Coll. Antropol. **37** (2013) Suppl. 2: 31–36
Original scientific paper

Influence of Kinematic Parameters on Result Efficiency in Javelin Throw

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A B S T R A C T

The aim of the research was to define the influence of the kinematic parameters in the javelin throw success in the top junior athletes at the European Junior Athletics Championships in Novi Sad. A set, consisting of 17 kinematic variables, was applied on a sample of 16 athletes, and the same variables were registered at the 2009 Novi Sad European Junior Championships. The criteria variable was the achieved throw length (javelin throw). The subjects were represented by 113 successful javelin throws. The results of the chosen kinematic variables correlation analysis showed the existence of multiple significant relations between the observed variables. Based on the observed kinematic variables correlation analysis, the next conclusion can be made: the javelin release speed has the most important role, followed by the fast front support leg placing. The results are expected and logical, and can be used in kinesiology practice, especially in the process of young throwers' technique learning and in development of motor abilities relevant for this athletic discipline.

***Key words**: juniors, javelin throw, correlation analysis*

Introduction

Top results are being achieved earlier and earlier than before. Therefore the need arises to start with the systematic work in sports in general earlier than before[1–3]. The Javelin throw is a highly demanding and technical track and field discipline. Due to its complexity and attractiveness, it consumes a great deal of media coverage at major sports events, and it is also a subject of much interest in athletes, coaches and scientists that study biomechanics. According to the structural complexity, the javelin throw is a mono-structural acyclic activity based on multi-phase motions. The character of the motor activity places the javelin throw into a group of natural motions with the use of an object which should be thrown as far as possible, respecting the biomechanical laws. The movement structure in the javelin throw is similar to other motions used to throw other objects (baseball, cricket...). The javelin throw is characterized by the sequential reaction of the body segments so as to develop the maximum speed in the most distal system segments while projecting the object[4]. There is a great deal of factors that jointly influence the final result in javelin throws such as: the athlete potential (performance potential), training, expert coach experience, knowledge, training conditions and also the development of motor programs (technique). Defining these javelin throw success determining factors is the main focus of biomechanical studies. In relation to the stated, the kinematic movement analysis of javelin throw implies precise definition of the spatial, temporal and spatial-temporal dimension, as well as the relations between movement structure motions of this athletic discipline.

The biomechanical description of kinematic parameters of elite javelin throwers has been the aim of many studies[5,6]. The most representative studies that analyze the difference between the different level javelin throwers were published in works by: Menzel (1986, 1987)[7,8], Whiting, Gregor, Halushka (1991)[9]. The characteristics of the motor ability existing in the javelin throw are similar to other movements during kicking or throwing an object. This is characterized by the fact that some segments act in a way that enables reaching the maximum speed in the distal system segments at the moment of kick or release of an object (projectile)[4,8]. According to

Received for publication September 25, 2012

the kinematic and dynamic technique characteristics, the release speed, optimum angle of release and the height of javelin flight present the most important three factors that define the final result of javelin throw[5,9–12]. The release speed realization is therefore a result of the efficient transfer of kinetic run-up energy through efficient leg positioning, as well as the application of law of mass inertia, connected by the kinetic chain, conveying the energy onto the shoulder area, elbow and finally, wrist. Such action presents a harmonious inter-muscular coordination and so called stretch reflex action[13]. The release angles optimum value is between 33 and 36 degrees[5,12,14]. The third parameter is the release height, mostly determined by the height of the athlete. The optimum height of the release should be 105% higher than the throweržs body height (Bottchner and Kuhl, 1998)[14]. Any deviation from these parameters will result in a shorter javelin throw. The measured speeds of the final phase of the release were 30 m/s[15,16]. The measured temporal intervals of the release were 0.16–0.18 seconds[6,15], showing that 70% of the achieved speed is gained during 0.1 seconds. Ikegami et al. 1981[17]; Miller and Munro 1983[18]; Komi and Mero, 1985[10]; Rich et al. 1985[19]; Whiting, Gregor and Halushka, 1991[9] and Mero et al. 1994[5] performed a detailed javelin throw biomechanical analysis. Generally, the most important finding was the influence of the javelin release speed (as the most important kinematic factor) on the length of the throw. Murakami, (2006)[20] analyzed the relation between the length of the throw and some kinematic parameters in 2005 Helsinki (Finland) World Championship finalists.

Lehman (2009)[21] performed a biomechanical analysis of javelin throw in male and female athletes participating at the World Athletics Championship in Berlin (2009). The analysis was a part of the Biomechanical research scientific project. Lehman stated that the medallists had a higher release angle than the other finalists, and the attack angle value was also higher. Obviously, the capability of release angle alteration was one of the decisive factors in medal winning. The medallists' cross stride was much longer than the release stride.

The object of this research is the study of the tool projection preparation processes and the performance of the projection as the key phase of successful javelin throw. The results of kinematic analysis of certain variables describing the javelin projection speed, ultimate stride length, position and angles of the body and certain body segments, answered the question of the existence of general technical pattern used by elite junior male and female athletes in their performance. The credibility of research quality was assured by the competitive performances of male and female throwers, whose range of competitive possibilities assured the appearance at such excellent international junior competition. Total number of successful attempts of competitors in qualification and final competition has been used in this research.

The results gained by exploring the competitive efficiency can be transferred and applied to the javelin throw training.

Therefore, the objective of this investigation is to determine the impact of some kinematic parameters on the javelin throw results in elite junior athletes. Since the number of the research is relatively small it will be interesting to determine the potential impact on the final result, compare the results with the indicators of the elite senior throwers, and to determine which parameters are missing in the achievement of elite senior results.

Sample and Methods

Sample of examinees

The examinees sample consisted of 30 participants of the European Junior Championships, aged 17 to 19. All the successful attempts (throws) performed during the qualification and the final part of competition were analysed. The entity sample of this research consisted of the total number of 110 throws. The recorded material was transformed into digital medium, and processed by the compatible biomechanical analysis software.

The recording was performed by three VHS 50 fps cameras. They were placed behind (camera 1) and on the side (camera 2 and 3) of the athletes.

Throw length (DH) – criterion variable.

Kinematic parameters:

1. OKPP – Vertical axis javelin deviation in the frontal plane during left foot placing (rear view)
2. OKIZ – Vertical axis javelin deviation in the frontal plane during release (rear view)
3. NKSN – Vertical axis trunk deviation in the frontal plane during release (rear view)
4. OTIZ – Smallest back support leg knee angle immediately before reaching central, strong position
5. BIZS – Release speed
6. KIZ – Release angle
7. KN – Attack angle
8. DZK – Ultimate stride length
9. VSPN – Time interval between placing right support and left support leg (strong position)
10. BZK – Average ultimate stride speed
11. NTPN – Trunk angle in relation to vertical axis in the sagittal plane during front support leg placing
12. KPNP – Front support leg knee angle at the moment of placing
13. KPNIZ – Front support leg knee angle at the moment of release
14. KSN – Back support leg knee angle in strong (central, two-support) position
15. KLCP – Throwing arm elbow angle in strong position
16. KKCP – Javelin angle in relation to run-up line in »strong position«
17. VPNIZ – Time interval between front support leg placing and javelin relea moment

Data processing methods

In concordance with the aim of this research, the following methods were used:

The basic descriptive parameters were calculated.

The correlation analysis was used in defining relation between kinematic parameters and javelin throw results.

The STATISTICA programme packages were used in processing the collected data.

Results and Discussion

Descriptive analysis

The basic descriptive parameters are shown in Table 1. The numeric values of the chosen kinematic parameters of the performed javelin throws are presented, in relation to the groups of entities which are the subject of this research.

The average length of all the performed throws (DH) was 67.27 m, with throw length span from minimum 58.65m to maximum 75.89m. The average javelin release angle (KIZ) was 39.02°, with minimum release angle of 29.0°, and the maximum release angle of 47.0°. The value of javelin deflection kinematic parameter in relation to the vertical axis in the frontal plane at the moment of front support leg placing was in average 22.96°, with the minimum angle of 8°, and the maximum angle value of 36°. The javelin deviation angle values, in relation to the vertical axis in frontal plane at the moment of javelin release (OKIZ) was 14.27° in average, with minimum values from –2.0 and maximum values of 27.00. This data presentation shows that most throwers perform a correction and reduction of release angle deviation in relation to the vertical axis in the frontal plane. This also suggests the possible reduction of shoulder axis angle in relation to hips axis in the sagittal plane. Release speeds (BIZS) were 25.02 m/s on average, with minimum release speed of 23.10 m/s, and the maximum release speed of 27.10 m/s. The minimum back support leg knee angle (MKSN) was 112.5 degrees, in average, with the smallest knee angle of 95°, and the maximum knee angle value of 134°. This variable is connected to the back leg efficiency. In the case of smaller angle, the efficient right hip pushing speed will be lower, what can sometimes be compensated by generating greater muscle force in thigh muscles. On the other hand, high angle value can mean that the right hip pushing speed is high, but also that the javelin outpace possibilities are too scarce, resulting in inefficient technical throwing technique. Through description of this variable, the efficiency of back support leg foot, at the moment of foot placing, can be described as well, taking into consideration the direction of foot placing in relation to the throwing direction. The value of this back support leg angle will obviously be optimum, in relation to the anthropological characteristics of the thrower, as well as the technical performance of the throw. The average numeric value of the attack angle ki-

TABLE 1
DESCRIPTIVE STATISTICS OF KINEMATIC PARAMETERS (N=113)

Variable		Min	Max	SD	Skew	Kurt	KS
DH	67.27	58.65	75.89	3.94	–0.03	–0.69	0.06
OKPP	22.96	8.00	36.00	6.19	–0.15	–0.50	0.10
OKIZ	14.27	–2.00	27.00	6.01	–0.23	–0.32	0.07
NKSN	112.50	95.00	134.00	8.23	0.11	–0.77	0.08
OTIZ	26.95	11.00	41.00	7.02	–0.13	–0.57	0.05
KIZ	39.02	29.00	47.00	3.57	–0.12	–0.44	0.08
BIZS	25.02	23.10	27.10	0.92	0.09	–0.82	0.07
KN	0.51	–4.00	5.00	1.81	–0.37	0.05	0.20
DZK	183.15	137.60	220.00	19.54	–0.37	–0.54	0.07
VSPN	0.212	0.14	0.27	0.03	–0.16	–0.43	0.11
BZK	8.66	5.29	10.90	0.96	–0.65	1.80	0.08
NTPN	17.50	6.00	28.00	4.15	–0.11	–0.15	0.08
KPNP	162.04	140.00	183.00	8.69	–0.39	0.28	0.07
KPNIZ	168.95	141.00	185.00	10.56	–0.85	–0.10	0.11
KSN	138.29	120.00	175.00	9.10	0.71	1.36	0.09
KLCP	141.73	115.00	168.00	9.99	0.20	–0.19	0.06
KKCP	38.50	30.00	49.00	3.62	–0.06	0.02	0.07
VPNIZ	0.131	0.120	0.17	0.01	0.89	1.70	0.24

Test=0.13

#variable with opposite metric orientation X – arithmetic mean, SD – standard deviation, Min – minimal result, Max –maximal result, KS – Kolmogorov–Smirnov test, Skew coefficient of asymmetry, Kurt – coefficient of kurtosis

TABLE 2
MATRIX OF CORELATIONS (N=113)

Variable	DH	OKPP	OKIZ	NKSN	OTIZ	KIZ	BIZS	KN	DZK
DH	1.00								
OKPP	0.22*	1.00							
OKIZ	0.30*	0.81*	1.00						
NKSN	0.40*	0.11	0.11	1.00					
OTIZ	–0.11	–0.02	–0.17	0.20*	1.00				
KIZ	–0.19*	0.07	0.21*	–0.13	–0.14	1.00			
BIZS	0.90*	0.20*	0.19*	0.41*	–0.05	–0.52*	1.00		
KN	–0.10	0.11	0.11	0.08	–0.06	0.20*	–0.12	1.00	
DZK	0.08	–0.05	0.17	–0.27*	–0.07	0.28*	–0.09	–0.09	1.00

Variable	VSPN	BZK	NTPN	KPNP	KPNIZ	KSN	KLCP	KKCP	VPNIZ
VSPN	1.00								
BZK	–0.66*	1.00							
NTPN	0.26*	–0.26*	1.00						
KPNP	0.04	0.11	0.22	1.00					
KPNIZ	–0.04	0.02	–0.04	0.31*	1.00				
KSN	0.28*	–0.21	–0.07	–0.01	–0.12	1.00			
KLCP	–0.29*	0.23*	–0.19	0.09	0.25*	0.06	1.00		
KKCP	0.35*	–0.08	0.38	0.11	–0.12	0.00	–0.16	1.00	
VPNIZ	0.06	–0.38*	–0.04	–0.30*	–0.25*	0.06	–0.08	–0.05	1.00

*p<0.05

nematic variable (KN) was 0.51° in average, with the result span of –4° to 5°. Ultimate stride length (DZK) was 183.15 cm in average, with minimum length of 137.60 and the maximum 220.00 cm. The time interval between back support leg and front support leg placing was 1.21 s in average, with the lowest value of 0.14 seconds, and the highest 0.27 seconds. Ultimate stride speed (BZK) was 8.66 m/s in general, with lowest speed of 5.29 m/, and the highest 10.90 m/s. Trunk lean angle value, in relation to vertical axis in vertical plane, was 17.50° in average, with lowest value of 6°, and the highest 28°. The average front support leg knee angle value during foot placing (KPNP) was 162.04°, with lowest knee angle value of 140°, and the highest 183°. The average knee angle value at the moment of javelin release (KPNIZ) was 168.95°, with lowest angle value of 141°, and the highest 185°. The back support leg knee angle (KSN) was 138.28° in average, with lowest angle value of 120°, and the highest 175°. The average throwing arm elbow central position angle (KLCP) was 141.73°, with the lowest angle value of 115°, and the highest 168°. The average javelin angle in relation to horizontal plane in central position (KKCP) was 38.50°, with lowest value of 30° and the highest value 49°. The time interval, starting at the moment of front support leg placing and ending at the moment of javelin release (VPNIZ) was 0.13 seconds in average, with the lowest value of 0.12 seconds and the highest value 0.17 seconds.

The analysis of the relation between kinematic variables in the total number of throws (Table 2) shows the existence of multiple significant relation between the observed kinematic variables. Since the throw length represents a criterion variable, it was primarily important to define which predictor kinematic variables are statistically significantly related to the criterion. The strongest relation, 0.90, is observed in the throw length (DH) and javelin release speed (BIZS) variables. This high correlation is no surprise since, the release speed is the factor with the strongest relation to the throw length (Vitasalo and Notvapalo 2003[22], r=0.75; Hay 1978[23], Ikegami et al. 1981[17]; Terauds 1978[24], r=0.72; Miller and Munro, 1983[18]; Komi and Mero 1985[10]; Mero et al. 1994[5]; Bartlett et al. 1996[25]; Menzel 1987[8]. Statistically significant correlation between the throw lengths (DH) and the rest of kinematic variables was noted in time interval between front support leg placing and javelin release (VPNIZ r=–0.49), in ultimate stride speed kinematic variable, (BZK) r=0.46), in front support leg knee angle at the moment of release kinematic variable (KPNIZ, r= 0.45), in central position elbow angle kinematic variable (KLCP, r=0.40), in lowest back leg angle kinematic variable (BLA, r=0.40), in time interval between back support and front support leg placing kinematic interval (VSPN, r=–0.34), in javelin deviation from vertical axis in the frontal plane at the moment of front support leg placing (OKPP, r=0.22). The explanation of negative correlation coefficient between DH and VPNIZ variables is the reverse scalarity – lower time interval is a quality characteristic of the successful throws. Obviously, better quality throws will have lower time period between front support leg placing and the moment of release. This is the only way of describing statistically significant relation between DH and BZK variables, more successful throws will have faster ultimate stride. Statistically significant relation between throw length and bigger front support leg knee angle at the moment of release (KPNIZ) can be defined by the statement that the stronger leg stretch will enable more efficient transfer of dynamic forces onto the upper parts of the kinetic chain. A statistically significant relation between DH and elbow angle (KLCP is understandable, from the point of view of more lasting influence onto the tool in a more stretched elbow position. Nevertheless, one should keep in mind that even the elite senior athletes keep the elbow somewhat bent in the central position phase. The observed statistically significant correlation between throw length and smallest back leg angle (OTIZ) can be explained by the role of the leg in the tool pass, efficient back leg hip forward pushing, enabling conditions of reaching the maximum tension phase, and the beginning of the efficient transfer of kinetic energy from the lower to the upper parts of the kinetic chain. Statistical significance between throw length, javelin deviation from the vertical axis in frontal plane in the front support leg placing phase and in the phase of javelin release, can be explained by directing the technical throwing performance towards more efficient and more adequately timed realization of maximum tension phase in the central position phase, which is also supported by the optimum transverse shoulder axis twist, in relation to transverse hip axis, through the deviation of the javelin from the vertical axis. Since the release speed variable is the most important in the process of generating success of throw length, it is interesting to describe its significant relation coefficient to certain predictor group kinematic variables. The strongest relation is the one with release angle (RA, r=–0.52), which can be explained only by the fact that only an optimum release angle (higher release speeds are achieved with smaller release angle) can enable the regularity of the throwing fist movement trajectory, and diminish, as much as possible, omnipresent irregular fist path with grip, in frontal and sagittal plane likewise. The relation of time interval between back support leg and front support leg placing (BSLT) on one hand, and release speed (r=0.48) on the other, can explain the temporal shortening of throws with higher release speed, in their central position achieving phase. Statistically significant relation of r=0.47, between the release speed and javelin throwing arm elbow angle, can be explained by the fact that the longer activity on the longer path will enable more efficient correlation, and finally, higher javelin release speed. Statistically significant correlation coefficient was noted between release speed and front support leg knee angle at the moment of release (KPNZ), r=0.46, what is a logical consequence of the fact that greater front support leg knee stretch will contribute to the more efficient kinetic energy transfer into the distant parts of the kinetic chain, and finally, higher release speed. Statistically the significant relation between release speed and javelin angle in central position, in relation to the horizontal plane (KKCP), r= –0.45, can be explained by the fact that only the optimum central position javelin angle, in relation to the horizontal plane, will enable the greatest javelin acceleration. If the angle is too large, the force will be lost, the kinetic energy forces vector will not be directed towards the javelin – the tip of the javelin, and on the other hand, the forces vectors will behave the same if the javelin angle is too small. In all of these considerations, the aerodynamic conditions of the throwing area should be taken into account (wind strength and direction). A statistically significant relation of ultimate stride speed (BZK, r=0.44) and release speed is also understandable. Since these are speed variables, it is assumed that higher ultimate stride speed will have a positive impact onto the release speed. Statistically significant correlation coefficient of r=0.41, between the lowest back leg angle (KSN) and the release speed kinematic variable, can be explained by the efficiency of back support leg hip push, and by success in achieving the central position, what is a prerequisite of efficient forces transfer inside the kinetic chain. Statistically important, but low relation between the variables of javelin deviation from the vertical axis at the moment of front support leg placing and at the moment of release, with the release speed variable (r=0.20, r=0.19), can probably be explained by the more efficient twist of the shoulders axis in relation to hip axis, what would consequently contribute to the more efficient maximum tension phase.

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UTJECAJ KINEMATIČKIH PARAMETARA NA REZULTAT BACANJA KOPLJA VRHUNSKIH JUNIORA

S A Ž E T A K

Istraživanje je sprovedeno sa ciljem da se utvrdi povezanost kinematičkih parametara na uspiješnost u bacanju koplja kod najboljih bacača – juniora. U tu svrhu na uzorku od 16 bacača primjenjena je baterija od 17 kinematičkih varijabli koje su se registrirale na Europskom juniorskom prvenstvu 2009 u Novom Sadu. Kriterijska varijabla bila je ostvarena duljina hitca (bacanja koplja). Entitete su predstavljali 113 uspješnih bacanja koplja. Analizirajući rezultate korelacijske analize izabranih kinematičkih varijabli vidljivo je kako postoje višestruko značajne veze među promatranim varijablama. Temeljem korelacijske analize promatranih kinematičkih varijabli moguće je donijeti sljedeće zaključke: Presudnu ulogu u dužini hitaca ima brzina izbačaja sprave, zatim brzo postavljanje prednje potporne noge. Rezultati su očekivani i logični te mogu poslužiti u kineziološkoj praksi, naročitu u procesu usvajanja tehnike mladih bacača koplja te u razvoju motoričkih sposobnosti relevantnih za uspjeh u ovoj atletskoj disciplini.