OVERWEIGHT AND UNDERWEIGHT IMPLEMENTS' IMPACT ON CRITICAL FACTORS OF ROTATIONAL SHOT-PUTTING TECHNIQUE.

Leah Klein, Justin Whitten, Megan Peach, James Becker

Department of Food Systems, Nutrition, and Kinesiology, Montana State University, Bozeman MT, USA

The purpose of this study was to evaluate the impacts of heavy and light implements on the kinematics of the rotational shot put technique. Ten collegiate shot putters completed three rotational shot put attempts using competition, overweight and underweight implements. Whole body kinematics were recorded on each throw to evaluate key aspects of shot putting technique including pelvis-torso separation, rear leg hip flexion, rear leg knee flexion, and peak pelvis angular velocity during specific phases of the throw. Results of this study highlight that when using an overweight implement, athletes have significantly less hip flexion compared to the competition-weighted implement (52.11° ± 15.47° vs. 31.98° ± 10.62°, p=.0097). No other critical factors of technique showed any significant changes between conditions. These findings support the strategic incorporation of heavy and light implements in rotational shot put training.

KEYWORDS: shotput, overweight implements, underweight implements, kinematics

INTRODUCTION: The shot put is a highly contested event in track and field, with extensive research aimed at evaluating strategies for improving performance. (Lipovsek et al., 2011; Schofield et al., 2022; Judge et al., 2012). Previous studies focus on assessing proper techniques and identifying performance-critical factors, including maximizing shoulder-hip separation angles and angular velocities throughout the throw with specific emphasis on the power position. (Hubbard et al., 2001; Coh et al., 2008; Young et al., 2005). However, few investigations have explored how athletes can incorporate changes in technique through constraints or specific training interventions. One intriguing avenue is the utilization of overweight and underweight implements to enhance performance. Prior research has demonstrated the positive performance benefits of manipulating implement weight during warm ups (Judge et al., 2010; Terzis et al., 2012; Esformes et al., 2011). However, the throws assessed in these studies were performed using regulation-weight implements and the effect of heavier or lighter implements on throwing kinematics remains unclear.

Research on hitting performance in baseball supports the use of weighted implements as specific strength training tools, but this is accompanied by a degradation in critical factors for batting performance (Castonguay et al., 2022; Nakamoto et al., 20212). Similarly, studies on baseball pitching extensively examine the use of heavy and light baseballs as training implements. In alignment with hitting and throwing research, the use of these balls increases acute pitch velocity (Jermyn et al., 2021; Caldwell et al., 2019; Erickson et al., 2020). However, they also reveal adverse effects on technique and pitch accuracy. In shot putting, where accuracy is less critical, one would expect the observed increase in pitch velocity from training with overweight and underweight implements to be advantageous. However, no studies have investigated the use of heavy and light implements and their impact on critical performance factors of rotational shot putting. Therefore, this study aimed to assess the influence of implement weight on critical factors of rotational shot-putting technique. We hypothesized that compared to regular weight implements, shoulder/hip separation angle, knee and hip flexion would significantly increase in the overweight condition, while peak pelvis angular velocity will be highest in the underweight condition for both women and men.

METHODS: Ten collegiate rotational shot putters (6 males, 4 females) participated in this study (Table 1). Data was collected on three non-consecutive days. Each day, participants performed a self-selected 15-minute general warm-up followed by three rotational style throws. Implement weight varied across data collection days with participants randomly assigned to either the competition (men: 7.26 kg, women: 4.00 kg, COMP), underweight (men: 6.35 kg, women: 3.00 kg, UNDER) or overweight (men: 8.16 kg, women: 4.53 kg, OVER) condition on each day. Rest time between each throw was 3-minutes.

Table 1. Participant demographics and performance history.

	Women	Men
Body mass (kg)	89.75 ± 12.50	110.50 ± 6.30
Height (cm)	172.50 ± 2.20	187.32 ± 9.83
Collegiate personal best (meters)	13.15 ± 1.72	14.34 ± 2.10

Whole-body kinematics were captured using 16 inertial sensors (IMU, MVN Link System, Xsens Technologies B.V, Enschede, Netherlands). Each sensor incorporates a tri-axial accelerometer (± 160 m.s2), gyroscope (± 2000 deg.s), and magnetometer (± 1.9 Gauss), sampling internally at 1000 Hz and exporting data at 120 Hz. Following manufacturer guidelines (Roetenberg, Luinge, & Slycke, 2009), sensors were strategically placed on dorsal feet, lateral shanks, lateral thighs, mid-posterior pelvis, scapular spines, lateral upper arm, lateral forearm, posterior hand, sternum, and posterior head. The biomechanical model for each participant was scaled based on anthropometric measures, including height, arm span, shoulder width and height, foot and leg length, hip, knee, and ankle dimensions, and hip width. Throwing distance was measured with a tape measure and the three furthest trials from COMP, UNDER and OVER were averaged and used for data analysis.

Temporal events of rear foot touchdown (RFTD), front foot touchdown (FFTD), and implement release (REL) were visually identified in the Xsens MVN Biomech Studio software. Sensor signals underwent fusion using Xsens's proprietary Kalman filter, and joint angles were computed using a Y-X-Z Cardan sequence, representing rotations about the medio-lateral, anterior-posterior, and axial axes. The orientation data in Euler angles and joint angles were exported to Matlab (Mathworks, Natick MA, USA). Pelvis and sternum sensor orientations were transformed from Euler angles to rotational matrices, and the pelvis's orientation relative to the torso (sternum) was calculated. Critical technical factors, including pelvis-torso separation at FFTD, rear leg hip flexion at FFTD, rear leg knee flexion at FFTD, and peak pelvis angular velocity around the axial axis between RFTD and REL, were then determined.

Critical factors of technique for each condition (COMP, UNDER, OVER) were averaged and used for further data analysis. A 2 (sex) x 3 (condition) mixed analysis of variance was used to evaluate differences between conditions, with an alpha of .05 used to indicate statistical significance. All statistics were performed using Statistical Package for the Social Sciences (SPSS ver. 29, IBM Corp, Armonk NY, USA).

RESULTS: Hip flexion was the sole parameter to display significant differences among implement weights. Compared to COMP, athletes demonstrated a significant decrease ($p=0.0097$) in hip flexion with OVER implements. No other kinematic variables exhibited statistically significant differences between the conditions. The mean values for the dependent variables are shown in Table 2.

Table 2. Mean throw distance and kinematics for the competition (COMP), overweight (OVER), and underweight (UNDER) conditions. PPAV: peak pelvis angular velocity between FFTD and REL; SH@FFTD: shoulder hip separation at FFTD; hip@FFTD: rear leg hip flexion at FFTD; Knee@FFTD: rear leg knee flexion at FFTD. * Indicates significantly different than baseline.

	Women			Men		
	COMP	OVER	UNDER	COMP	OVER	UNDER
Throw distance (m)	11.41 (± 1.20)	11.17 (± 1.27)	13.31 (± .66)	13.16 (± 1.15)	12.10 (± 1.27)	13.83 (± 1.71)
PPAV (°/s)	13.25 (± 1.84)	13.13 (± 0.84)	13.65 (± 0.81)	12.68 (± 2.90)	12.02 (± 2.85)	12.56 (± 2.90)
SH@RFTD (°)	40.62 (± 7.81)	37.38 (± 6.66)	28.48 (± 9.26)	29.40 (± 16.94)	28.37 (± 11.72)	28.53 (± 13.23)
Hip@RFTD (°)	58.23 (± 7.69)	37.38* (± 6.66)	56.74 (± 9.35)	47.63 (± 19.54)	28.38* (± 11.72)	44.95 (± 26.14)
Knee@RFTD (°)	44.29 (± 9.84)	42.98 (± 7.77)	43.17 (± 7.19)	49.62 (± 16.95)	45.67 (± 19.81)	47.56 (± 15.54)

DISCUSSION: The primary outcome of our investigation contradicts the initial hypothesis. Notably, alterations in implement weight demonstrated a significant impact solely on hip flexion angles. Athletes exhibited reduced hip flexion while throwing a heavier implement, putting athletes in a more extended position during FFTD. The observed decrease in hip flexion suggests that managing a heavier implement may hinder an athlete’s ability to produce vertical movement, leading athletes to unconsciously adopt a more upright posture across the ring. Thus, decreasing the amount of vertical force needed to successfully release the heavier shot put. Instead of the typical “up”, “down”, “up” movement pattern across the ring athletes may utilize an “up”, “up”, “up” pattern when looking at trunk and hip positions. Exploring phases beyond RFTD-REL could provide valuable insights, as athletes might modify movements across the ring. Presently, there is no evidence indicating that reduced hip flexion alone negatively influences shot put performance. Future research is needed to elucidate the optimal hip flexion angles for ideal technical performance.

The kinematic variables selected for this study, recognized as crucial elements of technique in prior research (Young et al., 2005; Judge et al., 2012; Kato et al., 2001), revealed no significant changes except for hip flexion angles. While not significantly different, it is noteworthy that women in the light condition exhibited a reduction in shoulder and hip separation (p=.175). Given the diverse anthropometrics, speed, and technical skills among individuals in shot putting, using a lighter shot put may lead some athletes to prematurely "open up", diminishing shoulder and hip separation at FFTD. While this variation may affect performance and kinematic sequencing for some, its impact may be less significant for others.

It is crucial to acknowledge the limited sample size in this study, and future research should aim to assess a more extensive sample size over a complete training period, incorporating a variety of both underweight and overweight implements. Despite this limitation, our findings emphasize the potential effectiveness of heavy and light implements as valuable training tools that do not adversely impact shot putting performance. Additionally, the integration of heavy and light implements in skill acquisition, velocity training, and periodization strategies may yield considerable benefits for shot put performance enhancement. Recognizing individual variations in movement patterns within shot putting is imperative. Coaches should possess the ability to identify specific issues and implement targeted constraints or tools to aid athletes in improving their athlete’s performance. This individualized approach, coupled with the strategic use of heavy and light implements, aligns with effective periodization methods, contributing to a comprehensive and tailored training regimen for shot put athletes.

CONCLUSION: Our study demonstrated a significant decrease in hip flexion when athletes used overweight implements, indicating an influence on rotational shot-putting technique. However, no significant differences were observed in other performance variables across conditions. Further exploration of optimal hip angles and their implications for performance is warranted. These findings highlight the need for tailored training strategies in optimizing shot put performance. The incorporation of overweight and underweight implements may prove beneficial in boosting performance and refining training cycles.

REFERNCES

Caldwell, J.E., Alexander, F.J., Ahmad, C.S. (2019) Weighted-ball velocity enhancement programs for baseball pitchers: a systematic review. Orthopedic Journal of sports medicine, 7(2):2325967118825469

Castonguay, T., Roberts, M., & Dover, G. (2022). Warming Up with a Dynamic Moment of Inertia Bat Can Increase Bat Swing Speed in Competitive Baseball Players. Journal of sport rehabilitation, 32(1), 1–8.

Coh, M., Stuhec, S., & Supej, M. (2008). Comparative biomechanical analysis of the rotational shot put technique. Collegium antropologicum, 32(1), 249–256.

Esformes, J. I., Keenan, M., Moody, J., & Bampouras, T. M. (2011). Effect of different types of conditioning contraction on upper body postactivation potentiation. Journal of Strength and Conditioning Research, 25(1), 143–148.

Erickson, B.J., Atlee, T.R., Chalmers, P.N., Bassora, R., Inzerillo, C., Beharrie, A., Romeo, A.A. (2020) Training With Lighter Baseballs Increases Velocity Without Increasing the Injury Risk. Orthopedic Journal of sports medicine, 8(3):2325967120910503.

Hubbard, M., De Mestre, N. J., & Scott, J. (2001). Dependence of release variables in the shot put. Journal of Biomechanics, 34(4), 449–456.

Jermyn, S., O'Neill, C., Coughlan, E. (2021). The Acute Effects From the Use of Weighted Implements on Skill Enhancement in Sport: A Systematic Review. Journal of Strength and Conditioning Research 35(10): p 2922-2935.

Judge, L. W., & Bellar, D. (2012). Variables associated with the of personal best performance in the glide and spin shot put for U.S. collegiate throwers. International Journal of Performance Analysis in Sport, 12(1), 37–51.

Judge, L. W., Bellar, D., & Judge, M. (2010). Efficacy of potentiation of performance through overweight implement throws on male and female high-school weight throwers. The Journal of Strength and Conditioning Research, 24(7), 1804–1809.

Kato, T., Urita, Y., Kintaka, H., Maeda, A. (2018). Relationship between momentum of athlete-shot system and release velocity in rotational shot-put technique. 891-2311.

Linthorne, N. P. (2001). Optimum release angle in the shot put. Journal of Sports Sciences, 19(5), 359–372.

Lipovsek, S., Skof, B., Stuhec, S., & Coh, M. (2011). Biomechanical factors of competitive success with the roational shot put technique. New Studies in Athletics, 26(1/2), 101–109.

Nakamoto, H., Ischii, Y., Ikudome, S., Ohta, Y.(2012). Kinesthetic aftereffects induced by a weighted tool on movement correction in baseball batting. Human Movement Science, 31: 1529–1540.

Schofield, M., Cronin, J. B., Macadam, P., & Hébert-Losier, K. (2022). Rotational shot put: a phase analysis of current kinematic knowledge. Sports Biomechanics, 21(3), 278–296.

Terzis, G., Karampatsos, G., Kyriazis, T., Kavouras, S., & Georgiadis, G. (2012). Acute effects of countermovement jumping and sprinting on shot put performance. Journal of Strength and Conditioning Research, 26(3), 684–690.

Young, M., & Li, L. (2005). Determination of critical parameters among elite female shot putters. Sports Biomechanics, 4(2), 131–148.