

ISSN 2311-6374

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
KHARKIV STATE ACADEMY OF PHYSICAL CULTURE

**SLOBOZHANSKYI
HERALD
OF SCIENCE AND SPORT**

Scientific and theoretical journal

Published 6 times in a year
English ed. Online published in October 2013

Volum 9 No. 1

Kharkiv
Kharkiv State Academy of Physical Culture
2021

P 48

UDC 796.011(055)“540.3”

Slobozhanskyi herald of science and sport: [scientific and theoretical journal]. Kharkiv: KhSAPC, 2021. Vol. 9. No. 1. 168 p.

English version of the journal “SLOBOZANS`KIJ NAUKOVO-SPORTIVNIJ VISNIK”

The journal includes articles which are reflecting the materials of modern scientific researches in the field of physical culture and sports.

The journal is intended for teachers, coaches, athletes, postgraduates, doctoral students research workers and other industry experts.

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**Publication of Kharkiv State Academy of Physical Culture
Publication language – English**

ISSN (English ed. Online) 2311-6374

ISSN (Ukrainian ed. Print) 1991-0177

ISSN (Ukrainian ed. Online) 1999-818X

Key title: Slobozhanskyi herald of science and sport

Abbreviated key title: Slobozhanskyi her. sci. sport

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Physical Culture, 2021



**RELATIONSHIP BETWEEN BIOMECHANICAL PARAMETERS
TECHNIQUES OF THE PRELIMINARY ROTATIONS AMONG ELITE
WOMEN HAMMERS THROWERS**

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Purpose: to determine the relationships technique of the first preliminary rotation of the hammer with technique of the second preliminary rotation of elite women's hammer throwers.

Material and Methods: the research was attended by 8 hammer throwers (women) finalists' of European championships, and World championship during the

2016-2019 seasons. Research methods used: analysis and generalization of literary sources, processing video materials, methods of mathematical statistics.

Results: very strong correlation was observed between times of the second preliminary swing linear, angular velocities of the hammer, centrifugal force of the hammer at the end of the second preliminary swing and angles in the right and left elbows at the end of the first preliminary swing $r=0,734-0,833$. The correlation coefficient showed that if research women hammer throwers have more angles in the right and left elbows at the end of the first preliminary swing they will have more time of the second preliminary swing, linear, angular velocities of the hammer, centrifugal force of the hammer at the end of the second preliminary swing. As a result correlations analysis was discovered that such parameters of technique first pre-swing as: linear velocity of the hammer, angular velocity of the hammer, centrifugal force of the hammer, time of the first preliminary swing don't have significant impact on the technique second pre-swing.

Conclusion: the findings suggest established that for effective implementation second preliminary swing during improvement technique of the first preliminary swing the most attention should devote angles in the elbow joints, trajectory of the hammer, angle in the right knee and height lifting of the left heel from support at the end of the first preliminary swing.

Keywords: technique, biomechanical parameters, preliminary swings, elite women athletes, hammer throw.

Introduction

Preliminary swings one of the most important phase of the technique hammer thrower. During Pre-swing sportsmen enter to the rhythm of the throw. If throwers do mistakes on this phase they cannot get high performance results in the hammer throw [1, 3]. The biomechanical parameters of the techniques pre-swing researched R. Isele [6], L. Judge [7], J. Silvester [10].

V. Rozhkov [2] K. Bartoniet [4], have determined that in general elite hammers throwers use two preliminary swings.

N. Fujii, Y. Koyama [5] was studied speed indicators of the hammer. They founded that in the process of the swing phase's velocity increment of hammer amounts until 50% of the maximal velocity of hammer. Researchers K. Murofushi, S. Sakurai [8] has found necessary gradual increase speed of the hammer during pre-swing for smooth entry into the first turn. Shuai, W., Jihe, Z. [9] was determined that time pre-swing should be 1,06 s for effective turn with hammer.

However, despite on a lot of researches technique of the preliminary swings no studies to date have attempted to examine angles parameters of the techniques pre-swing and relationship between biomechanical parameters techniques of the preliminary swings.

Connection of the study with scientific programs, plans, topics. This study was performed in accordance with the research theme of the Department of Athletics of the Kharkiv State Academy of Physical Culture "Features of the spatial-temporal characteristics of sports (athletics) and routine physical activity" state registration number 0119U103785.

Purpose of the study is to determine the relationships technique of the first preliminary swing with technique of the second preliminary swing elite women hammer throwers.

Material and Methods of the research

The research was attended by 8 hammer throwers (women) finalists' of European championships, and World championship during the 2016-2020 seasons. Research methods used: analysis and generalization of literary sources, processing video materials, methods of mathematical statistics.

Results of the research

Parameters techniques of elite women hammer throwers which they have at the end of the first preliminary swing present at the table 1

Most biomechanical parameters of the techniques first preliminary swing had coefficient of variation $V=5,3-14,0\%$. That showed that researched parameters of techniques was homogeneity and sportsmen didn't have significant differences between biomechanical parameters of the techniques first preliminary swing.

Coefficient of variation such parameters of the technique preliminary swings as height lifting of the left heel from support, linear velocity of the hammer, angular velocity of the hammer, centrifugal force of the hammer was $V=20,61-37,28\%$ %. That showed that researched women hammer throwers had significant differences in these parameters of the technique that explained individual parameters of the technique research hammer throwers.

Table 1

Biomechanical parameters technique elite women hammer throwers which they have at the end of the first preliminary swing

Indicators	\bar{X}	σ	V %
Angle in the right knee (°)	163,7	8,7	5,3
Angle in the left knee (°)	147,8	12,5	8,4
Height lifting of the left heel from support (cm)	9,6	3,1	32,2
Angle in the right elbow (°)	107,5	8,2	7,6
Angle in the left elbow (°)	106,9	8,4	7,8
Angle of the incline torso (°)	11,1	1,6	14,0
Height of the hammer (m)	1,95	0,2	8,9
Linear velocity of the hammer ($m \cdot s^{-1}$)	7,25	1,50	20,66
Angular velocity of the hammer ($rad \cdot s^{-1}$)	5,11	1,05	20,61
Centrifugal force of the hammer (kg)	21,0	7,81	37,28
Time of the first preliminary swing (s)	1,06	0,08	7,36

Parameters techniques of elite women hammer throwers which they have at the end of the second preliminary swing present at the table 2.

Analysis of the technique second preliminary swings identify heterogeneity such indicators as height lifting of the left heel from support, angle of the incline torso, centrifugal force of the hammer $v= 27,10-48,7\%$. That showed that researched women hammer throwers had significant differences in these parameters of the technique that explained individual parameters of the technique research hammer throwers.

Other parameters techniques of the second preliminary swing didn't have significant differences $V=3,2-14,68\%$.

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

Table 2

Biomechanical parameters technique elite women hammer throwers which they have at the end of the second preliminary swing

Indicators	\bar{X}	σ	V %
Angle in the right knee (°)	155,6	9,9	6,4
Angle in the left knee (°)	155,2	9,0	5,8
Height lifting of the left heel from support (cm)	9,2	4,5	48,7
Angle in the right elbow (°)	107,2	9,7	9,1
Angle in the left elbow (°)	107,9	10,0	9,3
Angle of the incline torso (°)	8,9	4,1	46,2
Height of the hammer (m)	1,99	0,06	3,2
Linear velocity of the hammer ($m \cdot s^{-1}$)	9,94	1,42	14,30
Angular velocity of the hammer ($rad \cdot s^{-1}$)	6,91	1,01	14,68
Centrifugal force of the hammer (kg)	37,6	10,2	27,10
Time of the first preliminary swing (s)	1,20	0,05	4,13

The relationship between biomechanical parameters of the technique preliminary swings among elite women hammer throwers present at the table 3.

Very strong correlation was observed between times of the second preliminary swing linear, angular velocities of the hammer, centrifugal force of the hammer at the end of the second preliminary swing and angles in the right and left elbows at the end of the first preliminary swing $r=0,734-0,833$. The correlation coefficient showed that if research women hammer throwers have more angles in the right and left elbows at the end of the first preliminary swing they will have more time of the second preliminary swing, linear, angular velocities of the hammer, centrifugal force of the hammer at the end of the second preliminary swing.

The correlation coefficient showed that if research women hammer throwers more up hammer above the ground at the end of the first preliminary swing they will have fewer angle in the left knee at the end of the second preliminary swing ($r=-0,791$).

Table 3

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

Biomechanical parameters first preliminary swing	Biomechanical parameters of the second preliminary swing										
	Angle in the right knee	Angle in the left 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	Centrifugal force of the hammer	Time of the second preliminary swing
Angle in the right knee	0,408	0,513	-0,056	0,509	0,528	-0,101	-0,218	0,704	0,636	0,589	0,100
Angle in the left knee	0,298	0,543	-0,440	0,209	0,248	-0,107	-0,514	0,190	0,158	0,075	-0,208
Height lifting of the left heel from support	-0,039	-0,201	0,799	0,316	0,390	0,084	0,540	0,362	0,280	0,329	0,151
Angle in the right elbow	0,059	0,388	-0,281	0,707	0,651	0,434	-0,143	0,753	0,830	0,810	0,833
Angle in the left elbow	0,072	0,385	-0,288	0,679	0,621	0,454	-0,152	0,734	0,816	0,789	0,825
Angle of the incline torso	-0,201	-0,207	0,399	0,519	0,496	0,335	0,224	0,580	0,611	0,655	0,370
Height of the hammer	-0,279	-0,791	0,728	-0,107	-0,027	-0,426	0,770	-0,212	-0,352	-0,185	-0,229
Linear velocity of the hammer	0,295	0,469	0,042	0,334	0,408	0,590	-0,517	0,418	0,445	0,272	-0,254
Angular velocity of the hammer	0,294	0,469	0,041	0,335	0,408	0,591	-0,518	0,419	0,446	0,272	-0,253
Centrifugal force of the hammer	0,261	0,533	0,049	0,324	0,396	0,617	-0,516	0,377	0,416	0,236	-0,205
Time of the first preliminary swing	-0,444	0,507	0,376	0,156	0,205	0,249	-0,231	-0,168	-0,087	-0,171	-0,202

Note: $R > R_{cr}$, if $R > (0,707)$

If research women hammer throwers have more up left heel and hammer above the ground at the end of the first preliminary swing they will have more up left heel from support at the end of the second preliminary swing $r=0,799$ and $r=0,728$.

Strong correlation was observed between Angle in the right elbow at the first and second pre swing $r=0,707$. Correlation showed increase angle in the right elbow at the end of the second preliminary swing if sportsmen will have more angle in the right elbow at the end of the first preliminary swing.

If research women hammer throwers have more hammer above the ground at the end of the first preliminary swing they will have more height of the hammer at the end of the second preliminary swing $r=0,770$

Strong correlation was observed between linear velocity of the hammer at the end of the second preliminary swing and angle in the right knee at the end of the first preliminary swing $r=0,704$. The correlation coefficient showed that if research women hammer throwers have more angle in the right knee at the end of the first preliminary they will have higher linear velocity of the hammer at the end of the second preliminary swing.

Conclusions / Discussion

The results of the present investigation suggest about importance angular parameters of techniques of the first preliminary swing for effective execution second preliminary swing. This research confirms results J. Silvester [10], K. Bartonietz [4], about increase height of the hammer at the second preliminary swing if hammer will have higher trajectory during first preliminary swing.

Studying speeds parameters of the techniques pre-swings K. Murofushi [8], N. Fujii [5] founded increase linear velocity of the hammer until 50% during second preliminary swing in the comparison first preliminary swing. However our research wasn't determined strong correlation between speeds parameters of the techniques pre-swings $r=0,418-0,486$.

The results of the study expanded information W. Shuai [9], about time parameters of the techniques pre-swings. We was determined that if sportsmen have

more angle in the elbow during first preliminary swing they will have spent more time on realize second preliminary swing $r=0,789-0,810$.

Determined that for effective implementation second preliminary swing during improvement technique of the first preliminary swing the most attention should devote angles in the elbow joints, trajectory of the hammer, angle in the right knee and height lifting of the left heel from support at the end of the first preliminary swing.

Prospects for further research in this area. Further studies will be devoted to the research Relationship between preliminary swings and turns with hammer.

Conflict of interests. The authors declare that no conflict of interest.

Financing sources. This article didn't get the financial support from the state, public or commercial organization.

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Received: 13.01.2021.

Published: 22.02.2021.

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