
A PILOT STUDY EXPLORING THE QUADRATIC NATURE OF THE RELATIONSHIP OF STRENGTH TO PERFORMANCE AMONG SHOT PUTTERS

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ABSTRACT

International Journal of Exercise Science 6(2) : 171-179, 2013. The purpose of this pilot study was to examine the quadratic nature of the relationship between the strength and throwing distance in the shot put. A survey was sent to throws coaches with Master Coach or USA Track and Field Level III distinction to examine fifty-three collegiate and elite throwers (24 male, 29 female). The coaches reported the thrower's personal best shot put distance and preseason weight room 1RM for bench press, power clean, and squat exercises. Relationship between distance and 1RM was determined via general linear model polynomial contrast analysis and regression. Data analysis showed significant linear and quadratic trends for distance and 1RM power clean for both male (linear: $p \leq 0.001$, quadratic: $p = 0.003$) and female (linear: $p \leq 0.001$, quadratic: $p \leq 0.001$) elite and collegiate shot put athletes. Analysis also provided a quadratic equation to compare personal best distance and 1RM power clean. The power clean was found to be more closely related to shot put distance as compared with squat and also with bench press, which is the least related. Based on the results of this investigation, in addition to strength exercises such as the squat and bench press, power exercises such as the power clean should also be incorporated into strength and conditioning programs of shot put athletes for optimal performance.

KEY WORDS: Power lifts, elite performance, throwing performance indicator

INTRODUCTION

The shot put event in track and field has an interesting history with significant changes to technique being made throughout the years. In 1951, American shot putter Parry O'Brien refined the sidestep technique to one that is now known as the glide. Since the early 1980's, the rotational (spin) technique, a style similar to the discus throw, has been gaining popularity among

coaches involved in all levels of track and field (18). Today both techniques are being utilized by the top throwers in the world. The competitive performance of a shot putter in track and field can be characterized as a very aggressive display of strength, power, and technique. The shot put event in track and field utilizes a technical pattern that attempts to create a summation of forces by creating torques between different parts of the body via

stretch reflexes. All of these torque-creating positions are performed in hundredths of a second. For this reason, it is essential that the body be finely tuned to optimally perform these techniques. Given the explosive nature of throwing events and the proper contraction sequencing that must take place, training routines are designed to emphasize strength, power and flexibility (16). Therefore, the exercises prescribed for these athletes are very important their success.

The application of free-weights as a means of developing physical capabilities for athletes has long been a common practice (11). Weightlifting training produces many benefits, including: injury prevention, improved flexibility, improved inter- and intramuscular coordination and sharpened psychological abilities (11). Weight room one repetition maximums (1RM) have been shown to be related to performance in the throwing events (27). However, the shot put in track and field itself uses a much lighter load (4 kg for women, 7.26 kg for men) than those used frequently during weight training sessions. Strength and conditioning coaches have many decisions to make when designing resistance training programs. Choices focused on exercise selection, the intensities at which they are performed, and the total volume that is lifted are all decisions that need to be made when designing resistance training programs. Strength and conditioning coaches that do not have access to information about throwing are left wondering which exercises produce the best results with the athletes they are working with and if certain athletes respond better to different exercises.

Aside from the teaching and training of necessary technical throwing skills, strength training is the foundation of success in the shot put event (15). "Strength" can be defined as a person's capacity to use muscular activity (enhanced by the use of weights) to exert resistance on external forces in order to overcome these outside forces (34). Strength is necessary to accelerate a mass and to achieve the desired velocity, impulse, and momentum for success in throwing. Strength has been described by Stone et al., (34), as the basis of high level performance in track and field. Why is strength so vital to long throws? Stronger athletes are able to hold the positions necessary to master the technique (34). Optimal technique is a set of muscle contractions and relaxations coordinated and synchronized to produce maximum acceleration of the implement (28, 29). The proportion of strength and power movements in the resistance training program may differ based on the stage of training, but strength training must to always remain a major element of the training program (2, 3, 4).

Power is the mechanical quantity that expresses the rate of performing work (7) and is largely dependent on the ability to exert the highest possible force (i.e. maximum strength) (30, 33, 34). Numerous studies and review articles have reported evidence and logical arguments for the use of explosive exercises for shot putters (4, 16, 33). Olympic-style lifts (Clean, Jerk, and Snatch) and their derivatives (Pulls and Shrugs) are the core of the resistance training program for shot put athletes. In addition to the weight lifting exercises, throws, sprint drills, and jumps, the workout contains sport-specific release movements that force core stabilization of

high velocity activities (15). Thus, how maximum strength and power are effectively developed are important issues for athletes and coaches.

Having discussed numerous considerations for improvement in the shot put throw, it is important that coaches prioritize training stimuli. In order for coaches to properly emphasize the key components to training a shot putter, it is also imperative that the coaches understand which variables are most essential to shot putting success. The purpose of this pilot study was to examine the quadratic nature of the relationship between the strength and throwing distance in the shot put.

METHODS

Participants

The institutional review board at Ball State University approved this investigation. The 24 male (mean=22.2, $s=2.2$ years) and 29 female (mean=22.5, $s=2.8$ years) athletes had a mean personal best performance of 16.93, $s=2.45$ meters for the men and 15.24, $s=2.85$ meters for the women. Of the 53 shot putters participating in the investigation, the majority utilized the glidetechnique (60.4%) ($n = 32$) and a smaller number utilized the rotational (spin) technique (39.6%) ($n = 21$). Characteristics for the participants can be seen in Table 1. It should be noted that based upon the reported personal bests, the athletes who volunteered were all NCAA Division I athletes or elite competitors and many were all conference performers or national qualifiers. Participants were also chosen based upon their coach being either a Level II coaching education instructor or Level III certified coach by USA Track and Field. This was selected as an inclusion criterion

in order to limit in some fashion the differences in technical instruction received by the athlete. Given the exploratory nature of this study, it was necessary to set parameters to enhance consistency in assessment. All 53 participants gave consent and were selected to be part of the present investigation.

Table 1: Participant Characteristics (Mean \pm s)

Variable	Male (n=24)	Female (n= 29)
Age	20.4 \pm 1.1yrs	20.2 \pm 1.6yrs
Height	1.87 \pm 0.06m	1.76 \pm 0.08m
Weight	123.2 \pm 10.8kg	95.5 \pm 16.3kg
Bench Press		
1RM	177.0 \pm 34.1kg	97.0 \pm 22.2kg
Squat 1RM	255.2 \pm 49.2kg	153.9 \pm 40.8kg
Power Clean		
1RM	139.2 \pm 22.6kg	96.1 \pm 25.2kg
Shot Put SB	16.93 \pm 2.45m	15.24 \pm 2.84m

Procedures

Experimental design: A survey instrument was developed to collect data regarding national level collegiate shot putters in the United States. The 24 males and 29 females athletes had a mean personal best performance equivalent to the mark needed to qualify for the NCAA division I outdoor nationals preliminary round. The sample included several national qualifiers, two national champions in shot put and three Olympians. Trends in the relationship between 1RM power clean and personal best in the shot put for male and female athletes were assessed via general linear model polynomial contrast analysis, and subsequent polynomial regression.

After giving consent, the coach of each athlete was asked to report via a datasheet the age, height and weight for each athlete, as well as their personal record in the shot put event and their weight room 1RM for

bench press, power clean and squat exercises (Table 1). Following the coaches' report, the data for each athlete was entered into a spreadsheet program and the data report sheets were destroyed in order to maintain athlete confidentiality.

Statistical Analysis

Variables of interest were entered into a linear multiple regression model to predict shot put personal record. Trends in the relationship between 1RM power clean and personal best in the shot put for male and female athletes were assessed via general linear model polynomial contrast analysis, and subsequent polynomial regression. Variables entered into the model were based upon previous work and included gender and power clean 1RM. Gender was included in the model to account for differences in male and female athletes (weight of the implement, strength levels, etc.). A modern statistical software package was used to perform the analysis (SPSS version 17.0) and statistical significance was set *a priori* at $\alpha < 0.05$.

RESULTS

General linear model analysis revealed both significant omnibus tests of the models (male likelihood ratio $\chi^2 = 56.716$, $p \leq 0.001$, female likelihood ratio $\chi^2 = 102.516$, $p \leq 0.001$) and significant linear and quadratic trends in the data for male and female shot put athletes when comparing 1RM power clean to personal best distance (male: Wald $\chi^2 = 179.937$, $p \leq 0.001$ linear, Wald $\chi^2 = 8.598$, $p = 0.003$ quadratic; female: Wald $\chi^2 = 738.577$, $p \leq 0.001$ linear, Wald $\chi^2 = 134.864$, $p \leq 0.001$ quadratic). Quadratic regression analysis resulted in strong curve fitting with both male ($r = 0.854$, $F = 28.361$, $p \leq 0.001$, versus $r = 0.828$ linear regression)

and female ($r = 0.935$, $F = 86.616$, $p \leq 0.001$, versus $r = 0.896$ linear regression) athletes data.

Regression model for male participants yielded the following equation:

$$PB = -0.0008411676818853924P_{wrcI2} + 0.3284949945786421P_{wrcI} - 12.08001098449343$$

Regression model for female participants yielded the following equation:

$$PB = -0.001045453485274876P_{wrcI2} + 0.2850773155884497P_{wrcI} - 1.706062763795432$$

Where PB is personal best in meters, and PwrCl is one repetition power clean maximum in kilograms for males (Figure 1) and females (Figure 2).

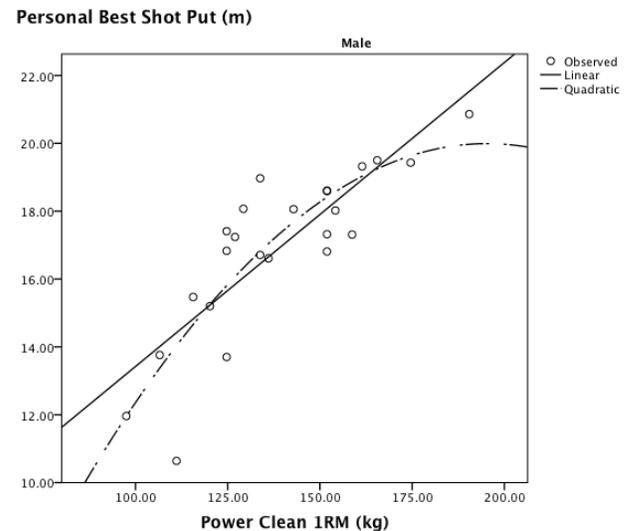


Figure 1. Scatterplot for Personal Best Throw (m) in the shot put by 1RM Power Clean (kg) for male participants. Dashed line represents quadratic regression, solid line represents linear regression (linear: $p \leq 0.001$, quadratic: $p = 0.003$).

Comparison by technique: Chi-square analyses were utilized to determine if there

was a difference in the 1RM power clean of glide vs. rotational (spin) shot putters. The analyses revealed no significant difference ($p > .05$) between the 1RM power clean of the athletes utilizing the glide technique (60.4%) ($n = 32$) and spin technique (39.6%) ($n = 21$). Generally the proportions of the 1RM power clean were comparable with similar distributions.

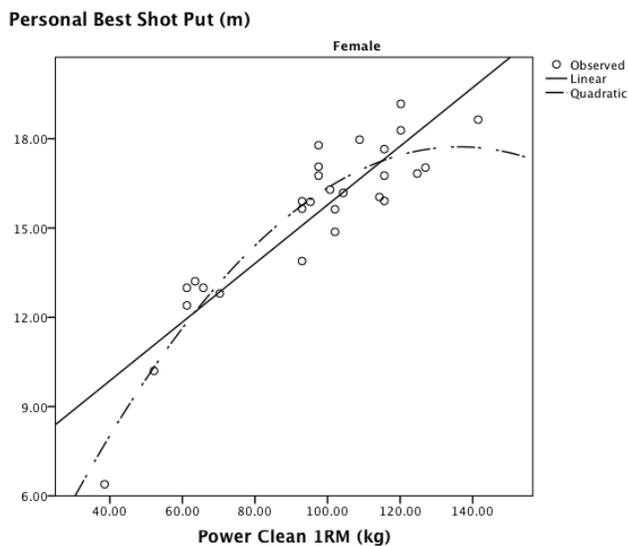


Figure 2. Scatterplot for Personal Best Throw (m) in the shot put by 1RM Power Clean (kg) for female participants. Dashed line represents quadratic regression, solid line represents linear regression (linear: $p \leq 0.001$, quadratic: $p \leq 0.001$).

DISCUSSION

The following results warrant more attention from professionals in the field of strength and conditioning. It should be noted that the average season's best performance among the male and female participants would have qualified for the preliminary rounds of the NCAA Division I outdoor track and field championships this past season, and among the group there were a number of NCAA outdoor national qualifiers. The group of shot putters examined was therefore composed of very

highly skilled athletes. This was in addition to the inclusion criteria that the coach of the athletes had to either possess a USATF level 3 or Master Coach distinction, this further attests to the likelihood that these athletes had well-developed and consistent technique, making for a good sample from which to draw conclusions about the relationships of preseason strength to competitive season performance. The preseason strength numbers were chosen for comparison because during the competitive season the vast majority of coaches of the shot put switch focus to the development of event specific strength and technique and are no longer devoting as much practice time to the development of absolute strength. This study does demonstrate that high strength levels are necessary in order to attain a level of performance that is necessary to be among the best of collegiate athletes. The mean kilograms lifted for all three lifts for both male and female athletes was very high and in all cases still well above the body weight of the athletes, which is impressive given the mass of the athletes in question.

Though it has long been known that strength is a necessary component of the performance in track and field throwing events (1, 19, 24, 36) it is not well understood what the relationships of the individual lifts are to competitive season performance. In discussions with college coaches, one can find that there is a lack of consistent thought about which of the three lifts, the bench press, back squat or power clean, is the most important for the shot put event. Most sources of training information for coaches suggest that all three lifts need to be covered within a training plan for a shot put athlete (15, 16, 18, 31).

General linear model analysis revealed both significant omnibus tests of the model and significant linear and quadratic trends in the data for male and female shot put athletes when comparing 1RM power clean to personal best distance. Based upon the results of the present investigation it is apparent that the power clean is closely related to elite performance in the shot put. Terzis, Georgiadis, Vassiliadou, and Manta (35) examined a group of shot putters and concluded that performance in the shot put was directly related to the strength and muscle fiber composition of the triceps brachii. However, this study was conducted on a relatively small sample and did not take into account the impact that lower body strength and power had on the performance of the athletes in question. In a later study, Terzis et al. (36) found a positive correlation between shot put performance and the 1RM squat and 1RM bench press. The present investigation appears to support those findings, but based upon a larger sampling of athletes, strength in both the lower and upper body is critical to performance in the shot put, and that the ability to overcome a heavy resistance during a complex lift such as the power clean may be the most predictive of success in the shot put event. But keep in mind that strength numbers can be misleading or misrepresented. As shown in the quadratic regression, there may be a leveling off effect towards the outer ranges of 1RM performance in the power clean whereby greater levels of strength are not related to large changes in shot put performance. The quadratic graphs suggests that while power development in shot putters is important and related to performance, the attainment of ever-increasing levels of strength may not be necessary to perform at very high levels.

Various studies and review articles have reported data and logical arguments for the use of explosive exercises for throwers (2, 15, 18, 19, 33). Olympic-style lifts (Clean, Jerk, and Snatch) and their derivatives (Pulls and Shrugs) are the core of resistance training programs of strength/power athletes (14, 33). Garhammer (10) reported that snatch and clean and jerk exhibit much greater velocities compared with squat and dead lift. Numerous investigations (13, 14, 32, 37) have examined the effects of training with weightlifting exercises on the performance of speed and power events. Stone et al., (32), reported that 14 weeks training with weightlifting exercises enhanced jump performance significantly. Hoffman et al. (13) compared the effects of 15 weeks of weightlifting (i.e. snatch) exercises versus power lifting (strength) exercises (i.e. squat, bench press, and dead lift) on jumping and sprinting performance, and reported that weight lifting exercises were more effective in improving jumping performance. Tricoli et al. (37) reported that the weightlifting group showed greater improvement in jumping and sprinting performance as compared with a vertical jump-training group after an eight-week training intervention. Hori et al. (14) reported the training of the weightlifting exercises such as the hang power clean may be effective to improve the athlete's capability of power, and subsequently athletic performance which requires high power for skills such as jumping and sprinting. The results of these studies support the importance of including explosive lifts in the training program of athletes in speed and power events like the shot put. Research has shown maximum strength and peak power have moderate to high correlations (32). But Hori et al. (14)

recommends that coaches take a holistic approach to training, which includes skill practice in addition to development of maximum strength and power.

Beyond physical characteristics, distinct motor abilities may also help to answer the questions of training emphasis. There has also been discussion that success in the rotational technique in the shot put may rely more on biomechanical advantages rather than on the strength of the athlete (20). There are inherent differences between the two different styles of shot putting (21), which extend to the creation of a great amount of pre-stretch in the musculature of the upper body in the rotational technique prior to the delivery of the implement (12). If greater prestretch is created in successful rotational shot putters then these muscles may react with higher force production, allowing athletes with lower levels of strength to deliver the shot put more effectively at the end of the movement. This may in part explain why a higher ratio of absolute strength in the bench press lift to personal best distance was reported among glide athletes by Judge, Bellar, McAtee, and Judge (17). Presumably, if development in the spin technique was more dependent on skill, beginners would likely perform better with the glide technique. Research on this very subject is inconclusive. Suggestions from practitioners indicate that the most important characteristics to be successful in the glide technique are size (both height and weight) and strength (5, 8, 15, 18, 23). Similarly it has been suggested that athletes using the spin technique possess good balance, coordination, flexibility and speed (25, 26, 38).

As the knowledge base for training strategies continues to evolve, coaches must

adapt their practices to ensure their athletes are being properly prepared for training and competition. Ignoring the benefits of weight lifting exercises like the power clean clearly puts the shot putter at a competitive disadvantage. Detractors suggest a much simpler training (bodyweight resistance & machines) approach is sufficient to obtain the necessary benefits without the danger of more complex efforts (9). The reasons for this disconnect between current research and practice is unclear, but coaches are creatures of habit and often become entrenched in traditional dogmatic practices (22). As Newton and Jenkins suggest, the reluctance to teach explosive exercises may be associated with the amount of time needed to master the technical intricacies of the snatch, clean, and jerk. This opposition may also reflect the challenge of acquiring adequate coaching of the lifts. Explosive exercises like the power clean can be easily administered by a strength and conditioning professional as required throughout a season according to the periodized training plan. Without concrete goals and objectives planning resistance training workouts becomes misguided and the plan will lack controls over training outputs.

Through the study of sport science, researchers have established a better understanding of how the human body reacts to different training stimuli (6). Olympic-style lifts (Clean, Jerk, and Snatch) and their derivatives (Pulls and Shrugs) are now the core of the resistance training program in many sports. It can be suggested to coaches of the shot put event that the power clean exercise be incorporated into the training plan of the athletes. The importance of the power in the power clean lift to performance among

collegiate and elite shot putters should be considered by coaches and tested on a regular basis. However, practitioners should be advised that with athletes of considerable ability in the power clean attainment of greater levels of strength in this lift may not be related to changes in shot put performance.

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