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FUNCTIONAL ASYMMETRIES OF EMG ACTIVITY AND DYNAMIC CHARACTERISTICS IN ELITE WEIGHTLIFTERS WHEN PERFORMING A COMPETITIVE CLEAN AND JERK EXERCISE

Yu.V. Koryagina, S.V. Nopin

FSBI "North-Caucasian Federal Research-Clinical Center of the Federal Medical and Biological Agency",
Essentuki, Russia

Annotation. The relevant issue of biomechanics and physiology of sports, as well as sports medicine, in the aspect of injury prevention, is to identify the asymmetry of sports movements. The aim of the study was to identify functional motor asymmetries manifested in the power and electromyography parameters of the leading muscles during the clean and jerk exercise in elite male and female weightlifters. In the study, using the developed method of biomechanical and electromyographic evaluation of the clean and jerk, the functional asymmetries of electromyographic activity and dynamic characteristics in elite weightlifters during the performance of the exercise were determined. Functional asymmetries of the vertical component of the effort of the right/left foot on the support were small with a predominance of right-sided asymmetry in both men and women. Men differed from women in large values of the average electromyographic amplitude of all the studied muscles, which indicates a greater strength. The laterality and magnitude of the asymmetry of the average electromyographic amplitude of the muscles during the performance of a clean and jerk also has gender characteristics. A large asymmetry is manifested in the squat and recovery phases, i.e. into phases characterized by greater dynamics of movement of the body of the athlete and the projectile. A large right-sided asymmetry of electromyographic activity indicates dominance of the body's right side in elite weightlifters. Overall, we can conclude that elite weightlifters perform the movement quite symmetrically and coordinately, which indicates a good balance and coordination of movements.

Keywords: functional asymmetries, motor asymmetries, biomechanics, electromyography, weightlifting exercises, clean and jerk.

Introduction. Research of the functional sensorimotor asymmetry are relevant from the point of determining effective strategies of adaptation and success prediction in sports [1]. In order to reveal features of biomechanics and physiology of the neuromuscular system, as well as to prevent injuries in sports, researchers apply identification of motor asymmetry during sports movements [2-3].

Currently, there are studies dedicated to manifestations of motor symmetry-asymmetry when separate and sports movements are being performed. Researchers have already studied to the fullest extent biomechanics and asymmetry of leg movements during walking [4].

Scientists from the Lesgaft National State University of Physical Culture, when researching asymmetry of the biomechanical structure of weightlifters' movements when performing the clean and jerk in the scissor or half-squat

position, have found that asymmetry is typical for parameters of kinematic movements in the elbow, hip, knee and ankle joints, as well as for vertical components of the support reaction power. The revealed asymmetry is significantly manifested in case of performing the clean and jerk in the scissor position, it decreases when performing the exercise in the half-squat position. Manifestations of asymmetry decrease as the external resistance and sports qualification of weightlifters grow [5].

Our published study of functional asymmetries of the EMG activity and dynamic characteristics in elite weightlifters during performance of the competitive snatch shows a reliably symmetrical performance and work of the neuromuscular system, which serves as an evidence for a good technical fitness of examined elite weightlifters, as well as appropriate muscle balance. Both in men and in women, the

study results revealed small right-sided functional asymmetries of vertical components of the support reaction power. We have also discovered an insignificant asymmetry of the average amplitude of muscle EMG: left-sided asymmetry for the trapezius muscle and right-sided asymmetry for the leg muscles (vastus lateralis, biceps femoris and gastrocnemius muscles). The greatest asymmetry manifestations were identified in the snatch phase. It is possibly related to a partially unsupported position of the body. According to EMG activity, dominating position of the right leg was revealed in weightlifters [2].

The weightlifting clean and jerk, performed in the scissors position, is a more asymmetrical exercise than the snatch. Thus, a study of functional asymmetries of power and EMG parameters that manifest in elite male and female weightlifters when performing the competitive clean and jerk is relevant.

The purpose of this study was to identify functional motor asymmetries, manifested in power and EMG parameters of leading muscles during performance the competitive clean and jerk by elite male and female weightlifters.

Methods and organization. The study was carried out in the Center for biomedical technologies of the FSBI NCFRCC FMBA of Russia in Kislovodsk on the Maloe Sedlo mountain, at an altitude of 1240 m, in conditions of training camps in the Federal State Unitary Enterprise “Yug Sport”. The study involved 45 male and female weightlifters with the Master of Sports qualification, members of the Russian national team in weightlifting.

We conducted biomechanical and EMG analysis of the weightlifting exercise with identification of power, kinematic and EMG parameters and following calculation of asymmetry calculations. The study was carried out on the BTS Motion System (BTS Bioengineering, Italy), including SMART-DX – the optoelectronic system with three infrared cameras and two video cameras, two sensor floor-standing tensodynamometric platforms sized 60×40 cm. In order to analyze the technique of the weightlifting exercise, we have developed a special method and acquired a patent for an invention:

“Technique of biomechanical and electromyographic express-evaluation of weightlifting exercises” № 2756567 C1 from 10/01/2021 [6]. To analyze the technique, we applied the phase structure of the clean and jerk developed by L.S. Dvorkin [8].

The coefficients of functional asymmetry of mean values in vertical components of the support reaction power, average EMG amplitude of the trapezius, vastus lateralis, biceps femoris (long head – middle part) and gastrocnemius (lateral head – middle part) muscles were calculated according to the following formula:

$$Cas = \frac{N_r - N_l}{N_r + N_l} \times 100\%,$$

where N_r – indicator for the right side of the body, N_l – indicator for the left side of the body.

The statistical data processing was made with the Statistica 13.0 software. It's main purpose was to compare indicators of groups divided by gender with the non-parametric Mann-Whitney U-test.

Results and discussion. The weightlifting clean and jerk is a complex coordination, speed-power exercise, in which an athlete lifts great weights in a short period of time. Unlike the snatch, the clean and jerk consists of two exercises: the hang squat clean (first four phases that match those in the snatch) and the jerk.

Results of studying the power dynamic indicator, i.e. the vertical component of the force applied with two legs on the support in the boundary moment between movement phases revealed that men significantly exceed women in all phases (table 1).

Comparison of functional asymmetry coefficients of the vertical components of the force made on the support with the right/left leg when performing the exercise revealed that women have a significantly greater asymmetry in the Snatch 2.2 phase. During all phases, both in men and in women, a very insignificant right-sided asymmetry prevails, except during the Squat 3.1 phase in women. The greatest signs of asymmetry were revealed in both groups during the Squat 3.1 phase and during the

Jerk 7 and Recovery after the jerk 8 phases in women only. Overall, we can conclude about a symmetrical and coordinately precise

performance of the movement by elite weightlifters, which shows good balance and movement coordination.

Table 1
Mean values of the vertical component of the force applied with two legs on the support in male and female weightlifters, $M \pm \sigma$, kg

№	Phases	Men	Women	p<
1	Pull 1.1	233.1 $\pm$ 47.26	168.0 $\pm$ 34.47	0.0002
2	Pull 1.2	186.4 $\pm$ 47.30	125.1 $\pm$ 26.05	0.0001
3	Snatch 2.1	256.4 $\pm$ 58.45	206.7 $\pm$ 35.65	0.01
4	Snatch 2.2	42.54 $\pm$ 58.50	27.58 $\pm$ 22.19	-
5	Squat 3.1	177.2 $\pm$ 36.63	131.8 $\pm$ 51.67	0.006
6	Squat 3.2	293.4 $\pm$ 54.75	235.4 $\pm$ 52.31	0.004
7	Recovery 4	140.2 $\pm$ 43.15	107.5 $\pm$ 29.89	0.03
8	Clean 6.1	330.0 $\pm$ 66.34	259.9 $\pm$ 50.58	0.004
9	Clean 6.2	65.92 $\pm$ 94.84	30.02 $\pm$ 28.32	-
10	Jerk 7	132.5 $\pm$ 52.84	93.13 $\pm$ 41.29	0.03
11	Recovery after the jerk 8	171.6 $\pm$ 47.18	101.6 $\pm$ 43.68	0.00004

Note: p – according to the Mann-Whitney U-test

Table 2
Functional asymmetry coefficients of the vertical components of the force made on the support with the right/left leg when performing the weightlifting clean and jerk by male and female weightlifters, $M \pm \sigma$, %

№	Phases	Men	Women	p<
1	Pull 1.1	2.55 $\pm$ 5.04	1.02 $\pm$ 4.56	-
2	Pull 1.2	1.17 $\pm$ 4.58	2.80 $\pm$ 3.17	-
3	Snatch 2.1	-2.06 $\pm$ 7.35	5.02 $\pm$ 10.65	-
4	Snatch 2.2	0.60 $\pm$ 8.10	5.31 $\pm$ 9.76	0.04
5	Squat 3.1	8.32 $\pm$ 19.45	-9.49 $\pm$ 26.47	-
6	Squat 3.2	2.08 $\pm$ 6.10	1.84 $\pm$ 5.83	-
7	Recovery 4	1.07 $\pm$ 4.97	1.63 $\pm$ 3.95	-
8	Clean 6.1	1.83 $\pm$ 5.00	0.69 $\pm$ 5.13	-
9	Clean 6.2	-0.54 $\pm$ 5.25	3.89 $\pm$ 5.61	-
10	Jerk 7	5.91 $\pm$ 84.45	11.69 $\pm$ 93.14	-
11	Recovery after the jerk 8	4.70 $\pm$ 86.69	10.89 $\pm$ 94.77	-

Note: p – according to the Mann-Whitney U-test

EMG recording and simultaneous registration of movement's biomechanical parameters during the exercise allowed us to obtain characteristics of electric activity of examined muscles. We have found that average amplitude of the right trapezius muscle in male weightlifters was higher during the Pull 1.2 and Squat 3.1 phases compared to women.

Indicators of the left trapezius muscle were not significantly different (table 3).

Comparison of the average EMG amplitude of the vastus lateralis muscle revealed greater values of EMG amplitude in men on the right during the Squat 3.1 phase and on the left during the 2.2 phase (table 4).

Table 3

Average EMG amplitude of the trapezius muscle in male and female weightlifters performing the clean and jerk, $M \pm \sigma$, mV

№	Phases	Right			Left	
		Men	Women	p<	Men	Women
1	Pull 1.1	0.16±0.11	0.10±0.06	-	0.15±0.11	0.13±0.07
2	Pull 1.2	0.48±0.21	0.34±0.16	0.03	0.46±0.19	0.38±0.17
3	Snatch 2.1	0.45±0.15	0.36±0.16	-	0.51±0.26	0.38±0.12
4	Snatch 2.2	0.47±0.19	0.40±0.17	-	0.45±0.22	0.41±0.18
5	Squat 3.1	0.31±0.13	0.21±0.09	0.03	0.30±0.11	0.23±0.12
6	Squat 3.2	0.51±0.19	0.54±0.22	-	0.57±0.26	0.55±0.21
7	Recovery 4	0.42±0.21	0.39±0.21	-	0.51±0.29	0.40±0.21
8	Clean 6.1	0.37±0.21	0.32±0.16	-	0.40±0.25	0.33±0.19
9	Clean 6.2	0.55±0.29	0.51±0.25	-	0.59±0.31	0.47±0.23
10	Jerk 7	0.68±0.27	0.64±0.21	-	0.71±0.31	0.65±0.21
11	Recovery after the jerk 8	0.64±0.33	0.66±0.30	-	0.61±0.35	0.67±0.38

Note: p – according to the Mann-Whitney U-test, indicators of the left trapezius muscle were not significantly different

Table 4

Average EMG amplitude of the vastus lateralis muscle in male and female weightlifters performing the clean and jerk, $M \pm \sigma$, mV

№	Phases	Right			Left		
		Men	Women	p<	Men	Women	p<
1	Pull 1.1	0.17±0.12	0.17±0.09	-	0.14±0.07	0.16±0.09	-
2	Pull 1.2	0.26±0.16	0.29±0.18	-	0.23±0.10	0.25±0.12	-
3	Snatch 2.1	0.34±0.18	0.34±0.13	-	0.33±0.15	0.30±0.18	-
4	Snatch 2.2	0.35±0.22	0.24±0.13	-	0.32±0.13	0.22±0.14	0.02
5	Squat 3.1	0.23±0.10	0.16±0.07	0.03	0.22±0.11	0.17±0.08	-
6	Squat 3.2	0.30±0.18	0.31±0.14	-	0.26±0.10	0.31±0.14	-
7	Recovery 4	0.38±0.25	0.33±0.15	-	0.29±0.17	0.30±0.19	-
8	Clean 6.1	0.23±0.15	0.22±0.10	-	0.20±0.09	0.22±0.16	-
9	Clean 6.2	0.39±0.28	0.27±0.14	-	0.35±0.15	0.28±0.14	-
10	Jerk 7	0.35±0.21	0.24±0.09	-	0.25±0.15	0.20±0.10	-
11	Recovery after the jerk 8	0.18±0.11	0.15±0.10	-	0.14±0.08	0.12±0.10	-

Note: p – according to the Mann-Whitney U-test

Functional asymmetry coefficients of the average EMG amplitude of the trapezius and vastus lateralis muscles in male and female weightlifters were not significantly different (table 5). Recording of the average EMG amplitude of the trapezius muscle revealed small right- and left-sided asymmetries (within 11%), both in men and in women. Recording of the average EMG amplitude of the vastus

lateralis also revealed small right- and left-sided asymmetries. Right-sided asymmetries had greater values during the Recovery 4, Jerk 7 and Recovery after the jerk 8, i.e. phases that are characterized by greater dynamics of body and barbell movements. During these phases, the vastus lateralis muscle serves the role of the active crus extensor in the knee joint, which plays a significant role in the effectiveness of

the whole exercise. The great right-sided asymmetry of EMG activity indicates the right-leg dominance in weightlifters.

The average EMG amplitude of the right biceps femoris muscle in men was higher during the Recovery 4 phase, left biceps femoris muscle – during Pull, Snatch, Squat and Recovery phases. In whole, man had higher

values of average EMG amplitude in the biceps femoris muscle compared to women (table 6). During movement phases of the clean and jerk, the biceps femoris muscle serves the role of the thigh extensor and crus flexor, great average EMG value indicates greater developing effort and an ability to lift greater weights in male weightlifters compared to female ones.

Table 5
Functional asymmetry coefficients of the average EMG amplitude of muscles in male and female weightlifters, $M \pm \sigma$, %

№	Phase	Trapezius muscles		Vastus lateralis	
		Men	Women	Men	Women
1	Pull 1.1	-0.9±24.5	-8.1±27.3	5.6±30.8	2.5±29.3
2	Pull 1.2	1.6±26.2	-4.0±27.9	3.1±30.1	3.6±31.2
3	Snatch 2.1	-0.6±25.3	-3.4±14.1	1.3±29.6	8.0±24.6
4	Snatch 2.2	5.1±16.8	-0.3±21.8	-1.4±28.5	5.7±30.4
5	Squat 3.1	1.0±15.0	-2.9±23.7	3.7±29.7	-2.1±19.0
6	Squat 3.2	-4.3±16.6	-1.7±19.1	4.0±27.5	0.4±19.8
7	Recovery 4	-11.6±23.5	-1.5±20.0	9.9±30.7	6.2±27.2
8	Clean 6.1	-2.6±26.4	3.3±25.6	1.3±32.3	5.6±29.8
9	Clean 6.2	-2.9±17.4	7.0±29.4	-1.5±31.7	-2.7±23.8
10	Jerk 7	-1.8±14.4	-0.7±10.0	13.3±37.7	12.4±30.1
11	Recovery after the jerk 8	6.1±29.0	5.0±37.3	11.3±38.0	14.8±35.2

Table 6
Average EMG value of the biceps femoris muscle in male and female weightlifters, $M \pm \sigma$, mV

№	Phases	Right			Left		
		Men	Women	p<	Men	Women	p<
1	Pull 1.1	0.12±0.08	0.08±0.03	-	0.10±0.09	0.08±0.02	-
2	Pull 1.2	0.32±0.12	0.23±0.08	-	0.30±0.10	0.19±0.06	0.006
3	Snatch 2.1	0.46±0.25	0.34±0.12	-	0.39±0.14	0.29±0.14	0.02
4	Snatch 2.2	0.33±0.18	0.22±0.10	-	0.29±0.16	0.16±0.10	0.01
5	Squat 3.1	0.24±0.15	0.16±0.10	-	0.21±0.11	0.14±0.05	0.04
6	Squat 3.2	0.31±0.24	0.22±0.11	-	0.29±0.25	0.21±0.09	-
7	Recovery 4	0.29±0.13	0.18±0.08	0.04	0.23±0.10	0.16±0.07	0.04
8	Clean 6.1	0.18±0.14	0.12±0.05	-	0.13±0.09	0.12±0.06	-
9	Clean 6.2	0.37±0.19	0.26±0.13	-	0.29±0.11	0.23±0.10	-
10	Jerk 7	0.32±0.17	0.22±0.08	-	0.18±0.13	0.15±0.09	-
11	Recovery after the jerk 8	0.17±0.11	0.13±0.08	-	0.10±0.08	0.08±0.07	-

Note: p – according to the Mann-Whitney U-test

Average EMG amplitude of the gastrocnemius muscle is significantly higher in men on the right during the Pull 1.1, Pull 1.2, Snatch 2.2, Squat 3.1, Jerk 7 phases, on the left

– during the Snatch 2.2 phase (table 7). The gastrocnemius muscle in the analyzed movement serves as a plantar sole flexor in the ankle joint, as well a sole stabilizer. High

average EMG amplitude of the gastrocnemius muscle in men indicates a developing effort in sole extension, especially during Pull and Snatch phases.

Functional asymmetry coefficients of the average EMG amplitude of the biceps femoris were only right-sided during all phases of the clean and jerk, both in men and in women (table

8). The greatest asymmetries for the biceps femoris were revealed in women during the Snatch 2.2 phase and in men during the Jerk 7 and Recovery after the jerk 8 phases. Great right-sided asymmetries during the final phase may indicate an enhancement of the leading right leg domination in case of fatigue.

Table 7

Average EMG value of the quadriceps femoris muscle in male and female weightlifters, $M \pm \sigma$, mV

№	Phases	Right			Left		
		Men	Women	p<	Women	Men	p<
1	Pull 1.1	0.09±0.08	0.03±0.02	0.005	0.08±0.08	0.05±0.03	-
2	Pull 1.2	0.17±0.07	0.10±0.05	0.02	0.17±0.10	0.13±0.06	-
3	Snatch 2.1	0.39±0.22	0.27±0.10	-	0.32±0.22	0.33±0.09	-
4	Snatch 2.2	0.24±0.15	0.12±0.06	0.05	0.25±0.18	0.12±0.04	0.03
5	Squat 3.1	0.15±0.13	0.07±0.06	0.009	0.10±0.09	0.05±0.03	-
6	Squat 3.2	0.21±0.14	0.15±0.08	-	0.18±0.11	0.20±0.09	-
7	Recovery 4	0.13±0.09	0.09±0.04	-	0.12±0.09	0.12±0.08	-
8	Clean 6.1	0.14±0.09	0.10±0.05	-	0.13±0.11	0.13±0.06	-
9	Clean 6.2	0.33±0.18	0.23±0.05	-	0.30±0.16	0.23±0.07	-
10	Jerk 7	0.23±0.15	0.12±0.05	0.01	0.15±0.07	0.16±0.06	-
11	Recovery after the jerk 8	0.14±0.09	0.11±0.06	-	0.14±0.07	0.15±0.07	-

Note: p – according to the Mann-Whitney U-test

Table 8

Functional asymmetry coefficients of the average EMG amplitude of muscles in male and female weightlifters, $M \pm \sigma$, %

№	Phases	Biceps femoris muscle			Gastrocnemius muscle		
		Men	Women	p<	Men	Women	p<
1	Pull 1.1	6.4±26.6	3.1±11.4	-	14.4±29.9	-24.1±21.8	0.002
2	Pull 1.2	3.8±13.2	9.0±8.2	-	4.9±28.0	-13.5±15.5	0.03
3	Snatch 2.1	5.2±18.0	8.3±11.5	-	12.0±25.4	-8.7±20.7	0.02
4	Snatch 2.2	4.3±26.8	16.0±28.2	-	4.2±28.1	1.2±19.2	-
5	Squat 3.1	2.4±22.1	2.9±31.0	-	15.2±32.3	13.4±17.0	-
6	Squat 3.2	4.2±22.7	1.0±21.7	-	5.7±40.4	-14.5±20.0	-
7	Recovery 4	11.8±24.2	4.8±13.5	-	4.4±35.5	-14.8±17.9	0.03
8	Clean 6.1	13.6±31.9	2.5±25.3	-	9.5±29.8	-11.0±22.7	-
9	Clean 6.2	7.5±29.3	3.8±15.2	-	6.0±31.9	-0.3±11.3	-
10	Jerk 7	29.1±40.8	19.6±36.4	-	18.6±28.6	-14.0±23.2	0.007
11	Recovery after the jerk 8	26.2±37.9	24.3±53.0	-	0.3±35.7	-14.3±27.8	-

Note: p – according to the Mann-Whitney U-test

Right-sided asymmetries of the gastrocnemius muscle were revealed in men. On the contrary, left-sided asymmetries prevailed in women. In terms of the asymmetry's scope and laterality, women were different from men in the Snatch 2.1, Recovery 4 and Jerk 7 phases. The greatest asymmetry were identified during the Pull, Squat and Recovery phases. When analyzing the asymmetry of the examined muscles, we can conclude that it has higher values in the biceps femoris and the gastrocnemius muscle. Apparently, the closer the muscles are to the core, the less pronounced their asymmetry is.

Conclusion. Therefore, we managed to identify functional asymmetries of the EMG activity and dynamic characteristics in elite weightlifters when performing the competitive clean and jerk using the developed method of biomechanical and electromyographic evaluation of the exercise.

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Functional asymmetries of the vertical components of the force made on the support with the right/left leg were small with the predominance of the right-sided asymmetry in both men and women.

Men were different from women by higher values of the average EMG amplitude of all examined muscles, which serves as an evidence of greater pronounced power. Laterality and scope of the asymmetry of the average EMG amplitude of muscles also have gender-based features. Greater asymmetry is manifested during Squat and Recovery phases, i.e. phases, characterized by greater dynamics of body and barbell movement. Great right-sided asymmetry of EMG activity indicates dominance of the right side of the body in weightlifters.

Overall, we can conclude that elite weightlifters perform the movement quite symmetrically and coordinately, which indicates a good balance and coordination of movements.

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INFORMATION ABOUT THE AUTHORS:

Yulia Vladislavovna Koryagina – Doctor of Biological Sciences, Professor, Head of the Biomedical Technologies Center, FSBI "North-Caucasian Federal Research-Clinical Center of Federal Medical and Biological Agency", Essentuki, e-mail: nauka@skfmba.ru.

Sergej Victorovich Nopin – Candidate of Technical Sciences, Lead Researcher of the Biomedical Technologies Center, FSBI “North-Caucasian Federal Research-Clinical Center of Federal Medical and Biological Agency”, Essentuki, e-mail: work800@yandex.ru.

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