MANIPULATING IMPLEMENT WEIGHT DURING WARMUP TO IMPROVE SHOT PUT PERFORMANCE

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The purpose of this study was to evaluate kinematics and kinetics of the shot put when participants warmup using standard, overweight, or underweight implements. Ten collegiate shot putters warmed up using regulation, heavy, or light implements then completed six maximal effort competition throws. Whole body kinematics and ground reaction forces were recorded on each throw. Consistent with the literature, throw distance was significantly further after warming up with the heavy implement (p = .002). However, there were no differences in critical kinematic factors or ground reaction forces between conditions. While using overweight implements during warmup improves shot put performance, the mechanism by which this occurs is not through altering the critical factors or forces produced during the throw.

KEYWORDS: Shotput, post activation potentiation, kinematics, forces

INTRODUCTION: The shot put is a commonly contested Athletics event. For rotational shotput in particular, previous studies have identified several kinematic parameters which are appear critical for performance including: pelvis-torso separation at rear foot touch down (RFTD), rear leg hip and knee flexion at RFTD, and peak pelvis angular velocity between RFTD and Release (REL) (Kato et al., 201; Lipovsek et al., 2011; Schofield et al., 2022; Young & Li, 2005). However, few studies identify technical or training interventions coaches could implement to improve performance on these factors. One possibility is to leverage the phenomena of post activation potentiation (PAP), the idea that a muscle's contractile history can enhance its production of force (Esformes et al., 2011). Performing explosive movements such as heavy Olympic lifts or short sprints prior to throwing can yield significant improvements in subsequent shot put performance (Dolan et al., 2017; Terzis et al., 2012). While suitable for training, these exercises are not feasible for competition environments. Instead, athletes could manipulate implement weight, using overweight implements during warmup to induce PAP. This approach has been shown to improve performance in over-the-head backward shot throws (Judge et al., 2016), and weight throws (Bellar et al., 2012; Judge et al., 2010).
While these studies highlight the practical benefits of using overweight implements during warmup, they do not address the underlying mechanisms. Therefore, the purpose of this study was to investigate how manipulating implement weight during warm up affects the kinematics and kinetics of shot put throwing. We hypothesized that throw distance would increase following a warmup with overweight implements and that increased throw distance would be accompanied by increased pelvis-torso separation at RFTD, rear leg hip and knee flexion at RFTD, greater pelvis angular velocity between RFTD and REL, and increases in the ground reaction forces applied by the athlete.

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 warm-up throws and six maximal effort competition throws. All competition throws were performed using regulation implements (men: 7.26 kg, women: 4.00 kg). Implement weight during warm-up throws varied across days, using regulation implements on day one, and then in randomized order, either overweight (men: 8.16 kg, women: 4.53 kg) or underweight (men: 6.35 kg, women: 3.00 kg) implements on days two and three. To simulate a competition environment, time between warm up and competition throws was 5-minutes, with an additional 3-minutes of rest between each competition throw.

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
Clean 1-rep maximum (kg)	88.50 ± 13.40	131.30 ± 25.70

Whole body kinematics were recorded using 16-inertial sensors (IMU, MVN Link System, Xsens Technologies B.V, Enschede, Netherlands). Each sensor integrates a tri-axial accelerometer, gyroscope, and magnetometer, internally sampling at 1000 Hz, and set to export data at 120 Hz. Sensors were placed on the dorsal feet, lateral shank and thighs, mid-posterior pelvis, middle of the scapular spines, lateral upper arm and forearm, posterior hand, sternum, and posterior head. Ground reaction forces were also recorded at 120 Hz using a custom throwing circle containing two force plates (dimensions: 1.016 x 0.762 m, manufacturer: AMTI, Waltham MA, USA) embedded and flush with the floor of the circle. Plates were spaced such that during the delivery of the implement the front and rear feet were on different plates. Collection of ground reaction forces and kinematics were synchronized.

Throwing distance was measured with a tape measure and the three furthest trials of competition throws for baseline (BASE), post-heavy (PH), and post-light (PL) conditions were used for data analysis. Temporal events RFTD, front foot touch down (FFTD), and REL were identified visually in the Xsens MVN Biomech Studio software. IMU sensor signals were then fused using the Xsens proprietary Kalman filter and joint angles calculated using a Y-X-Z Cardan sequence corresponding to rotations about the medio-lateral, anterior-posterior, and axial axes. Sensor orientations and joint angles were exported to Matlab (Mathworks, Natick MA, USA) where orientations of the pelvis and sternum sensors were converted from Euler angles to rotational matrices and the orientation of the pelvis relative to the torso (sternum) calculated. The critical kinematic factors of pelvis-torso separation, rear leg hip and knee flexion at RFTD, and peak pelvis angular velocity around the axial axis between RFTD and REL were then identified. Ground reaction forces were filtered using low pass Butterworth filters with a 50 Hz cutoff in Matlab. For both the front and rear feet the peak force, impulse, and peak rate of force development from time of foot touch down (either RFTD or FFTD, respectively) through REL were calculated and normalized to the sum of body and implement weight.

Within participants, dependent variables from the three throws in each condition were averaged. 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. To aid in interpretation effect sizes (Cohen's d) were calculated for all significant pair-wise comparisons, and interpreted in the ranges of <0.2 small, 0.4 – 0.6 moderate, > 0.8 large. All statistics were performed using Statistical Package for the Social Sciences (SPSS ver. 29, IBM Corp, Armonk NY, USA).

RESULTS: None of the dependent variables displayed significant sex-by-condition interactions or main effects of sex. Mean throw distances and participant kinematics are shown in Table 2. There was a significant main effect of weight for throw distance ($F_{2,16} = 4.123$, $p = .036$), with participants throwing further in the PH than the BASE ($p = .002$, $d = .306$). There were no significant differences between conditions for any of the kinematic measures. Ground reaction force variables are shown in Table 3. There were no significant differences between conditions for any of the ground reaction force variables.

DISCUSSION: The main finding of this study, in support of our hypothesis and consistent with previous results (Bellar et al., 2012; Judge et al., 2010, 2016), was that warming up with an overweight implement improves shot put throw distance in collegiate athletes. Contrary to our hypothesis, the increased throw distance was not accompanied by changes in critical kinematic factors or increases in ground reaction forces. This suggests other parameters in the throw may have changed. These may include the release parameters of the implement like the

Table 2. Mean throw distance and kinematics for the baseline (Base), post-heavy (PH), and post-light (PL) conditions. PPAV: peak pelvis angular velocity between rearfoot touch down and release; SH@RFTD: shoulder hip separation at rearfoot touch down; hip@RFTD: rear leg hip flexion at rear foot touch down; Knee@RFTD: rear leg knee flexion at RFTD. * indicates significantly different thane baseline.

	Women			Men		
	Base	PH	PL	Base	PH	PL
Throw distance (m)	11.41 (± 1.19)	11.89* (± 1.14)	11.82 (± 0.83)	13.15 (± 1.15)	13.54* (± 1.03)	13.21 (± 1.36)
PPAV (°/s)	13.26 (± 1.92)	13.24 (± 1.43)	13.14 (± 0.59)	12.81 (± 2.84	12.66 (± 2.67)	12.50 (± 2.57)
SH@RFTD (°)	40.01 (± 9.31)	40.74 (± 13.19)	30.17 (± 7.73)	29.20 (± 15.42)	29.29 (± 16.52)	26.20 (± 12.44)
Hip@RFTD (°)	58.08 (± 7.71)	55.23 (± 9.95)	55.18 (± 5.06)	54.15 (± 6.45)	56.94 (± 10.15)	51.30 (± 5.29)
Knee@RFTD (°)	44.20 (± 9.43)	43.66 (± 9.83)	48.15 (± 9.39)	43.69 (± 4.75)	40.51 (± 15.08)	41.73 (± 6.91)

Table 3. Mean ground reaction force metrics for the baseline (Base), post-heavy (PH), and post-light (PL) conditions. PF: peak force on the rear foot (RF) and front foot (FF); Imp: impulse from foot touchdown until release; RFD: peak rate of force development between foot touchdown and release. BW values are combined body and implement weight.

	Women			Men		
	Base	PH	PL	Base	PH	PL
PF-RF (BW*)	1.58 (± 0.16)	1.76 (± 0.42)	1.60 (± 0.11)	1.37 (± 0.13)	1.37 (± 0.11)	1.36 (± 0.15)
PF-FF (BW*)	1.44 (± 0.24)	1.30 (± 0.14)	1.44 (± 0.26)	1.31 (± 0.19)	1.31 (± 0.22)	1.31 (± 0.22)
Imp-RF (BW*s*)	0.41 (± 0.10)	0.42 (± 0.12)	0.39 (± 0.07)	0.31 (± 0.14)	0.43 (± 0.02)	0.34 (± 0.82)
Imp-FF (BW*s*)	0.15 (± 0.06)	0.13 (± 0.04)	0.16 (± 0.03)	0.23 (± 0.15)	0.17 (± 0.04)	0.13 (± 0.05)
RFD-RF (BW*s^{-1}*)	41.59 (± 13.33)	44.09 (± 15.54)	45.56 (± 16.54)	32.90 (± 12.61)	27.21 (± 5.01)	28.56 (± 5.18)
RFD-FF (BW*s^{-1}*)	38.55 (± 12.40)	37.05 (± 11.04)	37.86 (± 14.97)	29.69 (± 8.74)	33.62 (± 8.27)	30.23 (± 11.27)

Release velocity, angle, or height, which are fundamental in determining the trajectory of a projectile. The release angle of a shot put is heavily dependent on the release velocity, and optimal release angles are often slightly lower than those athletes naturally select (Hubbard et al., 2001; Linthorne, 2001). A heavier implement would be more difficult for an athlete to accelerate vertically as they need to overcome the additional mass. To maintain consistent release velocity, participants may have inadvertently adopted lower release angles with the overweight implement and kept these angles during the competition throws, thus improving their performance. As implement release parameters are strongly associated with upper extremity kinematics, it is possible there were beneficial changes in these values as well. While the IMU system used in the current study can measure the kinematics of the athlete, it cannot measure the kinematics of the implement itself. Thus, this represents an area for future research using different methodologies to determine if overweight implements influence throw kinematics.

Alternatively, the improvements in throw distance might be due to the mechanistic properties of PAP. PAP results from the combined effects of increased phosphorylation of myosin and increased motor unit recruitment rates (Downey et al., 2022; Evetovich et al., 2015). Terzis et al. (2003) demonstrated that earlier onset of triceps brachii activation was associated with better shot put performance. It is possible the PAP stimulus provided by using the overweight implements resulted in greater motor unit recruitment speeds in the triceps brachii, or other muscles, thereby allowing them to generate forces faster or at a more optimal time in the throw. Future studies using EMG on both upper and lower extremities are required to investigate this hypothesis.

CONCLUSION: The use of an overweight implement for warmup throwing which ends approximately 5-minutes prior to starting competition improves rotational shot put throw distance without changing critical kinematic factors or ground reaction forces of the throw. Since competition rules allow athletes to weigh in heavier implements for warmups, the use of this strategy could be one way for athletes or coaches to improve performance.

REFERNCES

Bellar, D., Judge, L. W., Turk, M., & Judge, M. (2012). Efficacy of potentiation of performance through overweight implement throws on male and female collegiate and elite weight throwers. *Journal of Strength and Conditioning Research*, *26*(6), 1469–1474.

Dolan, M., Sevene, T. G., Berninig, J., Harris, C., Climstein, M., Adams, K. J., & Debeliso, M. (2017). Post-Activation potentiation and the shot put throw. *International Journal of Sports Science*, *2017*(4), 170–176.

Downey, R., Deprez, D., & Chilibeck, P. (2022). Effects of postactivation potentiation on maximal vertical jump performance after a conditioning contraction in upper-body and lower-body muscle groups. *Journal of Strength and Conditioning Research*, *36*(1), 259–261.

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.

Evetovich, T., Keenan, M., Moody, J., & Bampouras, T. (2015). Postactivation potentiation enhances upper and lower body athletic performance in collegiate male and female athletes. *Journal of Strength and Conditioning Research*, *29*(2), 336–342.

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

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.

Judge, L. W., Bellar, D. M., Craig, B. W., Gilreath, E. L., Cappos, S. A., & Thrasher, A. B. (2016). Influence of postactivation potentiation on shot put performance of collegiate throwers. *Journal of Strength and Conditioning Research*, *30*(2), 438–445.

Kato, Tadahiko & Urita, Yoshihisa & Kintaka, Hirofumi & Maeda, Akira. (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.

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., Georgiadis, G., Vassiliadou, E., & Manta, P. (2003). Relationship between shot put performance and triceps brachii fiber type composition and power production. *European Journal of Applied Physiology*, *90*(1–2), 10–15.

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.