

Original Article

## Synchronization of biomechanical indicators of clean and jerk style key elements in performance weightlifting

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### Abstract

*Purpose.* This paper reveals the synchronization of the kinematic and dynamic indicators of the key elements of clean and jerk technique in performance weightlifting.

*Methods.* This scientific approach has led to a study conducted during the European Weightlifting Championship for juniors, Bucharest, 2011, with a group of 7 athletes, finalists of 56 kg class. The methodology of the research focused on video recording, transformation of video capture in AVI format (Pinnacle studio 9) and biomechanical video analysis of weightlifters' executions by means of a specialized program named Physics ToolKit. In order to highlight the synchronization of the key elements of clean and jerk style technique, the biomechanical analysis was made in two parts: 1) start, straightening, flipping, high pull, lifting from hockey – moment of concentration; 2) split jerk, the drive and the overhead barbell locking

*Results.* The study results point out the synchronization of barbell movement characteristics with the technique key elements in clean and jerk style at 56 kg category; the synchronization of the horizontal and vertical speed; opposite values in execution and small by calculation, which means a desynchronization of the phase; synchronization of the strength and energy characteristics; performances achieved in competitions and correlation of the biomechanical indicators with the performances obtained in competitions.

*Discussion.* The effectiveness of the synchronization of clean and jerk technique key elements was proved by execution duration, very small differences of the horizontal displacement in the first and second part of the analysis and also by the close values in vertical displacement and their resultant. The effectiveness of the synchronization of the key elements biomechanical indicators of the clean and jerk technique in accordance with the results achieved in 56kg competition highlight close connections at  $p < 0.05$  within jerk phase and between the phases of dive and bar driving and locking.

*Conclusions.* The standardization of the spatial-temporal parameters required for the video-biomechanical analysis of clean and jerk style in conformity with the movement postural orientation method highlighted the synchronization of the biomechanical indicators of the execution technique key elements related to the performances achieved in competition.

**Key words:** weightlifting, clean and jerk style, synchronization, biomechanics, performance.

### Introduction

At the present moment, the increasing performances in weightlifting are based on the improvement of training methods and technique. The upgrading of training and competition equipment and materials (scene, platform, podium, barbells, judging equipment, display, computerized programs for competitions carrying on) entailed the emancipation and selection of the lifting styles, judgment regulations and resulted in increased performance and spectacularity of this sports discipline (\*\*\*, 2009).

The number of training means in weightlifting decreased considerably following up the rationalization, especially because their inventory does not include the tactical means; the tactical thinking occurs in competitions only. Therefore the training means in this sports branch consist of physical and technical training workouts (Nicu, 1993).

One of the main issues in performance weightlifting refers to the gradual training of athletes for executing the competitive exercises of snatch style or clean & jerk style with a certain weight of the barbell when athlete's body condition is optimal. The factor that provides the best conditions to solve these problems is the rational sports technique (without infringing the competition regulations) which helps the athlete to use efficiently the possibilities of his physical, functional and psychological traits to lift the barbell with a maximum weight (Dvorkin, 2005; Ulăreanu & Nicu, 2014).

The analysis of long-term training of weightlifters at different levels of sports preparation allows the discovery and study of the individual characteristics. The pedagogical control data are the basis for decision-

making in the organization of athlete's training process (Marchenko, Dvorkin & Rogozjan, 1998; Ulăreanu 2014a).

The improvement of performance in weightlifting is the direct result of the quantity and quality of the effort made by the athlete during training. The training load must be gradually increased from the initial stage until the elite one depending on the physiological and psychological capacities of each athlete (Bompa, 2002).

The review of specialized literature has made it possible to establish that this part of sports theory and practice has been the subject of a special attention of the specialists in this activity field (Bojko,1987; Verhoshanskij, 1985; Marchenko & Rogozjan, 1995; Matveev, 1991; Ulăreanu, 2014b). The increase of the specific physical training can be considered as one of the primary tasks faced by the weightlifters. The improvement of muscles strength creates favorable conditions to increase speed-strength indicators and to optimize the clean & jerk technique. The more the athlete reaches sports mastery, the more the efficiency of using the previous training variants decreases gradually (Marchenko & Rogozjan, 2004).

Weightlifters' training is built in the form of training cycles, the purpose of which is to reach high sports results at a certain moment. One of the basic conditions in planning the loads for training is the variety. The gradual increase of loads volume can only take place in the categories of beginners and children, but also in skilled athletes' category after the transition period, when a new annual training cycle begins (Roman, 1986).

The effort parameters in performance weightlifting show the increase of effort intensity from one micro-cycle to another by increasing the load, the number of sets and reps; progressive increase of effort parameters, keeping them at maximum level and decreasing the volume before the competitive period (Potop, Urichianu & Ulăreanu, 2010).

*The main purpose of the paper* is to highlight the synchronization of the kinematic and dynamic indicators of the key elements of the clean and jerk technique in performance weightlifting.

*Hypothesis of the paper:* We believe that the standardization of the spatial-temporal parameters required for the video-biomechanical analysis of clean and jerk style in conformity with the movement postural orientation method will reveal the synchronization of the biomechanical indicators of the execution technique key elements in relation to the performances obtained in competition.

#### Methods

This scientific approach has led to a study conducted during the European Weightlifting Championship for juniors, Bucharest, 2011, on a group of 7 athletes, finalists of 56 kg class. We used the following research methods during the study: bibliographic study, observation method, method of movement postural orientation for sports technique analysis (Boloban, 2013; Potop, 2015), video computerized method, method of experimental study, statistical-mathematical method and graphical representation of study results. The methodology of the research focused on video recording, transformation of video capture in AVI format (Pinnacle studio 9) and biomechanical video analysis of weightlifters' executions by means of a specialized program named Physics ToolKit, where every successful movement has been divided into 24 sequences every 5 frames. The calibration of analysis phases into two parts has been performed using 5 frames per video frame while the speed of images was 30 frames / sec.

Due to the specific features of clean and jerk style, in which the duration of the preparation phase for jerk and the number of analysis steps must be consistent with the program, we have decided to split the phases of the style into two parts: 1) start, straightening, flipping, high pull, lifting from hockey – moment of concentration; 2) split jerk, the drive and the overhead barbell locking.

The processing of the statistical-mathematical data was made by means of KyPlot program, calculating the arithmetical mean and the standard deviation (mean  $\pm$  SD). To demonstrate the synchronization of the technique key elements of clean & jerk style related to the biomechanical indicators and the performances recorded in competition, a correlative parametric-linear analysis (Pearson) was made.

#### Results

Table 1. Results of bar displacement characteristics synchronization and the execution speed of technique key elements in clean & jerk style, 56kg category (n=7, mean  $\pm$  SD)

Analysis parts	Key elements	t(s)	X(m)	Y(m)	R (m)	Vx(m/s)	Vy(m/s)	V(m/s)
I	SP	0.00 $\pm 0.00$	0.00 $\pm 0.01$	0.21 $\pm 0.01$	0.21 $\pm 0.01$	-	-	-
	Str.	0.128 $\pm 0.01$	-0.01 $\pm 0.02$	0.33 $\pm 0.04$	0.34 $\pm 0.04$	-0.42 $\pm 0.29$	3.24 $\pm 0.71$	3.28 $\pm 0.69$
	Jk.	0.224 $\pm 0.03$	-0.01 $\pm 0.06$	0.76 $\pm 0.08$	0.76 $\pm 0.08$	0.07 $\pm 0.62$	4.16 $\pm 0.63$	4.19 $\pm 0.63$
	HP	0.347 $\pm 0.04$	-0.08 $\pm 0.11$	0.63 $\pm 0.03$	0.64 $\pm 0.02$	-0.21 $\pm 0.29$	0.20 $\pm 0.86$	0.85 $\pm 0.28$
	BL	0.667 $\pm 0.08$	-0.21 $\pm 0.27$	1.11 $\pm 0.04$	1.15 $\pm 0.11$	-0.17 $\pm 0.29$	-0.12 $\pm 2.02$	1.48 $\pm 1.29$
	SSJ	0.105 $\pm 0.04$	-0.11 $\pm 0.12$	1.19 $\pm 0.10$	1.19 $\pm 0.10$	-0.54 $\pm 0.51$	0.09 $\pm 0.34$	0.70 $\pm 0.39$
II	DOBL	0.414 $\pm 0.11$	-0.06 $\pm 0.23$	1.37 $\pm 0.16$	1.39 $\pm 0.16$	0.17 $\pm 0.12$	0.02 $\pm 0.48$	0.44 $\pm 0.23$

Note: SD – standard deviation; X – horizontal displacement; Y – vertical displacement; R – resultant; V – speed;  
 a) phases of the 1<sup>st</sup> part of the analysis: SP – starting position; Str.- straightening; Jk.- jerk; HP – high pull; BL – barbell lifting from hockey; b) phases of the 2<sup>nd</sup> part of the analysis: SSJ – semi-squat and split jerk; DOBL – the drive and overhead barbell locking

In table 1 are shown the results of the synchronization of kinematic characteristics indicators in terms of bar displacement and the execution speed in horizontal plane, vertical plane and the resultant (X; Y) of the key elements of clean and jerk style at 56kg category.

Figure 1 shows the trajectory of bar displacement in the key elements (phases) of clean & jerk technique used by the 56kg category weightlifters in terms of horizontal displacement, vertical displacement and their resultant.

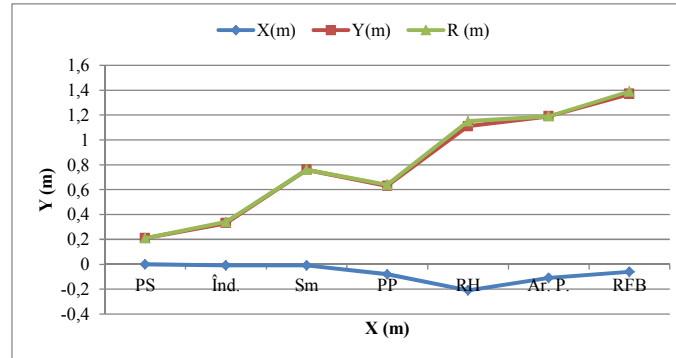


Fig. 1. Results of bar displacement synchronization in the execution of key elements of the clean & jerk

Figure 2 reveals the dynamics of bar displacement speed during execution of key elements (phases) of clean & jerk technique by 56kg weightlifters in terms of horizontal and vertical displacement and their resultant.

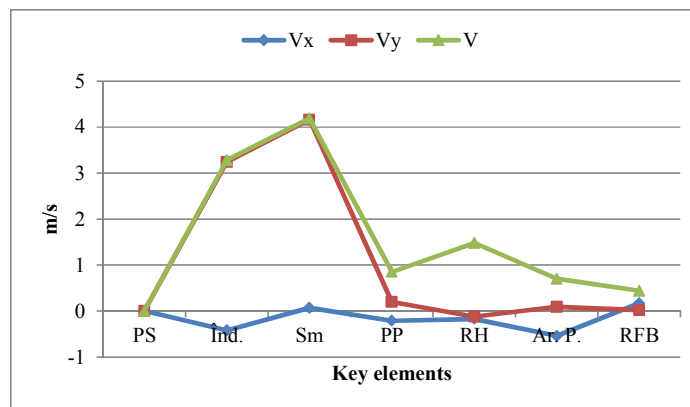


Fig. 2. Results of the synchronization of execution speed characteristics of the key elements in clean & jerk

Table 2 shows the results of the dynamic characteristics synchronization of the key elements (phases) of clean & jerk style (56kg category), regarding force (horizontal, vertical and resultant) and their energy (kinetic, potential and total).

Table 2. Results of dynamic characteristics synchronization of the key elements in clean & jerk style (n=7)

Key elements	t(s)	F <sub>x</sub> (N)	F <sub>y</sub> (N)	F(N)	KE(J)	PE(J)	TE(J)
PS	0.00 ±0.00	-	-	-	-	-	-
Înd.	0.128 ±0.01	310.21 ±1360.16	4837.14 ±2219.12	5005.71 ±2231.25	753.15 ±307.88	442.25 ±58.81	1196.08 ±339.98
Sm	0.224 ±0.03	-2188.57 ±732.65	-9867.14 ±2967.00	10114.28 ±2918.27	1219.13 ±408.15	994.49 ±69.22	2211.43 ±389.85
PP	0.347 ±0.04	893.96 ±1183.26	8347.14 ±1620.71	8451.42 ±1697.13	52.45 ±32.92	825.85 ±66.58	878.29 ±53.81
RH	0.667 ±0.08	-23.67 ±304.56	2359.39 ±4361.98	4056.92 ±2536.95	236.38 ±355.07	1462.85 ±78.04	1697.14 ±345.82
Ar. P.	0.105 ±0.04	407.21 ±988.84	-211.43 ±2814.45	2580.0 ±1171.28	42.005 ±38.79	1567.14 ±179.69	1611.43 ±188.27
RFB	0.414 ±0.11	-452.94 ±770.06	380.80 ±1080.06	1209.72 ±677.44	15.81 ±14.21	1805.71 ±237.68	1820.0 ±240.14

Figure 3 shows the dynamics of the force of bar displacement during the execution of the key elements of clean & jerk made by the 56kg category weightlifters in terms of force (horizontal, vertical and resultant).

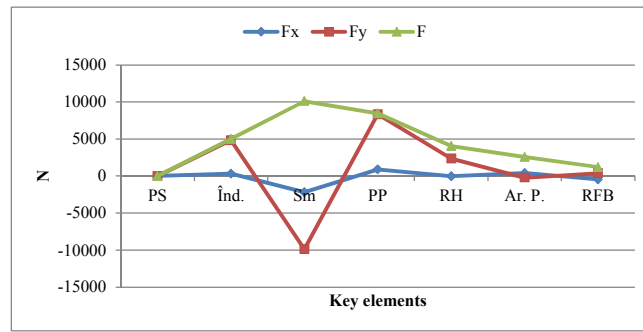


Fig. 3. Resultant of force synchronization in the execution of key elements of clean & jerk

Figure 4 highlights the synchronization of energy characteristics of bar displacement in the execution of clean & jerk style key elements by the 56kg weightlifters regarding the energy (kinetic, potential and total).

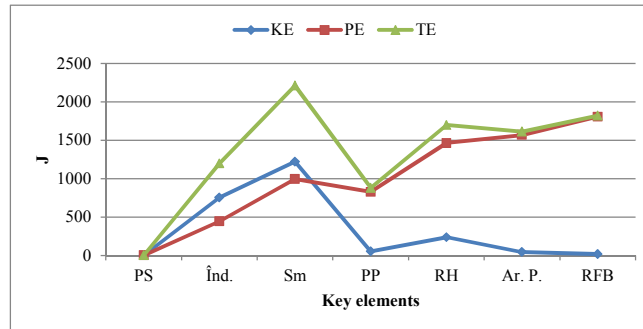


Fig. 4. Results of energy characteristics synchronization during execution of clean & jerk key elements

Table 3 shows the results obtained in competition by the finalist weightlifters in men's 56kg category, clean & jerk style during the European Championships for Juniors Bucharest, 2011, regarding the weight in competition, attempts and final results and also the calculation of the usual statistical indicators.

Table 3. European Championships for Juniors Bucharest, 2011, 56 kg class, men, clean and jerk style

No.	Full name	Nationality	Competition weight	Attempt (kg)			Results (kg)
				1	2	3	
1	CFI	ROU	55.95	139	142	149	149
2	CS	BLR	55.92	132	137	146	137
3	MS	BUL	55.98	131	135	141	135
4	SG	HUN	55.94	129	133	138	133
5	MS	ARM	55.60	131	138	138	131
6	BGJ	ESP	56.00	125	129	134	129
7	MA	BUL	55.75	115	123	127	127
	<b>Mean</b>		<b>55.88</b>	<b>128.86</b>	<b>133.86</b>	<b>139.0</b>	<b>134.43</b>
	SD		0.15	7.40	6.28	7.35	7.28
	Cv%		0.26	5.75	4.69	5.28	5.41

Table 4 presents the correlation results of the biomechanical characteristics and the competition performances achieved by 56kg category weightlifters in clean and jerk event, as for the relation between bar trajectory, speed resultant and force resultant in the key elements (phases): jerk, semi-squat and split jerk, the drive and overhead barbell locking.

Table 4. Results of the correlation of biomechanical characteristics and performances in competition

KE	Caract. Biomec.	Jk			DOBL		
		R (m)	V (m/s)	F (N)	R (m)	V (m/s)	F (N)
Jk.	R (m)	-	-	-	.398	.762	.733
	V(m)	-.473	-	-	.508	-.061	-.368
	F(N)	-.623	.826	-	.294	-.333	-.459
	Perf (kg)	-.784	.556	.785	.083	-.552	-.273
SSJ	R (m)	.208	.548	.443	.842	.373	.518
	V(m)	.103	-.300	.092	-.079	-.194	.354
	F(N)	-.422	.562	.576	.456	-.226	.225
	Perf (kg)	.295	.147	.815	-	-	-

Note: Jk.- jerk; SSJ – semi-squat and split jerk; DOBL – the drive and overhead barbell locking

## Discussion

The biomechanical analysis has been performed by means of Physics ToolKit program, using 19 recordings, executed by the 7 weightlifters finalists of 56kg class, men, clean and jerk style in European Championship for Juniors Bucharest, 2011.

The synchronization of the biomechanical characteristics indicators in the key elements (phases) of clean and jerk technique was made by standardization of the spatial-temporal analysis parameters regarding the images speed of 30 frames/sec, delimitation of frames to maximum 24 frames/ part of analysis, start position and selection of successful final attempts for each weightlifter (Potop & Crețu, 2015).

The results of bar displacement characteristics synchronization in the key elements of the clean & jerk technique - 56kg category (table 1, fig.1; n=7, mean  $\pm$  SD) reveal the duration of the 1<sup>st</sup> part executions: 0.8 sec and the second part – 0.6 sec, both with images calibration of 5 frames. In the 1<sup>st</sup> part, Start Position (SP) has an average of 0.21 $\pm$ 0.01m as for the distance between bar and floor. Straightening has an average of 0.33 $\pm$ 0.04m and was executed in the interval 0.25-0.38m with execution duration of 0.1-0.133 sec while the Jerk (Jk.) has an average of 0.76 $\pm$ 0.08m and was executed in the interval 0.65-0.88m (execution duration 0.2-0.267 sec), both elements (phases) have an average of -0.01 $\pm$ 0.02m horizontal displacement of the bar. The high pull has an average of 0.63 $\pm$ 0.03m and was executed in the interval 0.57-0.65m (execution duration 0.3-0.4 sec) while the barbell lifting has an average of 1.11 $\pm$ 0.04m and was executed in the interval 1.05-1.17m (execution duration 0.567-0.8 sec), with the horizontal displacement -0.08m and -0.21m. In the 2<sup>nd</sup> part, the Dive has an average of 1.19 $\pm$ 0.10m and was executed in the interval 0.98-1.29m (duration 0.067-0.167 sec) while the Overhead bar locking has an average of 1.37 $\pm$ 0.16m and was executed in the interval 1.14-1.63m (execution duration 0.3-0.6 sec), having the horizontal displacement of 0.19m and 0.16m.

The results of the synchronization of execution speed of clean & jerk technique key elements in 56kg category (table 1, fig.2; n=7, mean  $\pm$  SD) highlight, in the 1<sup>st</sup> part, no values for the starting position because this one is static, while the Strengthening has an average of 3.24 $\pm$ 0.71m/s (Vy) and the Jerk (Jk) has an average of 4.16 $\pm$ 0.63m/s (Vy); both vertical speeds influence the execution of the High Pull, in which both speeds (horizontal and vertical) are almost equal (synchronization) with an average of Vx- 0.21 $\pm$ 0.29m/s and Vy – 0.20 $\pm$ 0.86m/s; the barbell Lifting phase has opposite values in execution and small by calculation (-2.31; 3.94m/s). In the 2<sup>nd</sup> part, the Dive has an average of Vx – 0.54 $\pm$ 0.51m/s and Vy – 0.09 $\pm$ 0.34m/s while the Overhead bar locking has an average of Vx 0.17 $\pm$ 0.12m/s and Vy 0.02 $\pm$ 0.48m/s; the values are also opposite in execution and small by calculation, which show a desynchronization of the phase.

The results of the synchronization of force characteristics of clean & jerk key elements for 56kg category (table 2, fig.3; n=7, mean  $\pm$  SD) reveal, in the 1<sup>st</sup> part, the start position – static. The results analysis indicates higher values of the resultant, as shown hereby: the Straightening has an average of 5005.71 $\pm$ 2231.25 N; in the Jerk, the vertical force values are opposite to the resultant where Fy is -9867.14 $\pm$ 2967.00 N and force resultant (F) is 10114.28 $\pm$ 2918.27 N; in the High Pull, F has an average of 8451.42 $\pm$ 1697.13 N while the Barbell lifting has an average of 4056.92 $\pm$ 2536.25 N. In the 2<sup>nd</sup> part, the Dive has an average of 2580.0 $\pm$ 1171.28 N and the Overhead bar locking – 1209.72 $\pm$ 677.44 N.

The results of the synchronization of energy characteristics of clean & jerk key elements in 56kg category (table 2, fig.4; n=7, mean  $\pm$  SD) highlight in the 1<sup>st</sup> part, the start position – static, a progressive increase of the kinetic energy at Straightening 753.15 $\pm$ 307.88 J and at Jerk 1219.13 $\pm$ 408.15 J, a synchronization of the close values relation of the kinetic energy and total energy. In High Pull phases the values are close between the potential energy and total energy, which shows a synchronization of their values. Regarding the barbell Lifting and Dive, the bar lifting and locking, the values of the potential energy are increasing progressively between 825.85 $\pm$ 1805.71 $\pm$ 237.68 J with small differences of the total energy.

Regarding the performances achieved in competition (table 3) we notice that a number of 7 weightlifters participated in the finals, with an average of the weight in competition of 55.83kg under the weight category (0.17 kg); in the first attempt, the average is 128.86kg (1 failed attempt at 125 kg), in the second attempt the average is – 133.86 kg (1 failed attempt – 138kg) and in the third attempt – 139.0 kg (several failed attempts - 134kg, 138kg, 141kg and 146kg). The average of the final successful attempts is 134.43kg.

The results of the biomechanical characteristics correlation with the performances obtained in competition in 56kg category (table 4, n=7) reveal close connections at p<0.05 between the indicators of the Jerk phase: resultant of speed (Vm/s) and resultant of force (F N) – r=.826; the performance (kg) with the resultant of bar displacement (Rm)- r=.784 and F (N) – r=.785; R (m) with V (m/s) during the lifting and Overhead bar locking – r=.762; the performance with F (N) in the Dive phase – r=.815 and bar trajectory R (m) between the phases of Dive and Overhead bar locking – r=.842.

## Conclusions

The effectiveness of the synchronization of clean and jerk technique key elements was proved by execution duration, very small differences of the horizontal displacement in the 1<sup>st</sup> and 2<sup>nd</sup> part of the analysis and also by the close values in vertical displacement and their resultant. We also noticed the following aspects:

- increase of the vertical speed during the straightening phase and jerk phase; the synchronization of horizontal and vertical speed during the high pull execution and barbell lifting; the desynchronization of speed

opposite values during the dive by the increase of the displacement horizontal speed in split legs phase and during the overhead bar locking for the approach of the legs;

- synchronization of the vertical and horizontal speed and their resultant during the straightening phase; relationship between barbell lifting, dive, overhead barbell locking; opposite values of the vertical force and their resultant and improvement of horizontal force values throughout the entire execution;

- synchronization of kinetic and total energy in the straightening phase and jerk phase, close values of the potential and total energy (synchronization) during the high pull, progressive increase of the relationship of potential and total energy values if the phases of barbell lifting, dive and overhead bar locking.

Weightlifters' participation in competition reveals smaller values of body weight related to the weight category, increase of barbell load at each attempt consistent with the successful executions and the event final score. The effectiveness of the synchronization of the key elements biomechanical indicators of the clean and jerk technique in accordance with the results achieved in 56kg event highlight close connections at  $p < 0.05$  within jerk phase and between the phases of bar driving and locking. The standardization of the spatial-temporal parameters required for the video-biomechanical analysis of clean and jerk style in conformity with movement postural orientation method highlighted the synchronization of the biomechanical indicators of the execution technique key elements related to the performances achieved in competition.

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