International Journal of EXERCISE SCIENCE

Original Research

Variables Associated with High School Shot Put Performance

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ABSTRACT

International Journal of Exercise Science 15(6): 1357-1365, 2022. This study determined the relationship between high school athletes' maximal strength, jumping, and sprinting with shot put performance. High school athletes (*n* = 9; 16.9 ± 1 years; 110.4 ± 10.8 kg; 183.73 ± 9.33 cm) performed the broad jump, 1RM squat, 1RM bench, 40-yard dash with 10-yd split, and shot put. Strong positive correlations between shot put performance and broad jump (*r* = 0.89), 1RM squat (*r* = 0.90), and 1RM bench press (*r* = 0.87), and a strong negative correlation between shot put performance and 40-yd dash (*r* = -0.86) were observed. No significant correlation was found between shot put performance and 10-yd split times. Results indicate that shot put performance is associated with strength, jumping, and sprinting. It is valuable for coaches to understand relationships between physical fitness measurements, such as strength, power, and speed/acceleration, with shot put performance to predict competition performance, make training adjustments, and develop young throwers appropriately.

KEY WORDS: Youth development, throwing performance indicator

INTRODUCTION

In the 2018-2019 academic year, 1,093,621 U.S. high school girls and boys participated in outdoor track and field (29). Moreover, an average of seven athletes per school will compete in throwing events per year, like the shot put. The shot put is an athletic throwing event that involves putting, or pushing, a heavy metal ball (girls = 4 kg; boys = 5.4 kg) with one hand as far as possible. Shot putters need strong quadriceps, hamstrings, and gluteus maximus muscles to push off from the back of the circle and generate the initial thrust necessary to get the heavy metal shot moving across the circle.

Using either glide or rotational technique, shot-putters attempt to reach peak velocity of the body and shot through the triple extension of leg joints and high torque production from the hip musculature during the power position with a release shot angle of 37–41° (16). Therefore, the optimal technique is a set of muscle contractions and relaxations coordinated and synchronized to produce a maximum acceleration of the shot to create the highest release velocity of the shot possible (10, 21, 22). In addition, aside from training optimal technique, rate of force development (RFD) and impulse are building blocks of the shot put (4, 6). The RFD is the force-time curve during an explosive muscle contraction, and may play a significant role in the shot put (28). In human movements, such as the shot put, increasing the impulse will result in a greater momentum change, hence, greater release velocity. Taken collectively, powerful movements, or the ability to rapidly produce large amounts of force, are essential during the delivery and final thrust of the throw (28).

Shot put performance depends on the development of maximal force in minimal time. Previous research has shown that the greater an athlete's upper and lower body strength, the better the shot put performance. Greater strength assists in applying force and, subsequently, the higher velocity of release. Thus, it is vital to understand the relationship between maximal strength, RFD, and throwing performance. For instance, moderate to high positive correlations ($r \geq 0.63$) have been found between shot put performance and one-repetition maximum (1RM) bench press among collegiate and elite athletes (10, 20, 23, 24). Moreover, the majority of research has reported high positive correlations ($r \geq 0.71$) between shot put performance and 1RM squat among collegiate and elite athletes (10, 13, 19, 24), except for Kyriazis et al. (14), which found a low, non-statistically significant relationship (r = 0.35 to 0.38). Kyriazis et. al (14), however, studied nine highly ranked collegiate athletes who had more than six years of throwing and training experience. Therefore, these well-trained athletes may already have a solid foundation of strength, and further increases in muscular strength is not related to performance (14, 25).

Maximal sprint performance is an essential determinant of performance in many sports, and distances over 10- to 60-yards have been widely used to measure speed and acceleration among high school strength and conditioning coaches (5). The 40-yard dash, as well as the 10-yard split, assessed speed and acceleration, respectively. Plyometric movements like the shot put, jumping and sprinting demonstrate a relationship between RFD and jump height or sprint time, respectively. Therefore, one may assume that sprinting and jumping performance would also be related to shot put performance. However, data is rare. Landolsi et al. (15) found a moderate, positive correlation between vertical jump (VJ) height and shot put performance ($r = 0.51$, $p < 0.05$). Similarly, Reis et al. (20) reported a moderate, positive relationship between the standing long jump and shot put performance ($r = 0.53$); however, it was not statistically significant. Also, Kyriazis et al. (14) showed no significant correlation between VJ height and shot put performance (r = 0.23 to 0.27). To the best of our knowledge, no other researchers have examined the relationship between a broad jump and shot put performance. In addition, no research has examined the relationship between sprinting and shot put performance. Furthermore, previous data has been collected on collegiate, national, and elite shot putters. In contrast, no research has examined high school athletes.

This study aimed to determine the relationship between shot put performance and maximal strength, broad jump, and sprinting. It was hypothesized that shot putters with greater maximal strength, longer jump height, and quicker sprint performance would have better shot put performances. Results from this study may help coaches improve strength and conditioning programs and more accurately predict shot put performance in high school athletes.

METHODS

Participants

A Power analysis conducted with G*POWER 3.1 (Universitat Kiel, Germany) determined that nine participants were needed in the present study for a power of 0.80, with an effect size of 0.75 (large, accessible for sample recruitment), and an α = 0.05. Participants were Kansas high school shot putters with 1-6 years of track and field experience. They were free of any musculoskeletal injuries within the past six months. All participants provided written informed consent before participation, and the Institutional Review Board at Southern Utah University approved the protocol. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science.

Protocol

The participants performed assessments in one session. Testing took place at athletes' high school, using their gym and weight room. Therefore, testing was performed in one of three high school gyms/weight rooms with similar equipment. Before testing, participants completed a short survey asking about training age and participation in other sports. In addition, height and weight were recorded to the nearest tenth of a centimeter and kilogram, respectively. Finally, participants were instructed briefly on each assessment protocol and allowed to ask questions and further explanation.

Warm-up and Assessment Order: Participants performed a 10-minute general warm-up consisting of jogging, followed by dynamic stretching before the broad jump. After the warm-up, tests were performed in the order they are discussed, and participants rested for at least 10 minutes between tests to ensure complete recovery (19).

Broad Jump: The broad jump, horizontal or standing long jump, was performed as described by National Strength and Conditioning Association (NSCA)(18). The participant stood with their toes just behind the starting line and then performed a countermovement jump forward as far as possible. The distance from the starting line to the participant's rearmost heel was measured, and the best of three trials was recorded to the nearest hundredth of a meter. Participants were allowed three practice attempts at the broad jump. The broad jump has a strong association with lower body explosive power and is efficient and a low-cost test (2).

One Repetition Maximum Back Squat: A one-repetition maximum (1RM) back squat assessed lower body maximum muscular strength. Following the NSCA protocol for 1RM back squat (1, 23), participants performed a warm-up set of 5 to 10 back squat repetitions with light to moderate load and then rested one minute. Participants then performed a second warm-up set consisting of an estimated load that allowed participants to complete 3 to 5 repetitions. Following a 2-minute rest, participants performed a third and final warm-up set with a near-maximal load that allowed the athletes to complete 2 to 3 repetitions. After a 2 to 4-minute rest, participants attempted a 1RM. A maximum of five 1RM attempts were permitted, which did not include the submaximal warm-up repetitions (23). Following a successful 1RM attempt and in consultation with each athlete, the barbell weight was increased until no further weight could be lifted. Participants received 2- to 4-minute rest between 1RM attempts. For each squat repetition, athletes were instructed to perform the eccentric phase in a controlled manner until the tops of the thighs were parallel to the floor. Once the eccentric phase was completed, the athletes were encouraged extend the hips and knees at the same rate until they reached the starting position (1). The barbell was placed in a high bar position above the posterior deltoid at the base of the neck (1). The weight lifted for the 1RM was recorded in kilograms.

One Repetition Maximum Bench Press: A one-repetition maximum (1RM) bench press assessed upper body maximum muscular strength. The same 1RM protocol for the 1RM back squat was used for the bench press using load changes appropriate for upper body exercise (23). Athletes were instructed to grasp the bar with a closed, pronated grip slightly wider than the shoulders and to lightly touch the chest before returning to the top position while keeping the feet on the floor and the hips, upper back, and head on the bench (1).

Sprinting Times: Participants warmed up for the 40-yard dash with at least two practice runs at submaximal speed before testing (18). The participant assumed starting position using a two -, three-, or four-point stance behind the starting line. Similar starting positions were used for each trial (7). Then, on an auditory signal, the participant sprinted 40-yards at maximal speed. The best 10-yard split and 40-yard times in three trials were measured using a handheld stopwatch and recorded to the nearest 0.1 seconds. The participant performed active recovery or rested at least 2 minutes between trials. This study used handheld timing devices since handheld timing provides reasonably consistent times between trials, and using the mean of multiple timers improves precision (8, 17). Moreover, a previous study found high ICC, approximately 0.98, with a 95% confidence interval compared to electronic timing and handheld timing (8, 17).

Shot Put Performance: Athletes were allowed three warm-up throws before recorded attempts were collected. The best of 3 attempts was selected for the results of the study. Assessment day occurred near the end of the track and field season to allow for the most technological advancements in shot put performance.

Statistical Analysis
Data is presented as mean and standard deviation. Pearson's product-moment correlation coefficient was run to assess the relationship between shot put performance and the other variables of maximal strength, jumping, and sprinting. The strength of the relationship was interpreted using guidelines from Hinkle, Wiersma, and Jurs (9). A correlation coefficient between |0.9 to 1.00|was interpreted as ‘very high,’ |0.7 to 0.9| as ‘high,’ |0.5 to 0.7 | as ‘moderate,’ |0.3 to 0.5| as low, and |< 0.3| as “negligible.’ Finally, the coefficient of determination was calculated as the square of the correlation coefficient. Statistical significance was set *a priori* at alpha < 0.05. Statistical analysis was performed using SPSS Statistics Software Version 25® (IBM, Armonk, New York, USA).

RESULTS

Participants' characteristics are presented in Table 1. There were six males and three females who participated in the study. The descriptive statistics for the dependent variables are presented in Table 2. Correlation coefficients, p-values, and coefficient of determination between the shot put performance, and all other variables are presented in Table 3.

Table 1. Participant Characteristics

	Age (yrs)	Weight (kg)	Height (cm)	Training age (yrs)
Male (n = 6)	16.83 ± 0.75	115.68 ± 6.97	187.53 ± 7.08	2.00 ± 1.10
Female (n = 3)	17.00 ± 0.00	99.85 ± 9.77	176.11 ± 9.61	3.33 ± 2.52
Total	16.89 ± 0.60	111.40 ± 10.81	183.73 ± 9.33	2.44 ± 1.67

Note: Values are presented as means ± standard deviations (S.D.).

Table 2. Descriptive statistics for the variables

	Shot Put Performance (m)	Broad Jump (m)	1RM Squat (kg)	1RM Bench Press (kg)	40-yd Dash (s)	10-yd Split (s)
Male	12.48 ± 1.99	2.29 ± 0.17	170.38 ± 54.51	121.36 ± 51.44	5.76 ± 0.46	2.25 ± 0.22
Female	8.43 ± 1.06	1.60 ± 0.22	63.03 ± 22.64	40.61 ± 6.17	7.06 ± 0.39	2.40 ± 0.14
Total	11.13 ± 2.62	2.06 ± 0.39	134.60 ± 69.76	94.44 ± 57.39	6.19 ± 0.77	2.30 ± 0.20

Note: Values are presented as means ± standard deviations (S.D.).

Table 3. Correlation, significance, and coefficient of determination between shot put performance and all other variables.

	r	p-value	r^2
Broad Jump	0.888	0.001	78.9%
1RM Squat	0.898	0.001	80.6%
1RM Bench Press	0.873	0.003	76.2%
40-yd Dash	-0.861	0.003	74.1%
10-yd Split	-0.547	0.127	29.9%

Note: Values are presented as means ± standard deviations (SD). r = Pearson's product-moment correlation coefficient; p = statistical significance; r^2 = coefficient of determination.

DISCUSSION

The relationships between maximal strength, jumping, sprinting, and shot put performance are not well understood. This study examined the correlation between high school athletes' shot put performance and maximal strength, broad jump, and sprint performance.

First, we observed high, positive correlations between maximal strength and shot put performance, with strength explaining over 76% of the variation in the shot put. The relationship between 1RM back squat and shot put performance had the strongest correlation in this study (r = 0.898). This finding was in conjunction with what has been found in collegiate and elite level athletes, except for one case ($r \geq 0.78$)(10, 20, 25, 26). Kyriazis (14) found a non-significant relationship between 1RM squat and shot put performance during competition season (r = 0.38) in elite collegiate level athletes. Aside from Kyriazis, it appears that lower body maximal strength is strongly correlated to performance in young throwers, similar to collegiate and elite athletes. Since younger throwers have less time to dedicate to the technical mastery of the shot put, high school coaches may focus on lower body strength training to improve shot put performance.

The bench press is one of the most similar motions to the one-armed release of the shot put. Similar to our findings (r = 0.873), previous studies have found high, positive correlations between 1RM bench press and shot put performance ($r \geq 0.75$)(10, 20, 24-26). The bench press is a common exercise in high school weight rooms, especially among many football players who also throw shot put. However, some female athletes may be underexposed to the bench press in training. The consensus of research demonstrating a relationship with bench press and shot put recommends that bench press be utilized in training for young throwers.

Second, we found a high, positive correlation between the broad jump and shot put performance (r = 0.888), with the broad jump explaining approximately 79% of the variation in the shot put performance. Similarly, some studies have shown jumping (e.g., vertical jump or broad jump) to predict shot put performance ($r \geq 0.43$) (10, 12, 14). However, previous studies used the power clean rather than jumping to examine the relationship between power and shot put performance (10, 12, 15). Yet, unlike collegiate and elite athletes, many high school athletes have not learned the power clean. Therefore, the broad jump may be an alternative assessment and training exercise for younger athletes to develop power and thus improve shot put performance.

Third, we found a high, negative correlation between shot put performance and 40-yard dash time (r = -0.861) and a non-statistically significant, moderate, negative correlation between shot put performance and 10-yard split time (r = -0.547). The aim of the shot putter is to move the body as fast as possible across the ring to develop maximum impulse on the shot put. It takes approximately 2.28 to 3.24 seconds to throw across a 2.135 m shot put ring (27). Therefore, it seemed likely that speed and acceleration would relate to shot put performance. However, we only found a high correlation between the 40-yard sprint time and shot put, but not the 10-yard split time. Unfortunately, sprinting is not frequently used to assess shot putters of any age (10, 12, 14, 20, 27). Despite the positive correlation, the 40-yd dash may not be the best measurement to predict shot put performance since it is significantly longer than the length of the shot put ring. Moreover, to our knowledge, no other literature exists that examined the relationship between sprinting and shot put performance. It is possible that our athletes lacked specific sprint training, such as sprint starts, and therefore, inconsistent 10-yard sprint times did not correlate well with shot put performance.

Significant differences between beginner to advanced throwers lie in the technical mastery of the throw. In some cases, strength supersedes technique development; however, strength is also a limiting factor of technique development (11). Research conducted at the collegiate level considered coaching instruction, which suggests the athletes have sufficient technical instruction for improvement (10, 12). The scope of this study did not account for technical instruction beyond questioning how many years athletes participated in the shot put. Unfortunately, high school athletes may not have a dedicated throwing coach (27). Therefore, this study suggests that high school athletes may improve shot put performance by focusing on maximal strength, power, and speed when technical instruction is unavailable. Moreover, when technical instruction is available to an athlete, stronger, more powerful athletes are more likely to learn technique quicker than weaker athletes (11).

Limitations: A sampling of participants occurred during a global pandemic which signifies a potential selection bias. Due to the small sample size, the results of this study may not be generalizable to a larger athlete population. Additionally, the small sample size did not allow for the research to account for gender. Finally, we assumed a linear relationship between maximal strength and shot put performance, based on the assumption absolute strength is a contributing factor in maximal power (e.g., power = force x velocity) (3). If muscular strength, therefore, is increased, then higher forces can by exerted, resulting in increased impulse and acceleration. However, according to the force-velocity curve, strength capacity at slow movement velocity has a reduced impact on the ability of the muscle to produce high force quickly (3). Thus, the degree that absolute strength influences the shot put may diminish if the athlete already has an adequate level of strength (3, 14, 25), as Kyriasiz et al. (14) demonstrated with well-trained shot putters. It has been postulated that the relationship between maximal strength and shot put performance is quadratic (12). It would seem that future studies may examine athletes across the spectrum for skill and training experience by including a thorough screening process for athletes, coaches, or both. This will enable the researcher to limit skill variance and examine the quadratic relationship between strength and shot put performance, as well as determine the adequate level of strength per body weight necessary for optimal shot put performance. Finally, further research on explosive movements, such as jumping and sprinting, as a predictor of shot put performance may be needed.

Shot put performance is a multi-factorial, complex skill that requires mastery and considerable effort with athletic development. This study found a relationship between maximal strength, jumping, and the 40-yd sprint time with shot put performance. Therefore, the inclusion of bench press, squat, standing long jump, and 40-yd dash in a training program may benefit shot put performance in high school throwers. Coaches should be advised that considerable technique skill contributes to shot put performance, and that factor was not accounted for in this study.

ACKNOWLEDGEMENTS

We wish to thank the athletes, coaches, principals, and athletic directors for contributing to this research.

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