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# COMPARATIVE KINEMATIC ANALYSIS OF RELEASE OF THE BEST SERBIAN SHOT PUTTERS

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**A. Aleksić-Veljković, M. Puletić, A. Raković, R. Stanković, S. Bubanj, D. Stanković**

Faculty of Sports and Physical Education, University of Niš, Serbia

**Abstract**. *In recent years there have been a number of researchers studying the techniques of shot put parameters and factors that are crucial for achieving top results, as well as those necessary for optimal performance. The aim of this study was to determine differences in the parameters of release of top Serbian athletes. The throwing technique was taken at the Serbian Cup 2011 for the competitors who achieved the best results. The values of the variables were determined by using software for 2D kinematic analysis, "Human", version 6.0 HMA Technology Inc. 2005, United States of America (Human). The first place contestant scored a higher release speed of 13m/s¯¹ (13.79m/s¯¹), while the speed of the second and the third was much lower (11.9m/s¯¹ and 11.68m/s¯¹). The maximum height of release was determined for the second-placed competitor (2.22m), then for the first-placed (2.07m) and the third-placed competitor (2.05m). The angle of release for the top-placed competitor was 40.4˚, 42.8˚ for second placed and 41˚ for the third placed. In the case of the top-ranked competitor and the third there is the possibility of increasing the horizontal length of the shot put, which would lead to greater distance. The significance of this research is to obtain useful information for coaches and athletes, which will contribute to the further improvement of techniques. It is necessary to conduct further and more detailed studies of phases preceding the release, on which the proper performance of the release phase and achievement of the best possible results depends.*

**Key words**: *release velocity, release angle, release height.*

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**Corresponding author**: A. Aleksić-Veljković
Faculty of Sports and Physical Education, University of Niš, Serbia
E-mail: axy_gym@yahoo.com
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## INTRODUCTION

The shot put technique involves a series of complex movements within a limited area of a circle which must have a diameter of 2.135m (± 5mm) with a board firmly fixed to the fingers connected to the ground outside the outer limits of the circle. The rules require that the shot must be spherical, and weigh 7260kg for men and 4,000kg for women (IAAF Competition Rules 2010-2011). The achieved result of the throw depends on morphological characteristics, motor abilities, and throwing technique (Čoh and Jošt, 2005). In Linthorne's opinion (2001) the throwing technique requires great throwing explosive strength and the ability to perform the elements in the precise moment and in limited space. The goal of the athlete is to throw the shot away as far as possible, but according to the rules and regulations of the competition. Rotational (spin) and the Slide (O'Brien) throwing techniques are considered equal, but it was noticed that beginners and female athletes often use the slide technique, while men use the rotational technique of throwing more often (Young, 2009).

A large number of researchers in recent years have studied the rotational parameters of ball throwing techniques (Luhtanen, 1997; Čoh, Čuk and Jošt, 2005; Čoh, Stunec, Smajlović and Supej, 2008, Ariel et al., 2004) but the main objective is to determine the most important factors which influence the results, as well as the critical points in the execution (Linthorne, 2001; Liu, 2001; Harasin, 2010;). Luhtanen (1997) confirmed the earlier results that a major change in the speed of throw during the second phase is the most important double-leg factor for distance throws. The critical phase of the technique may be the phase of flight in the middle of the rotation since the speed is at its lowest rate at that point. In order to achieve the greatest possible distance the athlete has to project the best combination of throwing speed, angle and height of ejection. The highest correlation exists between the throwing distance and release velocity. That is the most important factor in throwing (Langhorne, 2001).

In their research Čoh and Jošt (2005) define some of the most important kinematic parameters of the rotational shot put technique. They used a 15-segment model of the thrower with 23 reference points defined. The results showed that the top result of the throw depends on release velocity, the optimal angle of release, the relation between the rotational motion and acceleration of the final shot, and the angular velocity of the elbow and shoulder joints of the used hand. The key phases which ensure correct rhythm and generate high release velocity of the shot are the following: flight phase, second single support phase and second double support phase.

The authors Čoh, Stunec, Smajlović and Supej (2008) investigated the rotational model of the two techniques of elite shot putters with different anthropometric measures. Differences were found for: release velocity, release height, the maximum angular velocity in the elbow joint of the throwing hand, the trajectory of the thrower and the shot, torsional rotation in the shoulder joint compared to the axis of the hip joint, maximum force focused on the ball, the kinetic energy independent of the sphere. Critical factors measured in this study included the speed of turning the right foot and the maximum force developed, the angle and height of release and release velocity during the last phase. These factors are examined in connection with each athlete's throwing distance.

A greater angle of release causes a higher shot flight from the ground, but lower speed. During the flight phase the shot acts as a projectile in free flight and its path can be calculated by using data on the conditions of release. Linthorne (2001) aims to assess the

accuracy of the method of calculating the angle of ejection for throwing shots. With this method the optimal angle of release, which produces the longest distance, is calculated by combining the equation for the range of missiles during free flight with a connection among the release velocity, release length and angle of release.

A crucial finding of the study of Harasin (2010) is that the swing of the left hand must be performed with an amplitude that allows the prestretching of structures that are active in the pushing phase or with an amplitude that does not allow an increase in the shot movement radius. Release parameters are very important for successful performance and are mutually dependent. When the throw is made above the horizontal plane, the length of the throw depends on the height, angle and velocity of the release (Wang and Chen, 2002). When athletes throw with a high angle of release, the shot is thrown to greater heights, but with lower velocity. Simple models of throwing were developed to explain the relationship between the release velocity, height and angle related to the anthropometric measures and motor abilities of athletes (Linhorne, 2001).

## THE METHOD

The aim of this study is a comparative analysis of the kinematic parameters of the shot put of elite Serbian athletes: Asmir Kolašinac (27 years old, 135kg, 187cm, BMI 38.6), Miloš Marković (22 years old, 135kg, 209cm, BMI 30.9) and Željko Milovanović (31 years old, 135kg, 192cm, BMI 36.6). They are the best competitors in the Serbian Cup in 2011, where the throws were also recorded.

The values of the variables were obtained using software for 2D kinematic analysis, "Human", version 6.0 HMA Technology Inc. in 2005, United States of America (Human, nd). The recordings were made with a Casio FX camera, which recorded a rate of 300 frames per second. The camera is positioned so that its lens is perpendicular to the direction of the movement. The 9-body segment model of asymmetrical launchers with 23 reference points was digitalized. Two throws were performed with a rotational and one with a glide technique, and only the last phase of the throw was analyzed. These results were compared with the results of previous studies in which respondents are top athletes, as well as comparing the optimal values of the parameters analyzed in previous studies.

## RESULTS

Table 1 shows the placement, and the results achieved for the parameter value span of the top Serbian shot putters. Image 1 (Kolašinac Asmir, frame 445), 2 (Miloš Marković, frame 390) and 3 (Željko Milovanović, frame 481) show the release moment of shots for each of the contestants.

The best measured throws were 20.50m for Asmir Kolašinac (this result was in the qualification norm for the World Championships in Daegu 2011), 18.29m for Miloš Marković and 17.71m for Željko Milovanović. The release velocity was highest for the top ranked athlete 13.79 $m/s^{-1}$, 11.90 $m/s^{-1}$ for the second and 11.68 $m/s^{-1}$ for the third ranked. Release angle, height of release and horizontal release distance were highest for the second ranked thrower (42.8˚, 2.22m and 0.20m). The lowest release angle was for the first ranked thrower (40.4˚) while the lowest height of the release and horizontal release distance was noted for the third ranked thrower (2.05m and 0.01m).

**Table 1**. The placement of competitors, the results achieved and the kinematic parameters of the release phase

| Competitor | Result | Distance (m) | Realise velocity ($m*s^{-1}$) | Realise angle (°) | Height of realise (m) | Horisontal release distance (m) |
|---|---|---|---|---|---|---|
| Kolašinac Asmir | Gold (1) | 20.50 | 13.79 | 40.4 | 2.07 | 0.13 |
| Marković Miloš | Silver (2) | 18.29 | 11.90 | 42.8 | 2.22 | 0.20 |
| Milovanović Željko | Bronze (3) | 17.71 | 11.68 | 41 | 2.05 | 0.01 |

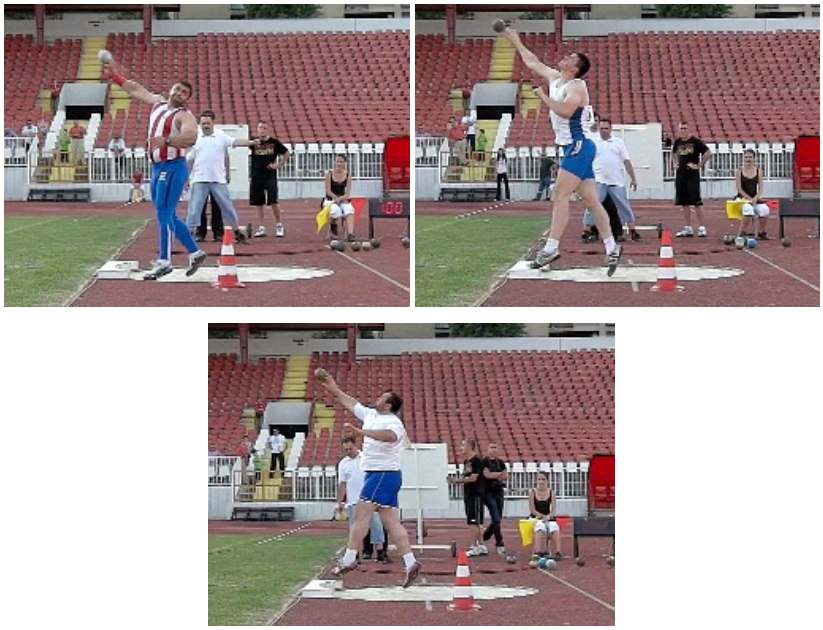

**Fig. 1**. Moment of release: Kolašinac Asmir (frame 445), Milos Markovic (frame 390) and Zeljko Milovanovic (frame 481)

## DISCUSSION

The release velocity of the analyzed results of the throw is similar to that determined by other authors in their studies. Only the winner contestant scored a release velocity higher than of 13 $m/s^{-1}$ (13.79 $m/s^{-1}$), which is necessary to achieve superior results to win medals in international competitions. For a throwing distance of 21m, a release velocity of 13.5 $m/s^{-1}$ (Young, 2009) is required. Release velocity is crucial in achieving results because the length of the throw is proportional to its square. The aim of coaches and scientists is to increase speeds over 13 $m/s^{-1}$ (Harasin, Milanović and Čoh, 2010). In the

case of the second and third-placed athlete, release velocity is significantly lower than that of the top thrower in the literature and is 11.9 $m/s^{-1}$ and 11.68 $m/s^{-1}$, which is not enough to achieve top results. The authors Čoh and Jošt (2005) indicate that the rate achieved during the release is associated with the angular velocity for the elbow and shoulder joints of the throwing arm. Release speed decreases with the increase of the angle, approximately 1.7 (m/s)/rad and decreases with the increase in height, approximately 0.8 (m/s)/m and is inversely proportional to the angle of release (Hubbard et al., 2001, Wang and Chen, 2002).

The height of the release of the best throwers is between 2 and 2.2m (Young, 2009). For the throws analyzed in this study the release height is 2.07m for the first-ranked, 2.22m for the second and 2.05m for the third-placed competitor, which is consistent with the previous studies. With the increase in the angle of release, the velocity decreases to 0.8 (m/s)/m (Hubbard et al., 2001). However, the height of release depends on the height of the thrower, since the highest thrower (measured at 209cm) had the highest release height (2.22m).

The angle of release is the relative angle between the horizontal axis and the shot trajectory and largely depends on the position of the trunk and the throwing arm. The inclination of the trunk in the sagittal plane and the angle of the extension of the throwing arm which is related to the trunk affects the angle of release (Young, 2009). The angle of release in the top-placed competitors is 40.4˚, 42.8˚ for the second placed and the third placed is 41˚. In all of the analyzed throws the angle of release is higher than recommended, although in the literature there is a considerable disagreement about the size of this angle. For the best thrower the angle of release is significantly lower than 40˚ in relation to the horizontal axis (Ariel et al., 2004; Čoh and Jošt, 2005).

The fourth parameter of release, which is rarely taken into account, is the horizontal length of the release, related to the foot board. A greater horizontal length of release is useful because it provides a favorable point of measuring distance. According to Lindsay (1994 cited in Young, 2009), the length of the horizontal distance of release of the rotational and sliding-throwing techniques is similar, and it ranges from 0.10m behind the boards to 0.25m in front of the foot boards. The official results of throwing represent the sum of the projected distance and horizontal release distance. To minimize the loss in the release distance, the horizontal length of the throw distance should be reduced (Liu and Wang, 2002). The horizontal distance decreases with the increase of the angle of release for about 1.7m/rad and increases with the angle of release of about 1.3m/m, with small differences between the two throwers (Liu and Wang, 2002). In the case of the top-ranked competitor and the third-ranked, there is the possibility of increasing the horizontal release distance, which would lead to greater results.

## CONCLUSION

The result of the shot put mostly depends on the ability of the athlete to make the throw with the best combination of velocity, the optimum angle, height and release distance. In this paper, the release parameters were compared with the best Serbian throwers. In order to obtain more precise data, which are necessary to correct errors in technique and execution to achieve better results, further research will focus on the analysis of other phases in both the rotational and slide throwing techniques. The significance of this research is to obtain useful information for coaches and athletes, which will make a contribution to further improvement in techniques and results.

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# KOMPARATIVNA KINEMATIČKA ANALIZA BACANJA NAJBOLJIH SRPSKIH BACAČA KUGLE

**A. Aleksić-Veljković, M. Puletić, A. Raković, R. Stanković, S. Bubanj, D. Stanković**

*U poslednjih nekoliko godina javio se veći broj naučnika koji se bave parametrima tehnike bacanja kugle i faktora koji su od ključnog značaja za postizanje najboljih rezultata, kao i onih koji su neophodni za optimalnu performansu. Cilj ovog istrazivanja bio je da se utvrde razlike među parametrima za bacanje vrhunskih srpskih sportista. Tehnika bacanja uzeta je sa Serbian Cup 2011 za one takmičare koji su imali najbolje rezultate. Vrednosti varijabli utvrđene su upotrebom programa za 2D kinematsku analizu, "Human", verzija 6.0 HMA Technology Inc. 2005, SAD (Human). Pobednici su imali veće vrednosti brzine pri bacanje 13m/s⁻¹ (13.79m/s⁻¹), dok je brzina drugo i treće plasiranog bila znatno niža (11.9m/s⁻¹ i 11.68m/s⁻¹). Najveću visinu bacanja postigao je drugoplasirani takmičar (2.22m), zatim prvoplasirani (2.07m) i trećeplasirani takmičar (2.05m). Ugao bacanja prvoplasiranog bio je 40.4˚, 42.8˚ drugoplasiranog i 41˚ za trećeplasiranog. Kod najbolje plasiranog takmičara i trećeplasiranog postoji mogućnost povećanja horizontalne dužine bacanja, što bi i dovelo do veće distance. Značaj ovog istraživanja je da prikupi informacije korisne za trenere i sportiste, koje bi omogućile dalje napredovanje tehnike. Neophodno je da se vrše dalje detaljnija istraživanja faza koje prethode bacanju, od čega zavise mogući rezultati.*

Ključne reči: *brzina puštanja, ugao bacanja, visina bacanja.*