DIFFERENCES IN PERFORMANCE OF ISOLATED ARM SWINGS IN ATHLETICS, VOLLEYBALL AND ARTISTIC GYMNASTICS

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Abstract

The objective of this paper is to determine if there is a difference in various variables in three different groups of athletes who conducted arm swing in isolated conditions. Sample consisted of 31 male athletes with experience in athletics (sprint and jumping disciplines), volleyball and artistic gymnastics. Sample of variables for validation of arm swing was ten kinematic, one kinetic and eighteen morphological variables. Statistically significant F-ratio was confirmed in three variables between the three groups of subjects divided by sport discipline: duration of arm swing (**DS**), fist mass (**FM**) and mass of forearm (**MFA**).

Key words: arm swing, ground reaction force, analysis of variance

Introduction

There are numerous researches in which different authors tried to explain how to achieve maximum effectiveness in performing vertical jump and on which external and internal factors depends its successful adoption and performance. Numerous authors tried to explain neuromuscular basis of movement as well as the adjustments that are occurring during the vertical jump performance (Harman and al., 1990). Although the jumps are moves which are requiring complex motor coordination of upper and lower body segments, numerous earlier researches explained the role of arm swing in vertical jump, and the development of explosiveness factors to jumping ability (Feltner and al. 1999; Lees and al. 1996). Vertical jump, as one of basic forms of human movement, is also vastly connected with arm swings, which in this basic motor form have the role of preserving the balance and allow the effective execution of movement (Carr and Gentile, 1994). The way of swing as well as characteristic running start on the skip, on the ground during execution of various different elements in sport gymnastics (Šadura, 1991), swing for preparation of volleyball player for jump in performing spike and reach for the ball in executing the block, (Đurković, 2008), and swings with crouch hands during jumps in some disciplines of athletics are in many ways connected with quality of execution of vertical jumps. To determine differences in execution of arm swing the research included three groups of subjects from different sports: athletics (ATL), volleyball (VOL) and artistic gymnastics (AG).

This paper will compare the differences of athletes in every particular sport (athletics, volleyball and artistic gymnastic) in kinematics, kinetic and four morphological variables.

Methods

Sample of subjects is compiled from 31 young and healthy males with training experience in sports which require quality exercise of arm swing for successful performance of elements or activity as a whole. Subjects are chosen as intentional sample from these sports: 10 subjects - athletics, average age 24.40 (±5.14), 11 subjects - volleyball, average age 22.81 (±3.18), and 10 subjects - artistic gymnastics, average age 22.10 (±4.77). Athletics subjects are active in their field 7.92 (±4.99) years in average, subjects in volleyball 9.68 (±4.07), and in artistic gymnastics duration of active practice of sport was 11.92 (±4.25) years. Average age of all subjects is 23.09 (±4.36), and the average of active practice with sport activity is 9.83 (±4.59).

Measurement protocol consisted from four parts: measuring of basic morphological features, performing vertical jump with an arm swing, performing vertical jump without an arm swing, and measuring ground relief with an arm swing in isolated conditions. Morphological measurements were comprised of seven body measures and were conducted in accordance with instructions of the International Biological Program (Mišigoj-Duraković, 2008). Eleven measures in total were conducted in accordance with instructions of the Regresion model II (Mejovšek, 1989). Sample of variables for evaluation of kinematic values consisted of ten variables: maximum velocity of arm swing (**VmaxS**), path of arm deceleration in swing measured on the middle of the left wrist joint (**AD**), elbow joint angle (**EJdeg**), duration of arm swing (**DS**), duration of acceleration arm swing (**AtS**), duration of deceleration arm swing (**DtS**), vertical height of the

wrist joint in the moment of maximum velocity of arm swing (**vhmaxV**), vertical jump with an arm swing (**VJwhS**), vertical jump without the arm swing (**VJwtS**), and calculated difference of the vertical jump with and without the arm swing (**hdiffJUMP**). Sample of variables for evaluation of kinetic values is force of arm swing in isolated condition (**FIAS**) and sample of variables for evaluation of morphological values consider four variables which are calculated by Regresion model II: mass of arm (**MA**), fist mass (**FM**), mass of upper arm (**MUA**) and mass of forearm (**MFA**).

Vertical jumps with and without the arm swing are measured according to "Bosco" measurement protocol (Bosco, 1997). Measuring equipment used in this research is consisted of anthropometric set (Larussport, Croatia), personal digital scales ("Silver Sense", Soehnle, Austria), platform for measuring ground force reaction "Quattro Jump", model 9290AD (Kistler, Switzerland), specifically designed seats and digital camera "EPIC 14MEGAPIXEL MYSTERIUM-X™" (RED, 34 Parker, Irving CA 96218, USA). Analysis of kinematic parameters of video was conducted with SkillSpector 1.2.4. Software manufacturer Video4coach. Part of two-dimensional 6-segment connected model was used for this measurement (Ashby and al., 2002), and arm model signified as shoulder, wrist and elbow was digitalized on every picture. Analysis of kinetic parameters was performed with data obtained on the platform for ground forces reaction measurement "Quattro Jump", model 9290AD (Kistler, Switzerland), and data analysis was performed with the help of application software Quatro Jump tip 2822A1-1, version 1.0.9.2.

Platform measurements covered the vertical ground force reaction values while the task, maximal arm swing in isolated condition, was performed.

Results

Basic descriptive parameters of the variables for assessing anthropometric characteristics are show in Table 1.

Table 1: Basic descriptive parametars of the assessing anthropometric characteristics (N=93)

variable	M	SD	min	max
ATHLETICS				
Height subjects (cm)	182.94	±8.21	169.80	200.00
Mass of subjects (kg)	81.24	±8.59	65.50	94.10
Mass of arm (kg)	9.10	±0.72	7.75	10.25
Mass fist (kg)	1.04	±0.90	0.89	1.18
Mass of forearm (kg)	2.33	±0.28	1.77	2.87
Mass of upper arm (kg)	5.72	±0.47	5.08	6.51
Arm length (cm)	74.20	±4.09	67.80	80.00
VOLLEYBALL				
Height subjects (cm)	192.00	±7.55	179.90	205.20
Mass of subjects (kg)	86.57	±9.28	74.20	105.40
Mass of arm (kg)	9.80	±0.81	9.04	11.48
Mass fist (kg)	1.19	±0.14	1.00	1.48
Mass of forearm (kg)	2.55	±0.35	2.14	3.26
Mass of upper arm (kg)	6.05	±0.42	5.56	6.91
Arm length (cm)	81.29	±3.56	75.10	87.40
ARTISTICS GYMNASTICS				
Height subjects (cm)	176.66	±7.26	168.00	189.00
Mass of subjects (kg)	72.99	±7.75	57.10	81.50
Mass of arm (kg)	9.53	±0.61	8.76	10.52
Mass fist (kg)	1.09	±0.91	0.93	1.19
Mass of forearm (kg)	2.32	±0.30	1.71	2.71
Mass of upper arm (kg)	5.59	±1.21	2.47	6.78
Arm length (cm)	75.45	±3.55	69.50	81.00

Purpose of analysis of variance was to check is there statistically significant difference between three chosen athlete groups in all measured variables. When normality of distribution was calculated by performing Kolmogorov-Smirnov test (K-S test), in Table 2., it was found no normality of distribution for the next variables: maximum velocity of arm swing (**VmaxS**), path of arm deceleration in swing (**AD**), difference in vertical jump height with and without the arm

swing (**hdiffJUMP**), mass of the upper arm (**MUA**) and execution of the vertical jump without the arm swing (**VJwtS**), so these variables weren't used in the further process of data analysis.

Results of the analysis of variance are shown in the Table 3, and the results are as follow. In most variables there is statistically significant F-ratio, except for the next four variables: angle of the elbow joint during the maximum swing velocity (**EJdeg**), duration of deceleration (**DtS**), vertical height of wrist joint in the moment of the maximum swing velocity (**vhmaxV**), and vertical jump with an arm swing (**VJwhS**), in which no significant differences in the groups of athletes were found.

Table 2: Descriptive parametars of the mesured variables and the results of the K-S test (N=93)

variable	M	SD	min	max	max D
VmaxS (m·s⁻¹)	11.00	0.93	8.49	12.86	0.55
AD (cm)	71.22	23.11	29.00	129.00	0.66
EJdeg (°)	12.17	17.38	83.80	168.13	**0.05**
DS (s)	0.32	0.04	0.25	0.42	**0.10**
AtS (s)	0.20	0.04	0.13	0.30	**0.06**
DtS (s)	0.12	0.03	0.05	0.20	**0.09**
hdiffJUMP (cm)	9.68	5.85	-8.30	19.70	0.20
MA (kg)	9.49	0.75	7.75	11.49	**0.09**
FM (kg)	1.11	0.13	0.89	1.46	**0.13**
MFA (kg)	2.41	0.32	1.72	3.26	**0.10**
MUA (kg)	5.80	0.77	2.47	6.91	0.20
vhmaxV (cm)	-18.91	0.23	-66.00	29.0	**0.08**
VJwhS (cm)	60.98	7.38	41.90	85.10	**0.12**
VJwtS (cm)	51.30	7.56	35.10	81.30	0.18
FIAS (N)	2987.95	1033.91	973.00	5193.27	**0.06**

Value of K-S TEST $p_{<0.05}$=**0.139**

Note: Mean (M), Standard Deviation (SD), Minimal Value of Variable (min); Maximum Value of Variable (max), Maximum Deviation of Empirical and Relative Cumulative Function (max D)

Table 3: Analysis of variance results (N=93)

variable	sum oft he squares	df	mean	F	p
EJdeg (°)	1025.75	2/90	512.87	1.72	.18
DS (s)	.03	2/90	.01	9.38	**.00**
AtS (s)	.01	2/90	.01	4.12	**.02**
DtS (s)	.00	2/90	.00	1.22	.30
FIAS (N)	7779961.10	2/90	3889980.55	3.87	**.03**
MA (kg)	7.81	2/90	3.91	7.91	**.00**
FM (kg)	.37	2/90	.18	15.35	**.00**
MFA (kg)	1.11	2/90	.55	6.02	**.00**
vhmaxV (cm)	.075	2/90	.04	.74	.47
VJwhS (cm)	133.69	2/90	66.84	1.23	.30

$p<0.05$

Note: Number of Degrees of Freedom (df), F ratio (F), Level of Significance (p)

To determine between which groups of athletes in chosen sports there is statistically significant difference in the arithmetic mean, post-hoc Scheffé test was conducted, which tests statistical significance between the couples of the arithmetic means in individual sports, and the results are shown in the Table 4.

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Table 4: Descriptive results of post-hoc Scheffé analysis in individual sports (N=93)

variable	sport	M (SD)	min	max	sport	t	p
DS.	AG	.33 (±0.05)	..26	.41	ATL	.04(*)	**.001**
					VOL	.00	.801
	ATL	.29 (±0.03)	.25	.35	AG	-.04(*)	**.001**
					VOL	-.03(*)	**.004**
	VOL	.33 (±0.04)	.26	.38	AG	-.00	.801
					ATL	.03(*)	**.004**
AtS	AG	.22 (±0.05)	.14	.30	ATL	.03(*)	**.029**
					VOL	.00	.841
	ATL	.19 (±0.03)	.13	.25	AG	-.03(*)	**.029**
					VOL	-.023	.097
	VOL	.21 (±0.04)	13	.28	AG	-.003	.841
					ATL	.023	.097
FIAS.	AG	2908.71 (±745.39)	1367.88	4411.00	ATL	-478,89	.187
					VOL	212.05	.705
	ATL	3387.60 (±1036.75)	1299.14	5193.27	AG	478,89	.187
					VOL	690.94(*)	**.028**
	VOL	2696.66 (±1163.00)	973.00	5089.84	AG	-212.05	.705
					ATL	-690.94(*)	**.028**
MA	AG	9.54 (±0.60)	8.77	10.53	ATL	.43	.063
					VOL	-.27	.325
	ATL	9.10 (±0.70)	7.75	10.26	AG	-.43	.063
					VOL	-.70 (*)	**.001**
	VOL	9.80 (±0.78)	9.04	11.49	AG	.27	.325
					ATL	.70 (*)	**.001**
MFA	AG	2.33 (±0.29)	1.72	2.71	ATL	-.01	.998
					VOL	-.23 (*)	**.013**
	ATL	2.33(±0.27)	1.78	2.87	AG	.01	.998
					VOL	-.23(*)	**.016**
	VOL	2.56 (±0.34)	2.14	3.26	AG	.23 (*)	**.013**
					ATL	.23(*)	**.016**
FM	AG	1.09 (±0.09)	.94	1.20	ATL	.05	.267
					VOL	-.10 (*)	**.002**
	ATL	1.04 (±0.09)	.89	1.18	AG	-.05	.267
					VOL	-.15(*)	**.000**
	VOL	1.19 (±0.14)	1.00	1.46	AG	.10 (*)	**.002**
					ATL	.15(*)	**.000**

(*) highlighted the significance level (p) up 0,05 **p<0.05**

Note: Artistic Gymnastics (AG), Athletics (ATL), Volleyball (VOL), Mean (M), The Minimum Value of Variable (Min), The Maximum Value of Variable (Max) Value of The T-Test (T), The Level of Significance (P)

Discussion

For duration of arm swing variable (**DS**), statistically significant differences between subjects was found between athletics (ATL) and the other two groups of subjects, artistic gymnastic (AG, post-hoc Scheffé: t=-0,04, p=0,001), and volleyball (VOL, post-hoc Scheffé: t=-0,03, p=0,004), while between subjects of artistic gymnastic and volleyball there was no statistically significant difference. According to the results of the analysis of variance it is clear that subjects that were practicing athletics (ATL), in average performed the shortest time of arm swing (0,29 s ±0,03). Also, duration of acceleration of arm swing (**AtS**) shows that there is statistically significant difference between the subjects practicing athletics (ATL), artistic gymnastics (AG), (post-hoc Scheffé: t=0,03, p=0,029), while differences in results of the other groups were not statistically significant.

Duration of acceleration of arm swing (**AtS**) is just a part of duration of an arm swing as a whole (**DS**). Results (Table 4.) show us that, for the subjects practicing athletics (ATL), acceleration was the shortest (0.19 s, ±0.03). Because of the smallest mean value of arm mass and the smallest mean value of arm length (Table 1.), subjects that were practicing

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(ATL) needed shorter arm swing duration time, and shorter acceleration duration time to achieve maximum arm swing velocity (11.26 m·s⁻¹ ±0.58).

Force of arm swing (**FIAS**) is statistically significant in subjects that were practicing athletics (ATL) and subjects that were practicing volleyball (VOL), (post-hoc Scheffé: t=690,94, p=0,028). Between the subjects practicing artistic gymnastics and volleyball no statistically significant difference was determined. In the group of variables measuring morphological characteristics of subjects, mass of arm (**MA**), fist mass (**FM**) and mass of forearm (**MFA**) were variables in which statistically significant difference was calculated regarding the group of subjects in dependence on the sport they were practicing. From the results shown in the Table 4. it is visible that subjects practicing volleyball (VOL) in variables fist mass (**FM**), and mass of forearm (**MFA**), statistically significant difference is determined regarding the other groups of subjects (AG post-hoc Scheffé: t=0.10, p=0.002; ATL post-hoc Scheffé: t=0.15, p=0.000). According to the results, mean value of fist mass (**FM**) in the volleyball subjects (VOL) is the largest and it is 1.19 kg (±0.14). With the subjects practicing athletics (ATL) the lowest mass of fist was measured and it amounts 1.04 kg (±0.09). Furthermore, mass of forearm variable (**MFA**), with volleyball subjects (VOL) was also achieving the largest values, and amounts 2.56 kg (±*0*.34), where the value of post-hoc Scheffé test towards the group of artistic gymnastics (AG) amounts t=0.23, p=0.013, and towards the athletics group (ATL), value of post-hoc Scheffé test was t=0.23, p=0.016.

In morphologic variable of mass of arm (**MA**), statistically significant difference is established between subjects practicing athletics (ATL) and subjects practicing volleyball (VOL), where the value of post-hoc Scheffé test was t=-0.70, p<0.001. According to results in Table 4. it is visible that the mass of arm (**MA**) of the athletics subjects (ATL) is the lowest (9.10 kg ±0.70), in relation to artistic gymnastic subjects (AG, 9.54 kg ±0.60), as to the largest arm mass of the volleyball subjects (VOL, 9.80 kg ±0.78).

Conclusion

By comparing the results of the analysis of variance (Table 3.), as well as the results of conducted post-hoc Scheffé test (Table 4.), by which the statistical significance between couples in arithmetic means in individual sports was determined, it is clear that subjects that are practicing athletics (ATL) for the variable duration of arm swing variable (**DS**), are statistically significant differing from subjects that were practicing athletics (ATL) and the other two groups of subjects, artistic gymnastic (AG, post-hoc Scheffé: t=-0.04, p=0.001), and volleyball (VOL, post-hoc Scheffé: t=-0.03, p=0.004), while between subjects of artistic gymnastic and volleyball there was no statistically significant difference. Also, subjects practicing volleyball (VOL) in variables fist mass (**FM**), and mass of forearm (**MFA**), statistically significant differed from other groups of subjects (AG post-hoc Scheffé: t=0,10, p=0,002, (ATL post-hoc Scheffé: t=0,15, p=0,000). In all other variables significant differences are noted in only one of those two groups. It should be noted that athletics subjects (ATL) had the lowest mean value of arm mass (9.10 kg ±0.70), and also the lowest mean value of arm length (74.20 cm ±4.09) (Table 1.).

Based on the results of the analysis of variance, statistically significant differences were determined in individual variables (Table 3). Analysis confirms that in variable duration of arm swing (**DS**) exists statistically significant difference between groups of subjects (F-ratio p<0.05) divided bay sport discipline. Also in two variables which measure morphological values (fist mass (**FM**) and mass of forearm (**MFA**) the results show statistical significant difference between all subject groups.

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