throwing trials, the start of the trials was 7 frames before the subjects lifted the foot for take-off in turn 1 and ended five frames after the hammer left the subject's hand. Trimmed videos were uploaded into the Vicon Motus manual digitizing software (Vicon, Oxford, UK). The nine points on all four poles were digitized in order, starting with the bottom point of pole 1 moving up until all 9 points on the pole were selected. The trimmed video from the side and back view was digitized using Vicon Motus. Twenty-four anatomical landmarks on the subject were digitized for each trial. The twenty-four

landmarks included the top of the head (vertex), the chin, the suprasternal notch, the right shoulder, the left shoulder, the right elbow, the left elbow, the right wrist, the left wrist, the right middle knuckle, the left middle knuckle, the right hip, the left hip, the sacrum, the right knee, the left knee, the right ankle, the left ankle, the right heel, the left heel, the right middle toe, the left middle toe, the handle, and the ball. For any landmark that was obstructed in a frame, the best estimate of the location of the landmark was digitized. The 2D coordinates were synchronized through a critical instant, hammer release. The identification process was done qualitatively by watching the recorded video.
Using the calibration points from the four poles, the direct linear transformation (DLT) procedure was used to obtain real-life three-dimensional (3D) coordinates of the global reference markers, anatomical body landmarks, and the center of the hammer from the 2D coordinates. Once the 3D coordinates were calculated and smoothed, landmark coordinates, segment angles, segment angular velocities, segment angular accelerations, segment lengths, segment centers of mass (COM) coordinates, and segment COM accelerations were obtained using MotionSoft software. For statistical analyses, SPSS version 22 was used (IBM, Chicago, IL). A bivariate correlation was computed to determine if the traditional associations between the release factors and the distance thrown are present. 1-way ANOVAs determined the differences between the release factors and TDG, year thrown, and gender to understand when changes or differences in throwing technique occurred. Significance was set at the .05 level. Throw distance groupings (TDG) were delineated as follows: 75m & above, 70-74.99m, 65-69.99m, and below 65m. Results were reported as a collective and separated by TDG, year, and gender.

RESULTS: The means and standard deviations for the variables of interests are found in Table 1 and Table 2.

Table 1. Critical factors means and standard deviations of release by throw group.

	75m plus	**70-74.99m**	**65-69.99**	**below 64.99**
Resultant release velocity (m/s)	29.02 ± 1.59	27.31 ± 2.02	26.61 ± 1.43	26.51 ± 1.65
Horiz. release velocity (m/s)	22.27 ± 1.60	21.06 ± 2.79	20.75 ± 1.93	19.88 ± 0.91
Vert. release velocity (m/s)	18.52 ± 1.86	17.11 ± 2.56	16.32 ± 2.23	15.07 ± 2.95
Release angle (deg)	39.73 ± 3.75	39.21± 6.70	38.16 ± 5.25	40.07 ± 1.98
Release height (m)	1.03 ± 0.26	1.16 ± 0.37	1.15 ± 0.26	1.05 ± 0.18
Lat. release velocity (m/s)	5.86 ± 6.61	- 0.27 ± 10.52	0.63 ± 7.66	-4.71 ± 3.04

Note: Total n = 94; 75m n = 19; 70-74m n = 36; 65-69.99m n = 31; below 64m n = 8

Table 2. Critical factors of release means and standard deviations by year.

	2019	**2018**	**2017**	**2016**	**All**
Resultant release velocity (m/s)	27.65 ± 1.74	27.20 ± 1.70	26.61 ± 1.43	27.29 ± 3.01	27.28 ± 1.98
Horiz. release velocity (m/s)	20.83 ± 1.57	20.15 ± 2.44	21.32 ± 1.75	22.58 ± 3.16	21.10 ± 2.27
Vert. release velocity (m/s)	18.16 ± 1.24	18.10 ± 1.83	15.79 ± 1.91	15.02 ± 3.03	17.10 ± 2.32
Release angle (deg)	41.10 ± 2.05	42.06 ± 5.35	36.54 ± 4.65	33.69 ± 6.53	39.04 ± 5.41
Release height (m)	1.08 ± 0.15	1.10 ± 0.29	0.99 ± 0.39	1.38 ± 0.34	1.12 ± 0.30
Lat. release velocity (m/s)	-3.90 ± 4.50	- 5.31 ± 7.00	5.08 ± 14.67	1.11 ± 2.75	-1.48 ± 8.75
Forward release velocity (m/s)	19.99 ± 1.35	18.21 ± 2.42	11.95 ± 9.46	22.37 ± 3.34	18.42 ± 5.80

Note: Total n = 94; 2019 n = 38; 2018 n = 20; 2017 n = 19; 2016 n = 17

Correlation analysis indicated relationships among variables exist; however, the correlations were at the moderate to low end of the scale. Correlation of the release factors to official throw distance for all throws (n=94) indicated that the resultant release velocity (r=.445, p<.000), horizontal release velocity (r=.287, p=.005), and the vertical release velocity (r=.249, p=.016) were correlated. Correlation of the release factors to the sex of the athlete (n=94) indicated that the horizontal release velocity (r=-.330, p=.001), lateral release velocity (r=.371, p=.001), and release angle (r=.320, p=.002) were correlated. Correlation of the release factors to TDG (n=94) indicated that the horizontal release velocity (r=-.280, p=.006), vertical release velocity (r=-.299, p=.003), and resultant release velocity (r=-.476, p=.000) were correlated. Correlation of the release factors to the year thrown (n=94) indicated that the resultant release velocity (r=-.548, p=.000), horizontal release velocity (r=.326, p=.001), vertical release velocity (r=267, p=.009), release angle (r=-.533, p=.000), and release height (r=.244, p=.018) were correlated.

One-way ANOVA determined that resultant release velocity ($F_{1,3}$ = 9.832, p<.001), vertical release velocity ($F_{1,3}$ = 2.957, p=.011), and lateral release velocity ($F_{1,3}$ = 3.964, p<.001) differed among the TDG. Tukey post-hoc indicated that resultant release velocity for throws for the 75m plus distance (29.02±1.59°/sec) were faster than throws at the 70-74.99m (27.31±2.02°/sec, p=.005), 65-69.99m (26.51±1.65°/sec, p<.001), and below 65m (25.99±0.64°/sec, p=.001) distances. Tukey post-hoc determined that vertical release velocity for throws at the 75m plus (-5.86±6.61°/sec) was significantly different from the 65-69.99m (0.63±7.66°/sec, p<.001).Tukey post hoc indicated that lateral release velocity for throws at the 75m plus (18.52±1.86°/sec) was significantly higher than the 65-69.99m (16.32±2.23°/sec, p<.001).

One-way ANOVA determined that horizontal release velocity ($F_{1,3}$ = 4.206, p<.001), vertical release velocity ($F_{1,3}$ = 15.262, p<.001), lateral release velocity ($F_{1,3}$ = 7.65, p<.001), release angle ($F_{1,3}$ = 16.104, p<.001), and release height ($F_{1,3}$ = 6.749, p=.000) significantly differed for the year thrown. Tukey post-hoc testing determined that the horizontal release velocity in 2017 (21.35±1.75m/sec) was significantly faster than the horizontal release velocity in 2019 (20.83±1.57m/sec, p=.034) and 2018 (20.15±2.44m/sec, p=.005); that the vertical release velocity in 2019 (18.16±1.24m/sec) was significantly faster than in 2017 (15.79±1.91m/sec, p<.001) and 2016 (15.02±3.03m/sec, p<.001) and that that the vertical release velocity in 2018 (18.10±1.83 m/sec) was significantly faster than in 2017 (15.79±1.91m/sec, p=.002) and 2016 (15.02±3.03m/sec, p<.001); that 2017 (5.08±14.67m/sec) throws were significantly further to the left of the center of the sector than 2018 (-5.31±7.00m/sec, p<.001) and 2019 (-3.90±4.50m/sec, p<.001); that throw release angle in 2016 (33.69±6.53°) was lower than during 2019 (41.10±2.05°, p=.000), 2018 (42.06±5.35°, p<.001), and 2017(36.54±4.65°, p=.000); and that throw release height was higher in 2016 (1.38±0.34m) than in 2017 (0.99±0.38m, p=.002),2018 (1.10±0.29m, p=.012), and 2019 (1.08±0.15m, p=.002).

One-way ANOVA determined that the vertical release velocity ($F_{1,1}$ =3.924, p=.05), horizontal release velocity ($F_{1,1}$ =11.241, p=.001), release angle ($F_{1,1}$ =10.513, p=.002) lateral release velocity ($F_{1,1}$ =14.675, p=.001) were significantly different between females and males. Females had lower vertical release velocity, greater horizontal release velocity, lower release angles, and a lateral release velocity that placed the hammer further to the right.

DISCUSSION: The release factors of resultant release velocity, horizontal release velocity, and vertical release velocity correlated with the official thrown distance for all throws analyzed but not the other traditionally accepted release factors, release height, and release angle. The release factors of resultant release velocity and horizontal release velocity correlated with the official thrown distance for male throws analyzed but not the other traditionally accepted release factors, release height, and release angle. The release factors of resultant release velocity, horizontal release velocity, and lateral release velocity correlated with the official thrown distance for female throws It is surprising that the traditionally accepted release factors, release height, and release angle did not correlate with official distance. Release height and angle impact maximal range when athletes utilize optimal release parameters (Hubbard, de Mestre, & Scott, 2001).

The analysis to determine the differences in release factors between TDG indicated that resultant release velocity and lateral release velocity were higher in the 75m plus TDG when compared to the other TDG. The higher release velocities are expected in the 75m plus. These high release velocities are typically the result of years of training and experience. The 65-69.99m and the below

65m TDG are populated with less experienced hammer throwers. Greater angular momentum plays a role in the greater lateral release velocity among the TDG. Again, due to higher velocities by the 75m plus TDG generating larger forces, the resulting angular momentum tends to carry the hammer further to the left of the sector center.

The analysis to determine the year in which changes to the release factors occurred indicated that 2018 and 2019 were significantly different from 2016 and 2017. Throws landed further to the left of the center of the sector, and horizontal release velocity increased, vertical release velocity increased, release angles were lower, and release heights were lower. Lateral release velocity in 2017 directed the throw further to the right of the center of the sector than 2018 and 2019. In 2017, horizontal release velocity was significantly faster than in 2018. In contrast, vertical release velocity was slower in 2016 and 2017 by approximately 2-3 m/s when compared to 2018 and 2019. Throw release angle was also lower in 2016 and 2017 than in 2018 and 2019. The changes in release factor utilization indicate that athletes are adopting more strength and power-related strategies to achieve throw distance, forsaking the optimal use of physics principals. Another explanation could be related to the balance of the system as the throw progresses to completion. An athlete who is part of an unbalanced hammer-thrower system will employ countermeasures to keep the throw progressing and legal.

The analysis of the differences between the sexes determined that female hammer throwers had higher lateral release velocities, greater horizontal release velocities, and lower release angles than male throwers. The larger release velocities are likely due to the combination of throw development, athlete strength, athlete power, and the lighter weight of the hammer. The angular momentum of the system developed during the throw is difficult to translate to a linear aspect. athlete not using optimal release factor conditions due to the strength and power of the female athlete. American hammer throwers emphasize strength levels to achieve throw distance. The higher horizontal release velocities generated by female hammer throw athletes decrease the need for optimal release angles to achieve throw distance.

CONCLUSION: Hammer throw athletes are changing training and throw techniques to use the critical release characteristics that allow for optimal use of momentum transfer for that athlete and their training. The changes may be the result of athlete strength and even the athlete attempting to maintain an unbalanced system until throw release. The hammer throw athlete is unable to affect influence on the implement once released. A suggestion for optimizing the release factors to improve the transfer of momentum is made to improve throw distances.

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