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Determinants of Shot Put Performance: A Mathematical Approach

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Abstract

Shot put is an athletic field event in which the distance of the throw depends on several physical and biomechanical factors. This study presents a mathematical analysis of shot put performance by applying the principles of projectile motion and mechanics. Important parameters such as the angle of release, initial velocity, height of release, and gravitational acceleration are considered to understand their influence on the range of the shot. Mathematical models are used to derive equations describing the trajectory of the shot and to determine the conditions for maximum distance. The analysis shows that optimal performance depends not only on the theoretical projection angle but also on the athlete's ability to generate maximum velocity and maintain proper technique. The study highlights how mathematical modeling can help in understanding shot put mechanics and can assist athletes and coaches in improving performance through scientific training methods.

Keywords: Shot Put, Projectile Motion, Mathematical Modeling, Angle of Release, Initial Velocity, Trajectory Analysis, Biomechanics, Athletic Performance.

1. Introduction

Shot put is one of the most significant and technically demanding field events in athletics. In this event, an athlete throws a heavy spherical object, known as a shot, from the shoulder with the aim of achieving the maximum possible horizontal distance. Unlike many other throwing events, the shot must be pushed or "put" rather than thrown, which makes the technique, body coordination, and strength of the athlete extremely important. The event requires a combination of muscular strength, explosive power, balance, and precise body mechanics. Because of these characteristics, shot put has become an interesting subject not only in sports science but also in biomechanics, physics, and mathematical modeling. The history of shot put can be traced back to ancient times when people competed by throwing heavy stones to demonstrate their strength and physical ability. Such contests were common in ancient civilizations and gradually evolved into organized sporting activities. During the seventeenth century, stone throwing competitions became popular in England and Scotland, where athletes competed in throwing heavy objects as part of local festivals and athletic events. Over time, the stone was replaced by a round metal ball, leading to the development of the modern shot put. The event became officially recognized in international athletics competitions and was included in the first modern Olympic Games held in Athens in 1896 for men. Later, the women's shot put event was introduced in the Olympic Games in 1948. Since then, shot put has remained an important event in

international athletics competitions such as the Olympic Games, World Championships, and national athletic meets. In modern competitions, the shot used by male athletes weighs 7.26 kilograms, while the shot used in women's competitions weighs 4 kilograms. The event is performed within a circular throwing area known as the throwing circle, which has a diameter of approximately 2.135 meters. Athletes must generate maximum force and momentum within this confined space while maintaining balance and adhering to strict competition rules. The throw must be executed in such a way that the shot leaves the athlete's hand from near the neck and travels through the air before landing in a designated sector. Over the years, athletes and coaches have developed different techniques to enhance performance in shot put. Two of the most widely used techniques are the glide technique and the rotational or spin technique. The glide technique, popularized by the American athlete Parry O'Brien in the 1950s, involves starting from a backward-facing position and sliding across the throwing circle before releasing the shot. This technique allows the athlete to generate forward momentum and increase the velocity of the shot at the moment of release. The rotational technique, on the other hand, involves a spinning movement similar to the technique used in discus throw. This method helps athletes generate greater angular momentum and often results in higher release velocities. Both techniques aim to maximize the speed of the shot while maintaining control and balance within the throwing circle. From a scientific perspective, the motion of the shot after it leaves the

athlete’s hand can be analyzed using the principles of classical mechanics, particularly the theory of projectile motion. Once released, the shot follows a curved path under the influence of gravity. The distance that the shot travels depends on several important factors, including the initial velocity of projection, the angle of release, and the height from which the shot is released. Among these factors, the initial velocity of the shot plays the most crucial role in determining the final distance. However, the angle of projection and the release height also significantly influence the trajectory and range of the shot. Mathematical analysis provides a useful framework for understanding how these variables interact and influence the performance of an athlete. By applying the principles of physics and mathematics, it is possible to develop models that describe the trajectory of the shot and predict the horizontal distance it will travel. Such models help in determining the optimal conditions for achieving maximum range. For example, theoretical analysis suggests that the optimal angle of release in shot put is typically less than the 45 degrees predicted for simple projectile motion, mainly because the shot is released from a height above the ground and the athlete’s body movement influences the trajectory. The study of shot put performance through mathematical analysis is important not only for theoretical understanding but also for practical applications in sports training and performance improvement. Coaches and sports scientists often use biomechanical and mathematical studies to evaluate athletes’ techniques and identify areas for improvement. By understanding the relationships between release velocity, projection angle, and release height, athletes can adjust their training strategies to achieve better results. Moreover, such analysis helps in designing training programs that enhance strength, coordination, and technical efficiency. The main objective of this study is to analyze shot put performance from a mathematical and physical perspective. The paper aims to examine the fundamental factors that influence the distance achieved in shot put and to develop a mathematical model that explains the projectile motion of the shot after release. Through this analysis, the study seeks to provide a clearer understanding of how different physical and mechanical parameters affect the performance of athletes. The findings of this analysis may contribute to improved training techniques and a deeper appreciation of the role of mathematics in sports science. Shot put, in athletics, is a game in which a spherical weight is thrown or “put” from the shoulder for a distance. Ancient people used to throw a piece

of stone instead of the present day round shaped ball (shot). Common ball throwing contests were organized in 17th century England, although Scottish athletics had an analogous event.

The first to use such shots instead of stones competitively were British military sports groups, and in the first modern Olympic Games (1896) the event adopted throwing a shot of weight 7.26 kg for men in international competition. The event was added to the women’s Olympic programme in 1948. The weight of the shot used for women’s competition is 4 kg. Lighter weight shots are also used in school, college and veteran competitions.

2. Standard Shot Weights

Table 1: Standard shot weights used in competitions.

Category	Shot Weight
Men	7.26 kg
Women	4 kg
School/Junior	Lighter weights

The shot generally is made of solid iron or brass.

3. Putting Style of Shot

It had long been conventional to start from a position facing a right angle to the direction of the put. Currently shot put competition generally uses two putting styles:

- Glide technique
- Spin technique

i). Glide Technique

The origin of the glide dates to 1951, when Parry O’Brien of the United States invented a technique that involves the putter facing backwards, rotating 180 degrees across the circle, and then releasing the shot. With this technique, a right-hand thrower begins facing the rear of the circle and kicks to the front with the left leg while pushing off forcefully with the right.

ii). Spin Technique

Instead of the glide, Alexander Baryshnikov used a new style called the spin technique. This technique was invented by his coach Viktor Alexeyev. It involves rotational movement similar to discus throwing to generate greater momentum.

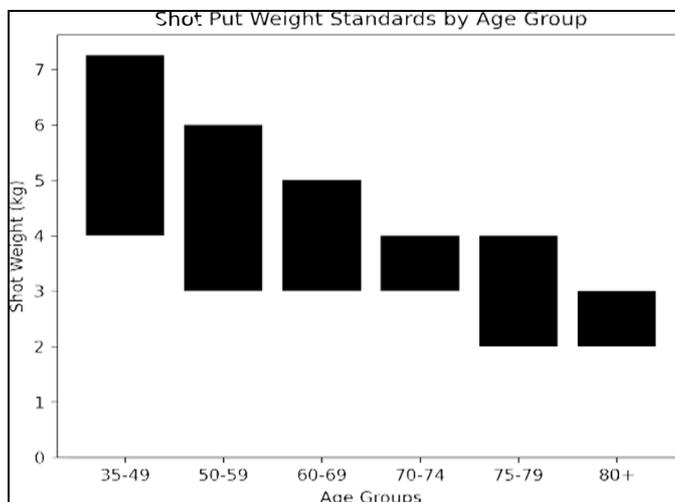


Fig 1: Statistical plot of the shot put performance

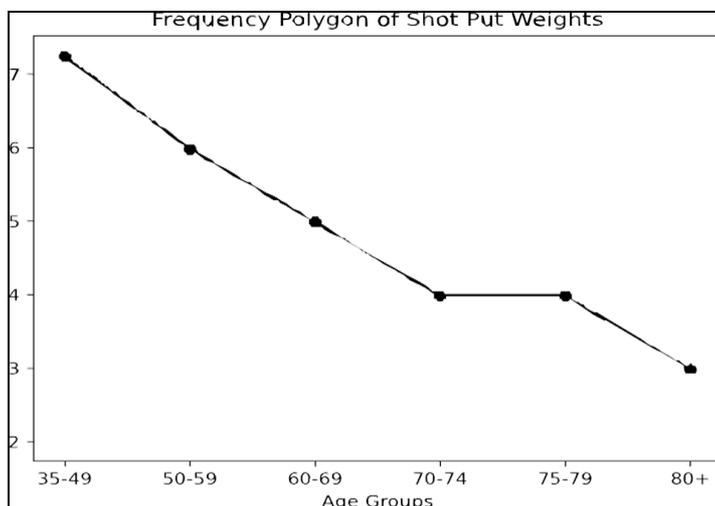


Fig 2: Statistical plot of the shot put performance

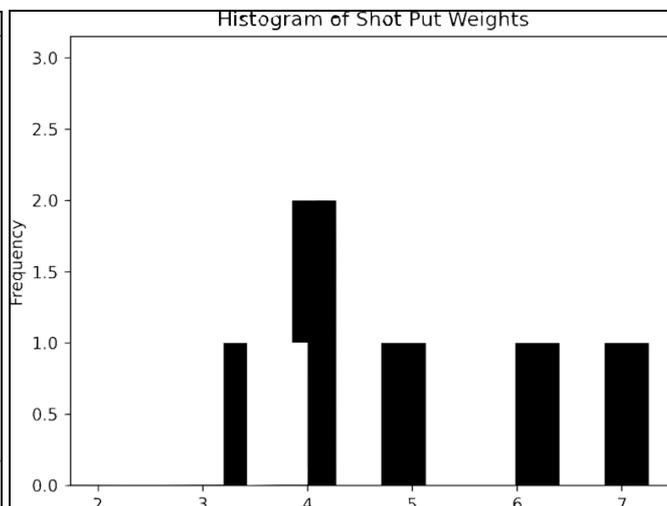


Fig 3: Statistical plot of the shot put performance

4. Conclusions

Shot put is a highly technical athletic event that requires a combination of strength, coordination, and proper technique to achieve maximum performance. In this study, the performance of shot put has been analyzed from a mathematical and physical perspective. By applying the principles of mechanics and projectile motion, it becomes possible to understand how different factors influence the distance traveled by the shot after it is released. The analysis shows that the trajectory of the shot follows the laws of projectile motion and is mainly governed by three important parameters: the initial velocity of the shot, the angle of projection, and the height of release. Among these factors, the initial velocity plays the most significant role in determining the horizontal range of the shot. A greater release velocity generally results in a longer throwing distance. However, the angle of projection and the release height also have a considerable influence on the final range, and an optimal combination of these parameters is necessary for achieving the best performance. The study also highlights the importance of proper technique in shot put, particularly the glide and rotational techniques used by modern athletes. These techniques help athletes generate greater momentum and release velocity within the limited space of the throwing circle. Through mathematical modeling and analysis, it becomes clear that improvements in technique can significantly enhance the effectiveness of the throw.

Furthermore, the mathematical analysis presented in this work provides valuable insights for coaches, athletes, and sports scientists. By understanding the relationships between physical variables and the resulting motion of the shot, athletes can optimize their training methods and improve their performance. Mathematical and biomechanical studies therefore play an important role in bridging the gap between theoretical science and practical sports performance. In conclusion, the application of mathematical principles to the study of shot put performance provides a deeper understanding of the mechanics involved in the event. Such analyses not only contribute to the academic study of sports science but also offer practical guidance for improving athletic techniques and achieving better results in competitive shot put events.

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