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Original research article

KINEMATIC DIFFERENCES IN PARAMETARS OF ELITE FOREIGN AND ELITE SERBIAN WOMEN JAVELIN THROWERS *

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Abstract. *The aim of this study is to determine the differences in kinematic parameters between the 2011 Serbian Cup Final female senior javelin throwers (N=10, age 18,3, height 170,5cm, weight 73,5kg), and the 2011 World Championships senior javelin throwers (N=3, age 27,6, height 176,3cm, weight 75,3kg). Statistical analyses were performed by using Statistica 7.0. (StatSoft Inc., Tulsa, USA). Statistically significant differences were found in the variables RES (p=0,000), RV (p=0,012), RH (p=0,038), AAR (p=0,048) and AAA (p=0,007) at the significance level of p<0,05. Female senior javelin throwers of the 2011 Serbian Cup Final should be directed towards further improvement of the javelin throwing technique, especially in the predelivery and the delivery phase while performing the impulse and the release stride.*

Key words: *Release velocity, release height, impulse stride, delivery stride.*

INTRODUCTION

The javelin throw is one of the throwing disciplines in athletics, in addition to the shot put, hammer and discus throw. The javelin technique includes an introductory phase, the run-up phase, maximum acceleration phase and release phase (Branković & Bubanj, R., 1997). During the run-up phase the thrower accelerates up to a level which will enable him to control and intensify his speed during further action (Bubanj, R., 1997). In correct throwing techniques the timely activation of the muscles is required. Bartonietz (2000)

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suggests that force during throws is generated by leg extension, hip rotation and trunk flexion. In the final phase of the throwing trajectories the center of gravity of javelin and the throwers body are the most important for research (Bubanj, R., 1997).

The most frequently analyzed kinematic parameters are velocity, height and angle of release, the run-up speed in the last strides, the angle of the knee joint of the right leg (Campos, Brizuela, & Ramon, 2004; Hong, Lee & Kim, 2004), and aerodynamic factors of javelin flight (Hatton, 2007; Xie et al., 2002). Efficient use of the run-up is important for achieving good results (Carr, 2004). The speed of the thrower to the last step is about 8-9m/sec so that in the phase of release the speed of the thrower decreases and the speed of javelin increases. Like other throwing disciplines, the release velocity is the most critical factor in the javelin throw. Increased velocity directly affects the achieved results. Moving too fast during the initial phase of running can lead to a slowdown during the release and it can lead to lack of time which is necessary for the thrower to transfer the optimal force to the javelin.

A great number of authors researched the technique of elite throwers (Mero, Komi, Korjus, Navarro, & Gregor, 1994; Morris & Bartlett, 1996; Morris, Bartlett & Navarro, 2001; Xie et al., 2002). There are also studies which compare national athletes with the elite ones in order to determine differences and point out errors in technique which should be corrected so that the results would approach the elite group (Campos, Brizuela, Ramon, & Gamez, 2002). Campos et al. (2002) point to the fact that the greatest number of differences is found in the release phase. The differences are: velocity and maximal velocity in the elbow and shoulder joints of the throwing hand, rotation of the hips and shoulder at the moment of release, as well as greater extension in the elbow joint and height of release. The author concludes that elbow and shoulder joint velocity and javelin velocity average differs from elite throwers. A study carried out by Leigh, Lin & Yu (2010) explores the variables that are correlated with higher release velocity in women javelin throwers. For female javelin throwers greater release speed was correlated with: shorter time in double support and greater run-up speed at left foot down, greater hip-shoulder separations at right foot down, and smaller left leg angle at left foot down. Also, the increase in release velocity is influenced by the speed of the run-up, blocking the left leg and reducing the total execution time. The trajectory of javelin flight depends on the angle of attack, angle of yaw, the height and rotation of the javelin. These are the parameters that change during the flight of the javelin (Linthorne, 2006).

The aim of this study was to determine the differences in kinematic parameters between the elite competitors in the World Championship 2011 and Serbian Cup competitors in 2011.

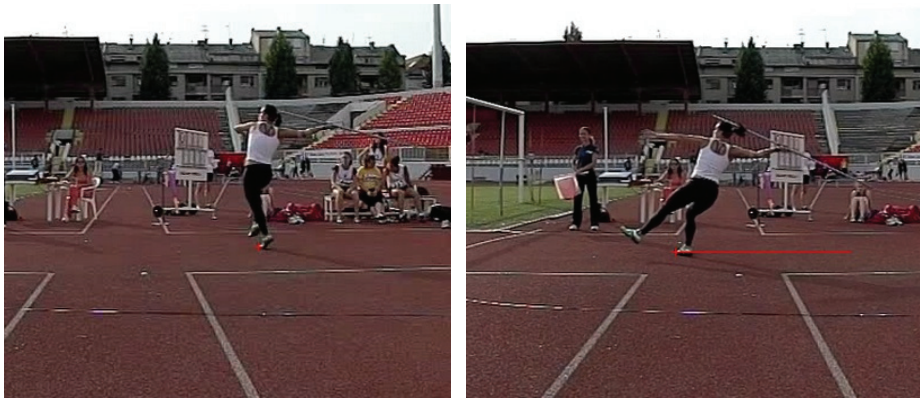
THE METHOD

The sample of participants

The study included the comparison between the female senior javelin throwers of the 2011 Serbian Cup Final held in Novi Sad (N=10, age 18,3 years, height 170,5cm, weight 73,5kg) and the best competitors, i.e., female senior javelin throwers of the 2011 World Championships held in Daegu (N=3, age 27,6 years, height 176,3cm, weight 75,3kg). All of the participants were healthy, physically fit and did not report any injuries during the competition. The study was approved by the local ethical committee and the Athletic Association of Serbia.

The variables

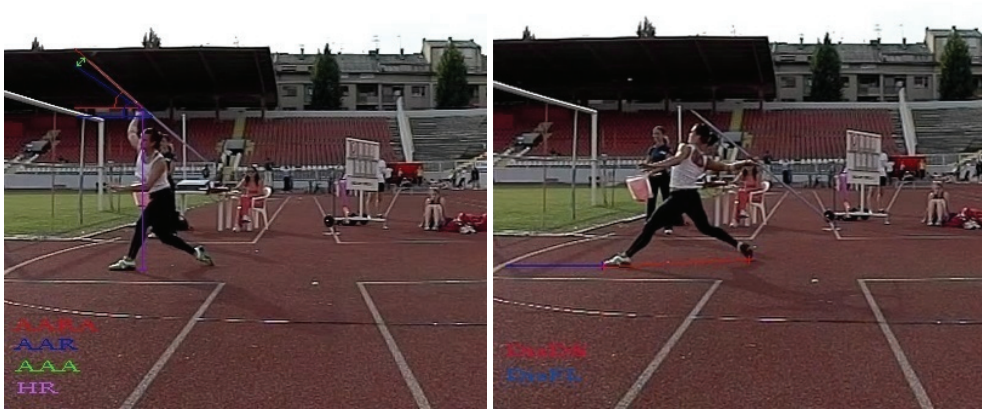
Twelve variables were selected for this research. The variable RES (result) is the most valid result achieved in the competition, as measured by the IAAF standards. RV (release velocity) is the speed of the javelin at the moment of the throw. RH (release height), the height of throw measured from the base to the hand at the time of javelin release (Fig. 1). AARA (attitude angle at release) is the angle formed by the path of the javelin and the horizontal at the moment of the throw (Fig. 1). AAR (angle at release) is the force direction determined by the movement direction of the hand (Figure 1). AAA (attack angle at release) is the difference between the angles AARA and AAR (Fig. 1).



Frame 0. *Frame 95.*

Fig. 1. Impulse stride.

The duration of the impulse stride DurIS (duration impulse stride) was measured from the moment of contact by the left foot, after the withdrawal phase of the javelin, until the moment of setting the right foot on the ground. The length of the impulse stride DisIS (distance impulse stride) measured in the same step was determined from the fingertips of the left foot to the top of the fingers of the right foot (Figure 2). The duration of the delivery stride DurDS (duration delivery stride) was measured from the moment of setting the right foot on the ground until the moment of setting the left foot on the ground in the pre-delivery phase. Delivery stride length was measured from the fingertips of the right foot to the top of the fingers of the left foot (Figure 3). The distance from the foul line DisFL (distance foul line) was measured from the fingertips of the left foot, in the last stride, to the foul line (Figure 3). DurR (duration of release) - duration of the release phase was measured from the beginning of the throw to the point where the javelin leaves the hand.



Frame 191. *Frame 155.*

Figures 2 and 3. Attitude angle at release, angle at release, attack angle at release, height of release (left) and distance delivery stride, distance foul line (right).

Procedures

In relation to female senior javelin throwers of the 2011 Serbian Cup Final held in Novi Sad, the values of the variables were obtained using the software for 2D kinematic analysis "Human", version 6.0 HMA Technology Inc. 2005. Canada (Human, n. d.). Techniques have been recorded in the sagittal plane with a Casio FX high speed camera at a rate of 300 frames per second. The camera was positioned so that the camera lens was perpendicular to the direction of movement. The contestants performed six throws, of which only the best score throw was included for analysis. The phases analyzed were after the run-up, which included the impulse stride, delivery stride, and the release phase. In relation to female senior javelin throwers of the 2011 World Championships held in Daegu, data were taken from the research project "Biomechanical analysis of the IAAF World Championships in Daegu 2011" carried out by The Korean Society of Sports Biomechanics.

Analyses

Statistical analyses were performed by using Statistica 7.0. (StatSoft Inc., Tulsa, USA). Mean values and standard deviations were calculated for descriptive statistics. To determine the differences between the elite and top javelin throwers, the Student's T-test for small independent samples was used, and the level of significance was set at $p < 0,05$.

RESULTS

Mean values and standard deviations of all the variables for the competitors are shown in tables 1 and 2. The T-test results are shown in table 3. Statistically significant differences were found in variables RES (p=0.000), RV (p=0.012), RH (p=0.038), AAR (p=0.048) and AAA (p=0.007) at a significance level of $p<0.05$.

Table 1. Descriptive statistics – female senior javelin throwers of the 2011 World Championships.

	Valid N	Mean	Minimum	Maximum	Std.Dev.	Std.Er.	Skewness
RES	3	70.65	68.38	71.99	1.9765	1.1412	-1.6486
RV	3	24.13	22.90	25.10	1.1240	0.6489	-1.0075
RH	3	1.74	1.65	1.87	0.1137	0.0657	1.2057
AARA	3	40.67	32.00	46.00	7.5719	4.3716	-1.5971
AAR	3	36.00	32.00	42.00	5.2915	3.0551	1.4579
AAA	3	6.00	2.00	12.00	5.2915	3.0551	1.4579
DisIS	3	1.64	1.49	1.84	0.1803	0.1041	1.1521
DisDS	3	1.43	1.39	1.48	0.0473	0.0273	1.3896
DisFL	3	2.14	0.95	3.59	1.3400	0.7737	0.8600
DurIS	3	299.00	270.00	327.00	28.5132	16.4621	-0.1576
DurDS	3	197.33	166.00	240.00	38.2797	22.1008	1.2155
DurR	3	117.00	84.00	147.00	31.6070	18.2483	-0.4233

Table 2. Descriptive statistics – female senior javelin throwers of the 2011 Serbian Cup Final

	Valid N	Mean	Minimum	Maximum	Std.Dev.	Std.Er.	Skewness
RES	10	34.83	27.65	49.54	6.7169	2.1241	1.3608
RV	10	17.42	14.38	25.26	3.7425	1.1835	1.2957
RH	10	1.89	1.71	2.00	0.0920	0.0291	-0.6860
AARA	10	43.70	36.00	53.00	6.1110	1.9325	0.2007
AAR	10	44.20	36.00	51.00	5.6725	1.7938	-0.1718
AAA	10	0.90	0.00	2.00	0.8756	0.2769	0.2235
DisIS	10	1.55	1.04	2.11	0.3290	0.1040	0.6439
DisDS	10	1.19	0.96	1.70	0.2057	0.0650	1.9405
DisFL	10	1.99	1.07	3.12	0.7099	0.2245	0.2774
DurIS	10	347.40	286.00	410.00	42.3981	13.4075	0.2512
DurDS	10	180.10	133.00	263.00	37.7107	11.9252	1.1274
DurR	10	153.10	103.00	176.00	25.9035	8.1914	-1.2301

Table 3. T-test.

Variable	Group	N	Mean	SD	t	p
RES	2011 World Championships	3	70.65	1.9765	8.8719	*0.00
	2011 Serbian Cup Final	10	34.83	6.7169		
RV	2011 World Championships	3	24.13	1.1240	2.9838	*0.01
	2011 Serbian Cup Final	10	17.42	3.7425		
RH	2011 World Championships	3	1.74	0.1137	-2.3450	*0.04
	2011 Serbian Cup Final	10	1.89	0.0920		
AARA	2011 World Championships	3	40.67	7.5719	0.7198	0.49
	2011 Serbian Cup Final	10	43.70	6.1110		
AAR	2011 World Championships	3	36.00	5.2915	-2.2223	*0.05
	2011 Serbian Cup Final	10	44.20	5.6725		
AAA	2011 World Championships	3	6.00	5.2915	3.2399	*0.01
	2011 Serbian Cup Final	10	0.90	0.8756		
DisIS	2011 World Championships	3	1.64	0.1803	0.4300	0.68
	2011 Serbian Cup Final	10	1.55	0.3290		
DisDS	2011 World Championships	3	1.43	0.0473	1.9211	0.08
	2011 Serbian Cup Final	10	1.19	0.2057		
DisFL	2011 World Championships	3	2.14	1.3400	0.2574	0.80
	2011 Serbian Cup Final	10	1.99	0.7099		
DurIS	2011 World Championships	3	299.00	28.5132	-1.8275	0.10
	2011 Serbian Cup Final	10	347.40	42.3981		
DurDS	2011 World Championships	3	197.33	38.2797	0.6923	0.50
	2011 Serbian Cup Final	10	180.10	37.7107		
DurR	2011 World Championships	3	117.00	31.6070	-2.0288	0.07
	2011 Serbian Cup Final	10	153.10	25.9035		

*significance level $p<0.05$

DISCUSSION

Of the twelve analyzed parameters, statistically significant differences were found in five parameters related to the javelin throw. The authors of previous studies (Best, Barlett, & Morriss, 1993; Hay & Yu, 1995; Hubbard, 2000) indicated the javelin release velocity as one of the most important parameters that affect the achieved results. Release velocity depends on the transfer quality of the kinetic energy, from the body onto the hand, and from it onto the javelin (Campos et al., 2002). Higher speed during the throw will increase the length of free flight in proportion to the square of the release velocity (Hubbard, 1984). Results showed that the elite competitors have a significantly greater release velocity (24.1 ± 1.12 m/s) than the top throwers (17.4 ± 3.74 m/s). The best Serbian thrower had a release velocity of 25,26 m/s, which, combined with other optimal parameters, would have been enough to achieve good results in international competitions. The most important factor for the release velocity increase is the increase of the run-up speed and the maximum speed during the left foot contact block. The increase of speed is also affected by the use of force on the javelin on a longer path, by increasing the range of motion during the throw. This is achieved by an external rotation of the shoulders and

trunk rotation before the throwing motion, and by placing the left foot further in front (Leigh et al., 2010). Release height was greater among the Serbian throwers (1.89 ± 0.09 m) than the elite throwers (1.74 ± 0.11 m). Although Čoh, Emberesić, & Žvan (2001) propose that the release height mainly depends on the athlete's body height, in our study that was not confirmed because the elite competitors had a higher average body height (176. 3 cm to 170. 5 cm compared to the Serbian athletes). The study of Campos et al. (2002) found that international throwers have a greater release height compared to the national ones who participated in the study (1.97m and 1.90m, respectively, p=0.021). Release height depends on the motion of the thrower in the final stage, primarily on the flexion in the elbow and the knee joint at the moment of release.

The angle of release among the elite throwers is 36˚ ± 5.29. among the top throwers is 44.2˚ ± 5.67 (p=0.04). the expected angle of release is about 45˚, however, the videos show that the angle of release is usually less than 45˚. Linthorne (2006) states that the optimum angle of javelin throwing is between 26 and 40˚. Among the elite throwers the angle corresponds to its optimal angle, while among the top throwers that angle is greater. The attitude angle of release showed no statistically significant differences, while the difference between these two angles showed a statistical significance at 0.01, resulting in increased maximum height of the javelin into the flight phase, which shortened the length of the throw in top throwers.

There are no statistically significant differences in the length and duration of the impulse and the delivery stride. However, the difference in the length of the delivery stride is evident, as seen from the obtained mean values (1.43 ± 0.04m and 1.19 ± 0.2m). The movement of the left leg is very important in the last stride, which has a high inhibitory characterization. It allows the effect of the inertial forces as the body attempts to maintain the previously obtained speed. Inertial forces will be greater if the braking of the pelvic-femoral part is stronger. This allows the active stretching of muscles active in the throwing, which contributes to the javelin acceleration in the last phase of maximum acceleration (Branković & Bubanj, R., 1997). Longer delivery stride among elite throwers contributes to a better use of inertial forces. The length of the impulse stride is approximately the same in both groups (1.64 ± 0.18m and 1.55 ± 0.32m) while the duration of the same stride, although there is no statistical significance (p=0.09), is shorter in the elite throwers (0.3 ± 0.03s and 0.35 ± 0.04s) i.e. the execution speed of the impulse stride is higher among elite throwers, which also contributes to the inertial forces increase. The duration of release is also shorter among elite throwers (0.12 ± 0.03s and 0.15 ± 0.03s). These results show that the execution speed of the last, release, phase is higher among elite than the top throwers, which contributes to the achievement of better results (Leigh et al., 2010).

CONCLUSION

In order to ensure a proper training process and training load in preparing athletes for future competitions, it is necessary to understand the proper biomechanical and neuromuscular demands of this athletics discipline. The results and information about the movement parameters during the javelin throwing technique should be used by coaches and athletes to improve competitive results. Female senior javelin throwers of the 2011 Serbian Cup Final should be directed towards further improvement of the javelin throwing technique, especially in the predelivery and the delivery phase while performing the

impulse and the release stride. Special attention should be paid to the angle of release, where statistically significant differences were found compared to elite throwers. Since most previous studies dealt with the release phase, future research should be directed towards the run-up phase.

REFERENCES

Bartonietz K. (2000). Javelin throwing: An approach to performance development. In: V. Zatsiorsky (Ed.), *Biomechanics in Sport*, p. 401-434.

Best, R., Barlett, R., & Morriss, C. (1993). A Three-dimensional analysis of javelin throwing technique. *Journal of Sports Sciences*, 11, 315-328.

Branković, M., & Bubanj, R. (1997). *Atletika – tehnika i metodika (Athletics – techniques and methodology*). "Srbijaexport", Niš. In Serbian

Bubanj R. (1997). *Osnovi primenjene biomehanike u sportu (Fundaments of applied biomechanics in sports*). Niš: Self edition of author. In Serbian

Campos, J., Brizuela, G., Ramon, V., & Gamez, J. (2002). Analsis of kinematic parameters between Spanish and world class javelin throwers. In: Gianikellis, K.E. (Ed.). Proceedings of 20th International Symposium on Biomechanics in Sports, Cáceres, Spain, July 1-5, 2002, p. 107-110.

Campos, J, Brizuela, G, & Ramon, V. (2004). Three-dimensional kinematic analysis of elite javelin throwers at the 1999 IAAF World Championships in Athletics. *New Studies in Athletics*, 19, 47-54.

Carr, G. (2004). *Sport mechanics for coaches* (2nd edition). Champaign: Human Kinetics.

Hatton, L. (2007). Optimizing the javelin throw in the presence of prevailing winds. Avalaible at: http://www.leshatton.org/Documents/jav2007a_paper.pdf

Hay, J.G., & Yu, B. (1995). Critical characteristics of technique in throwing the discus. *Journal of Sports Sciences*, 13 (2), 125-140.

Hubbard, M. (1984). Optimal javelin trajectories. *Journal of Biomechanics*, 17, 777-789.

Hubbard, M. (2000). The flight of sports projectiles. In: Zatsiorsky, V.M. (Ed.), *Biomechanics in sport: Performance enhancement and injury prevention*. Blackwell Science, Ltd., Oxford.

Hong, S.M., Lee, Y.S., & Kim, T.S. (2004). The kinematic analysis of the last stride landing and release phase in women javelin. *Korean Journal of Sport Biomechanics*, 14 (1), 51-63.

Leigh, S., Liu, H., & Yu, B. (2010). Associations between javelin throwing technique and release speed. In: Jensen, R., Ebben, W., Petushek, E., Richter, C., & Roemer, K. (Ed.). Proceedings of 28th International Symposium on Biomechanics in Sports, Marquette, Michigan, USA, July 19-23, Vol. 1 (1).

Linthorne, N.P. (2006). Throwing and jumping for maximum horizontal range. School of Sport and Education, Brunel University, Uxbridge, Middlesex, UB8 3PH, United Kingdom. Avalaible at: http://arxiv.org/ftp/physics/papers/0601/0601148.pdf

Mero, A., Komi, P.V, Korjus, T., Navarro, E., & Gregor, RJ. (1994). Body segment contributions to javelin throwing during final thrust phases. *Journal of Applied Biomechanics*, 10, 166-177.

Morriss, C., & Bartlett, R. (1996). Biomechanical factors critical for performance in the men's javelin throw. *Sports Medicine*, 21, 6, 438-446.

Morriss, C., Bartlett, R., & Navarro, E. (2001). The function of blocking in elite javelin throwers: are-evaluation. *Journal of Human Movement Studies*, 41, 175-190.

Xie, W., Teh, K.C., Tan, J., Koh, M., Yusoff, M.S., & Osman, N.A.A. (2002). Biomechanical analysis of the men´s javelin throw at the 21st South East Asian Games. In: Gianikellis, K.E. (Ed.). Proceedings of 20th International Symposium on Biomechanics in Sports, Cáceres, Spain, July 1-5, 2002, p. 115-117.

Čoh, M., Embersić, D., & Žvan, M. (2001). Correlation between anthoropometric characteristics and competition results of elite junior javelin throwers. In: Blackwell, J.R., & Sanders, R.H. (Eds). Proceedings of 19th International Symposium on Biomechanics in Sports, San Francisco, USA, June 25, p. 90-93.

RAZLIKE U KINEMATIČKIM PARAMETRIMA IZMEĐU VRHUNSKIH INOSTRANIH I SRPSKIH BACAČICA KOPLJA

Aleksandra Aleksić-Veljković, Miloš Puletić, Ratko Stanković, Saša Bubanj, Aleksandar Raković, Daniel Stanković

Cilj ove studije je utvrđivanje razlika u kinematičkim parametrima između bacačica koplja, učesnica Finala Kupa Srbije za seniore 2011. godine u Novom Sadu (N=10, starosti 18.3, visine 170.5 cm, težine 73.5 kg) i bacačica koplja, učesnica Svetskog prvenstva za seniore u Daegu-u 2011. godine (N=3, starosti 27.6, visine 176.3cm, težine 75.3 kg). Statistička analiza urađena je korišćenjem programa Statistica 7.0. (StatSoft, Inc, Tulsa, USA). Utvrđene su statistički značajne razlike u vrijablama RES (p=0,000), RV (p=0,012), RH (p=0,038), AAR (p=0,048) i AAA (p=0,007) na nivou značajnosti p<0,05. Bacačice koplja, učesnice Finala Kupa Srbije za seniore 2011. godine bi trebalo usmeriti ka daljem usavršavanju tehnike bacanja koplja, naročito u predizbačajnoj i izbačajnoj fazi prilikom izvođenja impulsnog i izbačajnog koraka.

Ključne reči: *brzina izbačaja, visina izbačaja, impulsni korak, izbačajni korak.*