DOI: 10.7251/SSH1502111B
Originalni naučni rad

UDC: 572.512.087:796.41
Original Scientific Paper

Uticaj uglovnog položaja pojedinih segmenata tijela bacača u projekciji X ose na dužinu dometa kugle

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Sažetak: Istraživanje je provedeno s ciljem da se utvrdi uticaj uglovnog položaja pojedinih segmenata tijela bacača u projekciji X ose na dužinu dometa kugle (rotacionom tehnikom). Provedeno je na jednom entitetu, a to je bosansko-hercegovački državni reprezentativac bacač kugle Hamza Alić. Izbor varijabli je usklađen sa uzorkom ispitanika koji je u ovom istraživanju specifičan i koji je uslovljen postavljenim senzorima na pojedine segmente tijela ispitanika prilikom snimanja. Za utvrđivanje kinematičkih parametara, A = ubrzanje pojedinih segmenata tijela bacača kugle u osi X, primijenjene su 22 varijable (prediktorski skup) i kriterijska varijablu za procjenu kinematičkih parametara bacača kugle koju čini dužina dometa kugle (tretiranih 36 ispravnih hitaca). Na osnovu rezultata koji su dobiveni regresionom analizom može se vidjeti da povećanjem uglova desnog i lijevog lakta te lijevog koljena dužina ostvarenog rezultata u bacanju kugle se povećava. Trenutak izbačaja se dešava kao posljedica aktivnog uglovnog kretanja prediktorskih modeliranih kinematičkih varijabli u X osi.
Ključne riječi: uglovni položaj, bacač kugle, rotaciona tehnika, dužina dometa.

Uvod

Početna brzina kugle rezultat je brzine koju kugla dobije u incijalnom ubrzanju tokom okreta koju dobije u finalnom ubrzanju tokom faze izbačaja. Obje brzine su posljedica koordinisanog kretanja i brzina više različitih segmenata kinematičkog lanca tijela bacača kugle. Svaki segment kinematičkog lanca pri tome odvija se rotacijom oko proksimalne osi zgloba i zajedno sa zglobom, a brzina kugle jednaka je vektorskoj sumi njihovih brzina. Do-

Impact of the Angular Position of Individual Body Segments of a Shot Putter in the Projection Onto the X-Axis to the Distance of the Shot Range

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Summary: The study was conducted with the objective to determine the impact of the angular position of individual body segments in the projection onto the x-axis to the distance of the shot range. It was conducted on one individual who is Bosnia and Herzegovina's national team shot putter Hamza Alić. The selection of variables was adjusted to the sample of the examinee which was specific in the study and which was conditioned by placing sensors on the examinee's individual body segments during the recording. For determining kinematic parameters, A = acceleration of shot putter's individual body segments in the x-axis, 22 variables were applied (predictor group) and criterion variable for calculating kinematic parameters of the shot putter which is made up of the distance of the shot range (36 proper throws). On the basis of the results gathered in regression analysis it can be inferred that by increasing the angle of the right and left elbow as well as left knee, the distance of the achieved result in throwing a shot put is increased.
Key words: angular position, shot putter, rotational technique, shot range

Introduction

The initial velocity of the shot put is the result of the velocity that the shot put gains in the initial acceleration during the rotation that it gets in the final acceleration in the release phase. Both velocities are a product of coordinated movements and speed of various segments of the kinematic body chain of the shot putter. Every segment of the kinematic chain occurs by rotation around the proximal axis around the wrist and with the wrist, while the velocity of the shot put is equal to the vector sum of sadašnja istraživanja pokazuju da se prirast brzine kugle podudara sa akcijom bacača kugle u drugoj dvopotpornoj fazi bacanja od 80 do 90% (Kerssenbrock, 1974; Stepanek i Sušanka, 1987; Palm, 1990; Bartonietz, 1994). Po rezultatima istraživanjima (Zaciorsky, Lanka i Shalmanov, 1981; Bartonietz, 1994; Lanka, 2000) najveći prirast brzine podudara se s momentom početka kretanja desnog ramena i desne ruke tokom faze izbačaja. Većina autora (Grigalka, 1974; Bartonietz, 1994; Luhtanen, Blomqvist i Vanttinen1997; Lanka, 2000) slažu se da je aktivnost bacača kugle u fazi finalnog naprezanja pri izbačaju najvažnija za nagli porast brzine kugle koja čini 85-90% početne brzine kugle što na kraju doprinosi dužini dometa kugle.

S obzirom da su sportske kretne strukture veoma kompleksne naravi neophodno je da se mjerenje segmentarnih pokreta mišićno-skeletnog sistema sprovodi stereofotogrametrijskim postupcima koji dozvoljavaju 3D - rekonstrukciju. Pošto savremena biomehanička analiza zahtijeva da se dijagnostika sprovodi u pretežno takmičarskim (situacionim) uslovima, od raspoloživih fotogrametrijskih sistema mogu se upotrijebiti samo oni koji se baziraju na kompletnom zapisu kretanja. Kinematičkim postupcima, koji se često obilježavaju i kao kinematografski postupci, određuju se kinematičke veličine put i vrijeme kao i iz toga izvedene veličine brzina i ubrzanje (Ćuk i Čoh, 1993; Čoh, 2001; Čoh i Štuhec, 2008.).

Cilj ovog istraživanja bio je utvrđivanje uticaja uglovnog položaja pojedinih segmenata tijela bacača u projekciji X ose na dužinu dometa kugle.

METOD RADA

Uzorak ispitanika

Ovo istraživanje sprovedeno je na jednom entitetu, a to je bosansko-hercegovački državni reprezentativac bacač kugle Hamza Alić (hronološke dobi 27 godina, tjelesne visine 1,95 m i tjelesne mase 129,5 kg).

Uzorak varijabli

Izbor varijabli je usklađen sa uzorkom ispitanika koji je u ovom istraživanju specifičan i koji je uslovljen postavljenim senzorima na pojedine segmente tijela ispitanika prilikom snimanja.

Prediktorski skup varijabli čine:

Za procjenu kinematičkih parametara, primijenjena su 4 parametra: S (prijeđeni put), V (brzina), A (ugao) i w (ugaona brzina).

Za utvrđivanje kinematičkih parametara, A = ubrzanje pojedinih segmenata tijela bacača kugle u osi X,

their velocities. Studies up to now show that the increase in velocity of the shot put coincides with the activity of the shot putter in the double-support second phase of the throw from 80% to 90% (Kerssenbrock, 1974; Stepanek i Sušanka, 1987; Palm, 1990; Bartonietz, 1994). According to studies (Zaciorsky, Lanka & Shalmanov, 1981; Bartonietz, 1994; Lanka, 2000) the highest increase in velocity coincides with the moment the right shoulder and right arm start moving in the release phase. Most authors (Grigalka, 1974; Bartonietz, 1994; Luhtanen, Blomqvist & Vanttinen 1997; Lanka, 2000) agree that the shot putter's activity in the phase of final exertion during release is the most important for rapid increase of velocity of the shot put and makes up 85-90% of the initial velocity of the shot put which at the end contributes to the distance of the shot range.

Considering that sports movement structures are of very complex character it is necessary for measuring segmental movement of the musculoskeletal system to be carried out by stereophotogammetric methods that allow for 3D – reconstruction. Since modern biomechanical analysis requires diagnosis to be carried out in competition (situational) settings, taking into account all the available photogrammetric systems, only the ones that are based on a complete record of movement can be used. Kinematic methods, which are often termed as kinematographic methods, the kinematic size of direction and time is determined and from that the size of velocity and acceleration. (Ćuk & Čoh, 1993; Čoh, 2001., Čoh & Štuhec, 2008.).

The aim of this study was determining the impact of the angular position of individual body segments of the shot putter in the projection onto the x-axis to the distance of the shot range.

STUDY METHODOLOGY

Sample of examinee

This study was conducted on an individual who is Bosnia and Herzegovina's national team shot putter Hamza Alić. (age: 27; height: 1.95 m; weight: 129.5 kg).

Sample of ariables

The selection of variables was adjusted to the sample of the examinee which was specific in the study and which was conditioned by placing sensors on the examinee's individual body segments during the recording.

The predictor group of variables is made up of:

For determining kinematic parameters, 4 parameters were applied: **S** (distance travelled), **V** (velocity), **A** (angle) i **w** (angular velocity) primijenjene su 22 varijable i to: AxL5S1 (L5 lumbalni pršljen i S1 krsni region), AxL4L3 (L4L3 lumbalni pršljenovi), AxL1T12 (L1 lumbalni pršljen i T12 grudni pršljen), AxT9T8 (T9T8 grudni pršljenovi), AxT1C7 (T1 grudni pršljen i C7 vratni pršljen), AxC1GL (C1 vratni pršljen i glava), AxDC7R (desni C7 vratni pršljen i rame), AxDRAM (desno rame), AxDLAK (desni lakat), AxDRZG (desni ručni zglob), AxLC7R (lijevi C7 vratni pršljen i rame), AxLRAM (lijevo rame), AxLLAK (lijevi lakat), AxLRZG (lijevi ručni zglob), AxDKUK (desni kuk), AxDKLJ (desno koljeno), AxDNZG (desni nožni zglob), AxDSTO (desno stopalo), AxLKUK (lijevi kuk), AxLKLJ (lijevo koljeno), AxLNZG (lijevi nožni zglob) i AxLLSTO (lijevo stopalo).

Kriterijska varijabla

Kriterijsku varijablu za procjenu kinematičkih parametara bacača kugle rotacionom tehnikom čini dužina dometa kugle (tretiranih 36 ispravnih hitaca).

Uslovi i tehnike mjerenja

Snimanje i mjerenje rotacione tehnike bacanja kugle na ispitaniku izvedeno je u prelaznoj takmičarskoj fazi priprema za Olimpijske igre u Londonu 2012. godine. Snimanje je obavljeno na stadionu Šiška u Ljubljani (Republika Slovenija). Korišten je krug za bacanje kugle prečnika 2,135m, sa segmentom i baždarenim metalnim metrom prema standardima IAAF. Teren i vremenski uslovi su bili optimalni. Na testiranju je snimljeno 85 izbačaja. Atletičar je bacao kuglu desnom rukom. Kod konačne analize uzeto je u obzir 36 najboljih i ispravnih hitaca. Snimanje je obavljeno sa dvije sinhronizovane kamere (Casio EX – F1) stavljene pod uglom 90° na njihovu optičku osovinu. Treća kamera (Casio EX – F1) stavljena je na visini 4 m, tačno iznad centra kruga za bacanje (Slika 1).

Analizirani prostor kruga bio je kalibriran sa referentnim okvirom dimenzije 1 m x 1 m x 2 m, a pri tome je za kalibriranje uzeto osam referentnih rubova (Slika 2). Dužinu analiziranog kretanja definisali smo sa “x” osom, visinu sa “y” osom i dubinu sa “z” osom. Za determinisanje kinematičkih parametara tehnike upotrijebili smo 3-D softwer APAS (Ariel Dynamics Inc., San Diego, Ca). Obavljena je digitalizacija 15-segmentnog modela tijela bacača, kojeg smo definisali sa 18 referentnih tačaka. Osamnaesta tačka bila je definisana sa centrom kugle. Segmenti modela prikazuju dijelove tijela povezane sa tačkastim zglobovima. Mase i centri gravitacije segmenata kao i centar gravitacije tijela izračunati su na osnovu antropometrijskog modela (Dempster,1955). Koordinate

For determining kinematic parameters, A = acceleration of shot putter’s individual body segments in the x-axis, 22 variables were applied: AxL5S1 (L5 lumbar vertebrae and S1 loin area), AxL4L3 (L4L3 lumbar vertebra), AxL1T12 (L1 lumbar vertebrae and T12 thoracic vertebra), AxT9T8 (T9T8 thoracic vertebrae), AxT1C7 (T1 thoracic vertebra and C7 cervical vertebra), AxC1GL (C1 cervical vertebra and head), AxDC7R (right C7 cervical vertebra and shoulder), AxDRAM (right shoulder), AxDLAK (right elbow), AxDRZG (right wrist), AxLC7R (left C7 cervical vertebra and shoulder), AxLRAM (left shoulder), AxLLAK (left elbow), AxLRZG (left wrist), AxDKUK (right hip), AxDKLJ (right knee), AxDNZG (right ankle), AxDSTO (right foot), AxLKUK (left hip), AxLKLJ (left knee), AxLNZG (left ankle) and AxLLSTO (left foot).

Criterion variable

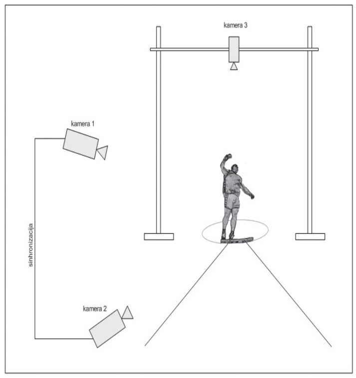
Criterion variable for calculating kinematic parameters of the shot putter which is made up of the distance of the shot range (36 proper throws).

Conditions and techniques for measurement

The recording and measuring of the rotational technique of the examinee’s shot put throwing was conducted in the transitional competition training phase for the 2012 Olympic Games in London. Recording was done at the Šiška stadium in Ljubljana (Republic of Slovenia). A shot put circle was used with a diamater of 2.135 meters, with a segment and calibrated metal meter in accordance with IAAF standards. The field and weather conditions were ideal. We recorded 85 throws at the testing. The athletes threw with their right arm. The best and most proper 36 throws were taken into account for final analysis. Recording was carried out with two synchronized cameras (Casio EX-F1) placed at a 90° angle. The third camera (Casio ExX-F1) was placed at a 4 meter height above the shot put circle (picture 1).

The analyzed range of the circle was calibrated with a reference frame of 1 m x 1 m x 2m, while for calibrating we took eight reference borders (picture 2).The distance of analyzed movement was defined with an »x« axis, height with a »y« axis and depth with a »z« axis. . For determining kinematic parameters of technique we used 3-D software APAS (Ariel Dynamics Inc., San Diego, Ca). Digitialization was done of a 15-segment model of the shot putter›s body, which we defined with 18 reference points.The eighteenth point was defined with the centre of a shot put ball. Model segments show body parts connected with joints. Mass and centre of gravity segments as well as center of body gravity were calculated on the basis of the anthropometric tjelesnih tački izravnate su sa digitalnim Buterworthovim filterom 7. stepena. Sa programskim paketom ARlEL dobiveni su podaci o S-putu, V-brzini, A-uglu, w-ugaonoj brzini u X, Y i Z osi.

Slika 1. *Položaj kamere /* ***Picture 1.*** *Situation of camere*



Da bi utvrdili uticaj prediktivnih vrijednosti kinematičkih parametara pojedinih segmenata tijela bacača kugle - uglovnih A vrijednosti u X osi u trenutku izbačaja (prediktorski skup varijabli) na dužinu dometa kugle (kriterijska varijabla), primijenjena je regresiona analiza.

Rezultati i diskusija

Regresiona analiza dužine izbačaja na osnovu varijabli uglovnih (A) vrijednosti u X osi – trenutak izbačaja

models (Dempster,1955). Coordinates for body points were arranged with a digital 7th order Butterworth filter. With the program packet ARlEL we gathered data on S-trajectory, V-velocity, A-angle, w-angle velocity in x, y and z axes.

Slika 2. *Metode obrade podataka /* ***Picture 2.*** *Methods for data processing*

In order to determine the impact of predictor values of kinematic parameters of a shot putter's individual body segments – angular A values in the x-axis at the moment of release (predictor variable group) onto the distance of the shot put range (criterion variable), a regression analysis was applied.

Results and Discussion

Regression analysis of the distance of the throw on the basis of angular variable (A) values in the x-axis – moment of release.

Tabela 1. / Table 1. *Model Summary*

Model		R	R Square	Adjusted R Square	Std. Error of the Estimate R Square Change	Change Statistics F Change	df1	df2	Sig. F Change	
dimension0	1	.923a	.853	.632	.21907	.853	3.862	21	14	.006

a. Prediktori: (konstanta), AxLSTO, AxDKLJ, AxLRAM, AxLKUK, AxDC7R, AxLNZG, AxLRZG, AxLKLJ, AxDSTO, AxLC7R, AxDNZG, AxDRZG, AxLLAK, AxDLAK, AxDRAM, AxT9T8, AxC1GL, AxDKUK, AxL4L3 , AxL5S1, AxT1C7

a.Predictors: (Constant), AxLSTO, AxDKLJ, AxLRAM, AxLKUK, AxDC7R, AxLNZG, AxLRZG, AxLKLJ, AxDSTO, AxLC7R, AxDNZG, AxDRZG, AxLLAK, AxDLAK, AxDRAM, AxT9T8, AxC1GL, AxDKUK, AxL4L3 , AxL5S1, AxT1C7

Tabela 2. / Table 2. *ANOVAb*

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.892	21	.185	3.862	.006a
	Residual	.672	14	.048		
	Total	4.564	35			

a. Prediktori: (konstanta), AxLSTO, AxDKLJ, AxLRAM, AxLKUK, AxDC7R, AxLNZG, AxLRZG, AxLKLJ, AxDSTO, AxLC7R, AxDNZG, AxDRZG, AxLLAK, AxDLAK, AxDRAM, AxT9T8, AxC1GL, AxDKUK, AxL4L3, AxL5S1, AxT1C7

b. Završna varijabla: Dužina

a. Predictors: (Constant), AxLSTO, AxDKLJ, AxLRAM, AxLKUK, AxDC7R, AxLNZG, AxLRZG, AxLKLJ, AxDSTO, AxLC7R, AxDNZG, AxDRZG, AxLLAK, AxDLAK, AxDRAM, AxT9T8, AxC1GL, AxDKUK, AxL4L3, AxL5S1, AxT1C7

b. Dependent Variable: Distance

Tabela 3. / ***Table 3.*** *Coefficients*[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
	B	Std. Error	Beta			Zero-order	Partial	Part
(Constant)	25.380	1.938		13.097	.000			
AxL5S1	.110	.095	1.026	1.155	.267	-.011	.295	.118
AxL4L3	1.531	1.171	.874	1.307	.212	.025	.330	.134
AxT9T8	-.058	.207	-.205	-.282	.782	.082	-.075	-.029
AxT1C7	-.264	.155	-2.331	-1.704	.111	-.008	-.414	-.175
AxC1GL	.195	.159	1.466	1.227	.240	-.031	.312	.126
AxDC7R	-.027	.035	-.237	-.766	.456	-.027	-.201	-.079
AxDRAM	-.074	.034	-.707	-2.142	.050	.176	-.497	-.220
AxDLAK	.058	.026	1.126	2.251	.041	.121	.516	.231
AxDRZG	-.018	.012	-.572	-1.493	.158	.020	-.371	-.153
AxLC7R	-.172	.058	-1.133	-2.942	.011	-.168	-.618	-.302
AxLRAM	-.020	.022	-.319	-.919	.373	-.010	-.239	-.094
AxLLAK	.073	.027	1.458	2.746	.016	.189	.592	.282
AxLRZG	-.001	.006	-.023	-.111	.913	-.343	-.030	-.011
AxDKUK	-.141	.043	-1.827	-3.295	.005	.074	-.661	-.338
AxDKLJ	-.022	.078	-.077	-.282	.782	-.040	-.075	-.029
AxDNZG	-.017	.014	-.336	-1.205	.248	-.278	-.307	-.124
AxDSTO	-.012	.009	-.314	-1.400	.183	-.066	-.350	-.144
AxLKUK	-.223	.067	-3.012	-3.324	.005	-.147	-.664	-.341
AxLKLJ	.119	.054	.404	2.208	.044	-.157	.508	.226
AxLNZG	.008	.010	.140	.729	.478	-.006	.191	.075
AxLSTO	-.031	.014	-.409	-2.125	.052	-.104	-.494	-.218

Zavisna varijabla: *Dužina* / ***Dependent Variable:*** *Distance*

U Tabeli 1. prikazani su rezultati regresione analize prediktorskog sistema uglovnih vrijednosti pojedinih segmenata tijela u X osi u trenutku izbačaja sa kriterijskom varijablom dužina dometa kugle.

Koeficijent multiple korelacije koji iznosi R=.92 i koeficijent determinacije R Square =.85 ukazuju da je objašnjeno 85% zajedničke varijanse kriterijske varijable, odnosno da istraživani prediktorski sistem generalno objašnjava 85% uticaja na dužinu dometa kugle, dok preostali dio uticaja od 15 % pripada drugim endogenim i egzogenim faktorima koji nisu istraživani ovim radom.

Povezanost ova dva sistema je na nivou značajnosti p<.01, što znači da možemo pristupiti daljem analiziranju parcijalnog uticaja prediktorskog sistema uglovnih vrijednosti pojedinih segmenata tijela u X osi u trenutku izbačaja sa kriterijskom varijablom dužina dometa kugle.

Statistički značajane koeficijente parcijalne korelacije na nivou p<.01 imaju vrijednosti ugla desnog kuka – AxDKUK (Beta=-1.82) i lijevog kuka AxLKUK (Beta

Table 1. shows the results of regression analysis of the predictor system of angular values of individual body segments in the x-axis at the time of release with a criterion variable of the distance of the shot put throw.

The coefficient of multiple correlation which is R=.92 and the coefficient of determination R squared =.85 indicate that 85% of the common variance of the criterion variable is explained, namely that the studied predictor system generally explains 85% of the impact onto the distance of the shot range, while the remaining impact share of 15% belongs to other endogenous and exogenous factors that were not examined in this study.

The correlation of these two systems is on the level of significance p<.01, which means that we can advance to further analysis of the partial impact of the predictor system of angular values of individual body segments in the x-axis at the moment of release with the criterion variable of the distance of the shot put throw.

Statistically significant coefficients of partial cor-

=-3.01), čije su projekcije na kriterijsku varijablu negativne.

Negativni predznak pojedinačnog uticaja na kriterijsku varijablu sa statističkom značajnošću p<.05 ima ugao desnog ramena AxDRAM (Beta=-.70) i ugao lijevog ramena u nivou sedmog vratnog pršljena AxLC7R (Beta = -1.13) (Tabela 3).

Iz dobijenih rezultata možemo vidjeti da manje vrijednosti ostvarenih uglova, desnog ramena, desnog i lijevog kuka ugla i lijevog ramena u nivou sedmog vratnog pršljena doprinose većoj dužini bacanja kugle. Trenutak izbačaja se dešava kao posljedica aktivnog uglovnog kretanja prediktorskih modeliranih kinematičkih varijabli u osi X. Rotaciona tehnika je uslovljena uglovnim položajem svih segmenata tijela tokom cijelog njenog izvođenja. U trenutku izbačaja manje uglovne vrijednosti navedenih varijabli doprinose većoj dužini hica kao kriterijskoj varijabli. To pokazuje da će dužina hica biti veća ako se bacač u trenutku izbačaja nalazi u što manjem uglovnom položaju sa X osom, tj. desni i lijevi kuk, desno i lijevo rame dolaze i postavljaju u poziciju tako da su paralelni sa osom X, tj. okomiti na smjer izbačaja kugle. Takođe, negativni predznak projekcije u trenutku izbačaja ose X, ima ugao lijevog ramena u nivou sedmog vratnog pršljena koja je nastala uglovnim pomijeranjem ramenog sistema u negativnu projekciju ose X u odnosu na smijer bacanja što je prouzrokovalo pozitivan efekat na dužinu hica kao kriterijsku varijablu.

Rotaciona tehnika bacanja kugle karakteriše se veoma kompleksnim kretanjem koje se izvodi velikom brzinom u ogrančenom prostoru. Radi lakše analize tehnike, usavršavanja tehnike i u svrsi naučnog istraživanja, rotaciona tehnika bacanja kugle podijeljena je u četiri faze, u biomehaničkoj analizi može se dijeliti na sedam faza, ali ipak ona je cjelovita tako da se kod njenog izvođenja ne primjećuje prelaz iz faze u fazu. Zbog velikog uglovnog odstupanja prilikom kretanja, tj, moguće greške nastale u jednoj fazi mogu uticati na pravilno izvođenje kretanja tijela u sljedećoj fazi i poslije izbačaja kugle, dovodi krajnji domet kugle u pitanje.

Domet bacanja (rezultat takmičenja) definisan je dužinom puta djelovanja sile na kuglu, na koju utiču brzina izbacivanja, ugao izbacivanja i visina izbacivanja (Palm, 1990; Gemer, 1990; Bartonietz, 1994; Oesterreich et. al., 1997; Luhtanen et. al., 1997; Lanka, 2000; Hubbard et. al., 2001).

Brzina izbacivanja jedan je od najvažnijih parametara tehnike na kojeg utiču predhodne faze, naročito faza konačne akceleracije. Na visinu izbacivanja utiču naročito antropometrijske karakteristike (tjelesna visina,

relation with a level p<.01 are present in the value of the right hip angel– AxDKUK (Beta=-1.82) and left hip AxLKUK (Beta =-3.01), whose projections onto the criterion variable are negative.

A negative sign of individual impact onto the criterion variable with statistical significance p<.05 is seen in the angle of the right shoulder AxDRAM (Beta=-.70) and the angle of the left shoulder at the level of the seventh cervical vertebrae AxLC7R (Beta = -1.13) (Table 3).

From the gathered results we can see that lower values of the reached angels, the right shoulder, right and left hip and the left shoulder at the level of the seventh cervical vertebrae contribute to the longer distance of a shot put throw. The moment of release occurs as a result of active angular movement of predictor model variables in an x-axis. The rotational technique is conditioned with the angular position of all body segments during the entire execution. At the time of release, lower angular values of mentioned variables contribute to the longer distance of the throw as a criterion variable. It shows that the distance of the throw will be longer if the shot putter is in a lower angular position with the x-axis at the time of release, meaning the right and left hip, as well as the right and left shoulder are in a position parallel to the x-axis, that is vertical to the direction of the shot put throw. Another negative sign of the projection at the time of release of the x-axis can be seen with the angle of the left shoulder at the level of the seventh cervical vertebrae which is a result of angular shifting of the shoulder system in a negative projection of the x-axis in relation to the direction of the throw and which has caused a positive effect on the distance of the throw as a criterion variable.

The rotational rechnique of a shot put throw is characterised with very complex movement which is performed at a high speed in a limited space. For the purpose of easier technique analysis, improving the technique and for scientific study, the rotational technique of the shot put throw is divided into four phases; in biomechanical analysis it can be divided into seven phases, but after all it is integral and transition from phase to phase cannot be noticed in its execution. Due to high angular discrepancies during movement, the possible mistakes that occur in one phase can have an effect on proper body movement in the next phase and after the shot put release, which has an impact on the ultimate distance of the shot put.

The throwing distance (competition result) is defined with the length of influence of force onto the shot put, which is influenced by the release velocity, angel of release and the height of release (Palm, 1990; Gemer, 1990; Bartonietz, 1994; Oesterreich et. al., 1997; Luhtanen et. al., 1997; Lanka, 2000; Hubbard et. al., 2001).

dužina ruke) i tehnika bacanja. Povećanje visine izbacivanja proporcionalno utiče na povećanje dužine bacanja (Lanka, 2000).

Statistički značajan pojedinačni uticaj Beta koeficijenta sa pozitivnim predznakom na nivou $p<.05$ imaju vrijednosti ugla desnog lakta – AxDLAK (Beta=1.12), lijevog lakta AxLLAK (Beta =1.45) i lijevog koljena AxLKLJ (Beta=.40), čije su projekcije na kriterijsku varijablu pozitivne.

Analizirajući rezultate regresione analize dužine izbačaja na osnovu varijabli uglovnih (A) vrijednosti pojedinih segmenata tijela u X osi, u trenutku izbačaja, koji prediktorskim sistemom varijabli daju uticaj na tretiranu kriterijsku varijablu dužina izbačaja kugle se povećava, povećanjem uglova desnog i lijevog lakta te lijevog koljena.

ZAKLJUČAK

Može se zaključiti da se sa povećanjem uglova desnog i lijevog lakta, te lijevog koljena dužina ostvarenog rezultata u bacanju kugle povećava. Trenutak izbačaja se dešava kao posljedica aktivnog uglovnog kretanja prediktorskih modeliranih kinematičkih varijabli u X osi.

Rotaciona tehnika je uslovljena uglovnim položajem svih segmenata tijela tokom cijelog njenog izvodenja. U trenutku izbačaja pozitivan uticaj na tretiranu kriterijsku varijablu u osi x (čeono) imaju uglovni položaj lijevog lakta, koji usljed kretne inercije tijela vrši pozitivno uglovno kretanje u odnosu na smjer bacanja, odnosno nalazi se okomito sa osom X i svojim zaustavljanjem, za sobom povlači uglovni položaj desnog lakta u pozitivnu projekciju ose X koji svojim uglovnim položajem sistemu desna šaka–sprava omogućava pozitivno i pravilno kretanje prema trenutku izbačaja.

Takođe, pozitivnu projekciju u trenutku izbačaja ose X, ima ugao lijevog koljena koji je nastao vertikalnim opružanjem lijeve noge, potpomognut djelovanjem kretne aktivnosti i sile iz desne noge, sistema kukova i kretnom inercijom centripetalne sile. Što je veća visina izbačaja, a time i elevacioni ugao, dužina hica će biti veća. To je direktno povezano sa povećanjem uglovnih vrijednosti tretiranih varijabli.

Release velocity is one of the most important technique parameters which is influenced by previous phases, especially the final acceleration phase. The height of release is especially inflenced by anthropometric characteristics (body height, arm length) and throwing technique. The increase of release heigth proportinally impacts the increase of the throwing distance (Lanka, 2000).

Statistically significant individual effect of Beta coefficient with a positive sign at the level of $p<.05$ are seen in angle values of the right elbow– AxDLAK (Beta=1.12), left elbow AxLLAK (Beta =1.45) and left knee AxLKLJ (Beta=.40), whose projection onto the criterion variable are positive.

Analysing the results of regression analysis of the throwing distance on the basis of angular value variables (A) of individual body segments in the x-axis, at the moment of release, which give an effect to the referred criterion variable of the throwing distance by the predictor system.

CONCLUSION

It can be concluded that with the increase of the angles of the right and left elbow, as well as the left knee, the distance of the throw is increased. The moment of release occurs as a result of active angle movement of predictor model kinematic variables in an x-axis.

The rotational technique is conditioned by the angular position of all body segments during its entire execution. At the time of release, there is a positive effect on the referred criterion variable in an x-axis (lateral) with the angular position of the left elbow, which in the midst of body momentum performs a positive angular movement in relation to the direction of the throw, namely it is parallel to the x-axis and by halting, it effects the angular position of the right elbow in a positive projection of the x-axis which enables by way of its angular position for the right hand-instrument system to have positive and proper movement at the time of release.

A positive projection at the time of release of the x-axis is seen in the angle of the left knee which has emerged by vertically extending the left leg, supported by the movement activity and force from the right leg, the hip systems and moving momentum of centripetal force. The higher the release height and thereby the elevation angle, the distance of the throw will be longer. It is directly related to the increase of angular values of referred variables.

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Autori pridonijeli jednako.

Konflikt interesa
Mi izjavljujemo da nemamo konflikt interesa.

Authorship statement
The authors have contributed equally.

Financial disclosure
We declare that we have no confl icts of interest.

LITERATURA / REFERENCES

Bartlett, R., Muller, E., Lindinger, S., Brunner, F., & Morriss, C. (1996). Three-dimensional evaluation of the kinematic release parameters for javelin throwers of different skill levels. *Journal of Applied Biomechanics, 12*, 58-71.

Bartonietz, K. (1994). Rotational shot put technique: Biomechanic findings and recommendations for training. *Track and Field Quarterly Review, 93* (3), 18-29.

Čoh, M. (2001). *Biomehanika atletike.* Ljubljana: Fakulteta za šport Univerziteta v Ljubljani. [In Slovenian]

Čoh, M., & Štuhec, S. (2008). *Trodimenzionalna kinematička analiza rotacione tehnike bacanja kugle.* Ljubljana: Fakultet za šport, Institut za kineziologiju, Biomehanička dijagnostika i metode u atletskom treningu. [In Slovenian]

Ćuk, I., & Čoh, M. (1993). *Kinematičke veličine.* Ljubljana: Fakultet za šport Univerziteta u Ljubljani. [In Slovenian]

Gemer, G. V. (1990). Overview of the Shot Put technique. *New Studies in Athletics*, *1*(5), 31-34.

Grigalka, O. Y. (1968). *Talkanije jedra, Legkaja atletika.* Moskva. [In Slovenian]

Hubbard, M., Neville, J., & Scott, J. (2001). Dependence of release variables in the shot put. *Journal of Biomechanics, 34,* 449-456.

Kerssenbrock, K. (1974). *Analysis of rotation technique.* In: The Throws (izdao F. Wilt), 39-41. Tafnews Press, Los Altos, CA.

Lanka, J. (2000). Shot putting In Biomechanics in sport (izdao VM Zatsiorsky), str. 435-457. *International Olympic Commitee*.

Luhtanen, P., Blomqvist, M., & Vanttinen, T. (1997). A comparasion of two elite shot putters using the rotational shot put technique. *New Studies in Athletics, 12*(4), 25-33.

Oesterreich, R., Bartonietz, K., & Goldmann, W. (1997). Rotational technique; A model for the long-term preparation of young athletes. *New Studies in Athletes, 12*(4), 35-48.

Palm, V. (1990). Some biomechanical observations of the rotational shot put. *Modern athlete and coach*, *28*(3), 15-18.

Stepanek, J., & Susanka, P. (1986). Discus throw: Results of a biomechanics study. *New Studies in Athletics*, *1*, 25-36.

Zatsiorsky, V. M., Lanka, G. E., & Shalmanov, A. A. (1981). Biomechanical analysis of shot putting technique. *Exercise and sport sciences reviews*, *9*(1), 353.

Primljen: 05. marta 2015. / Received: March 05, 2015
Izmjene primljene: 27. jun 2015. / Received: June 27, 2015
Prihvaćen: 24. novembar 2015. / Accepted: November 24, 2015