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Original Article

Relationship between the biomechanical parameters technique for preliminary swings among elite hammer throwers

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Abstract:
The purpose of this study was to establish the relationships between techniques of the pre-swing elite hummer throwers. The research was attended by eight hammer throwers. Measurements were taken in competitive conditions at the world Championship in 2017 (London). Biomechanical parameters were determined by processing video materials of the best attempts of hammer throw. For determine biomechanical parameters using the program Dartfish. Our results show very strong correlation between time of second pre-swing and height hammer at the first pre-swing r=-0,809, angle left knee at the second pre-swing and angle incline torso at first pre-swing r=-0,835. Strong correlation observed between angles in right knee at the first pre-swings and such parameters of techniques second pre-swings as: height lifting left heel from support r=-0,746, angle right elbow r=0,713, angle left elbow r= 0,755, height of hammer r=0,787; between angle in left knee at first pre-swing and angle in left knee r=-0,796 and height hammer at the second pre-swings; time first preliminary swing and time second preliminary swing r= 0,732. As a result correlations analysis was discovered that such parameters of the technique of the first preliminary swing as: height lifting of left heel from support, angle in right elbow, angle in left elbow, linear velocity of hammer, angular velocity of hammer, centrifugal force of hammer don't have significant impact on the technique of the second preliminary swing. Thus, the data obtained during research demonstrates importance of the, time parameters, angular parameters and height of the hammer during pre-swings for effective implementation pre-swing.
Keywords: technique hammer throw, qualified athlete, relationship preliminary swings, phase

Introduction

Hammer throw it is a complex coordination of movements' type athletics throwing (Dapena, J. 1986). High level of achievements in the international arena requires of the improvement of technical training of hammer (Shesterova L., Rozhkov V., 2018). Pre-swing begin from the static posture, its purpose is to make the hammer to obtain a certain speed, create conditions to the rotation (Silvester J., 2003). Mostly athlete uses two pre-swing (Davila J., 2005, Wang, Ye. 2018). During pre-swing hammer have specific trajectory with high and low points which do circular motion around the human body (MorlyM., 1995, Barclaly L., 1998, Hirose, K. 2016).

Technique involved in pre-swing is the central element for successful hammer throwing. S. Dowlan (2002), D. Jesus (2003) determined that if sportsmen make wrong on this phase he cannot effective make phase of final effort. Several researchers have conducted analysis of the phase pre-swing elite hammer throws. Was observed times parameters of the hammer, cable force of the hammer during pre-swing (Kagemoto, Y. 1989, Brice, S. 2008). M. Raiph & A. Otto (1992) founded that at the swing phase's velocity increment of hammer amounts until half of the maximal velocity of hammer. Researchers V. Lapp (1986), N. Fujii (2007), S. Brice (2011) determined a direct correlation between the linear hammer speed and the thrower applied forces during pre-swing. If throwers applied more forces they will have higher linear hammer speed. M. Ryszard (1991) determined that long radius generates relatively low angular velocity of hammer during pre-swing. For a good throw, the athlete should increases hammer speed during pre-swings (Bartonietz K., 2000).

Several researchers were determined correlation between technique of the pre-swings and other phases of hammer throw. L .Judge (1999) determined that if pre-swing time too long hammer throws did not have high speed when he do first turns with hammer. Correlation between parameters technique of the pre-swing and technique of the turn with hammer found that reasonable advance rotary pre-swing speed will make subsequent rhythm more compact (Shuai W., Jihe Z., Chong J, 2014).

However previous researches don't describe cor between biomechanical parameters which have hammer throws during first and second pre-swing.

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The aim of this study is to determine the characteristics of the relationships between parameters of techniques first and second pre-swing.

Results of this article able to improve efficiency techniques preparations of hammer throw.

Materials & methods

The subjects of this study were eight hammer throwers, finalist's international competition during 2016-2018 seasons. Measurements were taken in competitive conditions at world Championship (London) in 2017. The throwers' age was 25-42 years, the body weight was 90-128 kg, and the body height was 177-190 sm. All subjects were right-handed. Three final attempts were analyzed. The research related to human use has been complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki.

Biomechanical parameters were determined using the program Dartfish. For this was used video cameras Panasonic and fps 1000, which were installed from both sides of the sector for hummer throw. Recording mode cameras were 1920x1080, with frame frequency 25 p and 1300 p. The Dartfish program processed videos increasing speed view record for 1 second twice. This allowed processing biomechanical indicators hummer throwers with an accuracy of 0.02 s per frame. During biomechanical analyzing in the Dartfish program were determining next parameters: width of the placement of the legs; height lifting of the right heel from support; height lifting of the hammer; time of the phase final effort; angle departure of the hammer; angular speed of the hammer; centrifugal force of the hammer, speed of a departure of the hammer.

All statistical data were processed with the use of the Statgraphics Centurion 18 (Version 18.1.11). The normality of the distributions was determined with the Shapiro-Wilk test. The standard deviation was determined for analyzing dispersion of values of a random variable relative to its mathematical expectation. The arithmetic mean was determined for calculation values of the general totality. The coefficient of variation was determined for the calculation of the relative scatter of a random variable. If coefficient of variation was 0-10 % - homogeneity of the indicators was observed. If coefficient of variation was 10-15 % - average homogeneity of the indicators was observed. If coefficient of variation was more than 15 % was observed heterogeneity of the indicators.

Spearman's correlation coefficients were calculated to describe the correlation between biomechanical parameters of the techniques first and second pre-swing

Results

Measurements parameters of techniques hammer throw were taken at competitive conditions. At the end of pre-swing elite hammer throwers have next parameters of the techniques table 1, 2.

Table 1. Parameters technique elite hammer throwers which they have at the end of the first pre-swing

Parameters of technique	$\overline{X}$	σ	V (%)
Angle in the left knee(°)	153,1	6,3	4,1
Angle in the right knee(°)	164,6	6,1	3,7
Height lifting left of the heel from support (cm)	11,1	2,2	20,1
Angle in the right elbow (°)	112,2	11,8	10,5
Angle in the left elbow (°)	113,2	12,5	11,0
Angle of the incline torso (°)	15,5	1,5	10,0
Height of the hammer (m)	1,85	0,11	5,8
Linear velocity of the hammer (m s)	9,96	1,19	11,92
Angular velocity of the hammer ($rad \cdot s^{-1}$)	7,14	0,97	13,60
Centrifugal force of the hammer (kg)	73,5	21,2	28,83
Time of the first preliminary swing (s)	1,4	0,11	8,24

Analyses of the technique determine growing most parameters of the technique during second pre-swing. Linear velocity hammer at the end of the second pre-swing increases to 22,7% angular velocity hammer to 11,5%, centrifugal force to 18,6%, height hammer to 6,1%, angle incline torso to 18,3%, angle left elbow to 8,1%, angle right elbow to 11,2%.

Also during the second pre-swing decreases such parameters of technique as angle left knee to 0,5%, angle right knee to 7,2%, height lifting left heel from support to 5,4% and time second preliminary swing to 7,6%.

Coefficient of variation such parameters of the technique as height lifting left heel from support, angle incline torso, centrifugal force hammer was 26,5-28,8%. That showed that researched hammer throwers had significant differences in these parameters of the technique that explained individual parameters of the technique research hammer throwers.

Table 2. Parameters technique elite hammer throwers which they have at the end of the second pre-swing

Parameters of technique	$\overline{X}$	σ	V (%)
Angle in the left knee(°)	150,9	9,7	6,4
Angle in the right knee(°)	152,0	12,3	8,1
Height lifting left of the heel from support (cm)	10,6	2,3	21,4
Angle in the right elbow (°)	123,3	12,4	10,1
Angle in the left elbow (°)	121,3	14,0	11,5
Angle of the incline torso (°)	18,2	4,8	26,5
Height of the hammer (m)	2,00	0,07	3,51
Linear velocity of the hammer (m s)	12,69	1,35	10,60
Angular velocity of the hammer (rad · s $^{-1}$)	8,27	0,82	9,87
Centrifugal force of the hammer (kg)	93,6	17,5	18,7
Time of the second preliminary swing (s)	1,27	0,10	8,0

To determine influence parameters technique of the first pre-swing on the parameters technique of the second pre-swing we conducted Pearson pair correlation analysis.

The correlation between parameters of the technique pre-swing among elite hummer throwers present at the table 3.

Table 3. Correlation between parameters of the technique pre-swing among elite hummer thrower

Biomecha-nical parameters first prelimina-ry swing	Biomechanical parameters of the second preliminary swing										
	Angle in the left knee	Angle in the right knee	Height lifting of the left heel from support	Angle in the right elbow	Angle in the left elbow	Angle of the incline torso	Height of the hammer	Linear velocity of the hammer	Angular velocity of the hammer	Centrifu gal force of the hammer	Time of the second pre-swing
Angle in the left knee	**-0,796**	-0,585	-0,248	0,270	0,355	-0,105	**0,744**	0,505	0,190	0,373	0,282
Angle in the right knee	-0,421	-0,400	**-0,746**	**0,713**	**0,755**	0,078	**0,787**	0,353	-0,005	0,205	0,373
Height lifting of the left heel from support	0,241	0,521	-0,033	0,556	0,400	0,180	-0,236	0,424	0,442	0,495	-0,191
Angle in the right elbow	0,153	0,287	-0,017	0,421	0,260	0,412	0,097	0,098	0,025	0,164	0,180
Angle in the left elbow	-0,028	0,336	0,084	0,328	0,191	0,422	-0,003	0,063	0,029	0,144	-0,182
Angle of the incline torso	**-0,835**	-0,334	-0,369	0,543	0,608	0,017	0,578	0,256	-0,019	0,151	-0,265
Height of the hammer	0,071	0,314	-0,012	0,257	0,253	-0,275	-0,498	0,260	0,390	0,308	**-0,809**
Linear velocity of the hammer	0,585	0,309	-0,011	0,213	0,132	-0,054	-0,344	0,668	0,519	-0,635	0,143
Angular velocity of the hammer	0,587	0,203	-0,168	0,144	0,116	-0,106	-0,314	0,614	0,478	-0,597	0,046
Centrifugal force of the hammer	0,364	-0,040	-0,135	0,086	0,101	-0,259	-0,098	0,500	0,434	-0,545	0,341
Time of the first pre-swing	-0,225	-0,572	-0,320	0,224	0,271	-0,168	0,638	0,244	-0,010	0,133	**0,732**

Note: R > Rcr, if R > (0,707)

Very strong correlation was observed between angle incline torso at the first pre-swing and angle left knee at the second pre-swing r= -0,835. Also very strong correlation was observed between heights hammer at the first pre-swing and times second pre-swing r=-0,809.

Very strong correlation was observed between angle of the incline torso during first preliminary swing and angle in the left knee during second pre-swing r= **-0,835.** Also very strong correlation was observed between heights hammer at the first pre-swing and times of second pre-swing r=-0,809.

Strong correlation was observed between angles left knee at the first pre-swing and such parameters of the second pre-swing as: angle left knee r=-0,796 and height hammer r= 0,744.

Strong correlation was observed between angles in right knee at the first pre-swing and such biomechanical parameters of the second pre-swing as: height lifting left heel from support r= -0,746, angle in right elbow r=0,713, angle in left elbow r=0,755, height hammer r=0,787.

As a result correlations analysis was discovered strong correlation between time of the first pre-swing and time of the second pre-swing r=0,732

Discussion

This study investigated relationships between parameters technique pre-swings qualified hammer throwers. As result of ours research was determined that if throws do faster first pre-swings they will spend less time on second pre-swing r=0,732.This research confirmed hypotheses that if hammer do faster first pre-swing they will do faster second pre-swing (Murofushi K., 2007; Bartonietz K., 2000). Also we determined that if hammer throwers more up hummer at the first pre-swing they will have do faster second pre-swing r= -0,809.

About high depend of velocity which during second pre-swing from velocity during first pre-swing descriptions K. Murofushi (2007), L. Judje (1999). They study showed velocity increment in the process of the pre-swing phase of the last to about half of the initial. However ours research technique elite hammer throws didn't found very strong correlation between velocities hammer during pre-swing phase. As result correlation analyses was discovered appreciable correlation between linear velocity hammer during pre-swings r= 0,668 that showed on possible increase linear velocity hammer at the second pre-swing if during first pre-swing hammer have more velocity.

The results of the present investigation suggest that if throwers have more angles in left knee and incline torso at the first pre-swing they will have fewer angles in left knee at second pre-swing r=-0,796, r= -0,835. Also we was founded that throwers have more angles in right knee at first pre-swing they will have more angles in right and left elbows at the second pre-swing r=0,713, r= 0,755. Those improve knowledge about influence angular parameters of the technique which have hammer throwers during first pre-swing on biomechanical parameters of technique second pre-swing among elite hammer throwers (Judje l., 1999; Judje l.,2000).

Previous study observed height of the hammer during pre-swings determined depended height of the hammer during pre-swings on velocity of the hammer. Founded that if sportsmen more up hammer at the end of the first pre-swings they have more velocity at the first part second pre-swing (Isele R.,2010; Shuai W., 2014). Nevertheless previous study don't research influence parameters of techniques which have throwers during pre-swings on the height of hammer. The findings suggest established that if sportsmen during first pre-swings have more angle in left and right knee they will have more up hammer at the end of the second pre-swings r= 0,774, r= 0,787. Moreover research influence angle in right knee which have sportsmen during first pre-swing on the parameters of techniques second pre-swing we was observed increase height lifting of left heel from support during second pre-swing if throws had less angle in right knee during first pre-swing r=-0,746.

Research biomechanical parameters of the techniques pre-swings we was determined that such parameters of techniques as height lifting of left heel from support, angle in right elbow and angle in left elbow which had throwers during first pre-swing don't have impotent influence on the techniques second pre-swings, about this testified weak correlation r= -0,033- 0,442.

Conclusion

The findings suggest the importance of angle time parameters during pre-swing for the effective implementation pre-swing and preparation to the rotation with hammer. The results demonstrated strong correlation between height of hammer during second pre-swing and angle in left, right knee at the first pre-swing. Strong correlation was observed between angle in right knee at the first pre-swing and height lifting of left heel from support, angle in right elbow and angle in left elbow at the second pre-swing. Strong correlation was observed between angle in left knee during second pre-swing and angle in left knee and angle of incline torso during second pre-swing. Very strong correlation was observed between time second pre-swing and height hammer during first pre-swing and time of first pre-swing. As a result correlations analysis was discovered that such parameters of technique first pre-swing as: height lifting of left heel from support, angle in right elbow, angle in left elbow, linear velocity of hammer, angular velocity of hammer, centrifugal force of hammer don't have significant impact on the technique second pre-swing.

The findings suggest established that for effective implementation second pre-swing during improvement technique first pre-swing the most attention should devote into angles in left and right knees, angle of incline torso, height hammer and time of the first pre-swing.

Conflict of interest. The authors declare that there is no conflict of interest.

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