Assessment of cyclists' pedaling techniques by patterns of muscle bioelectrical activity

UDC 796.61

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Received by the editorial office on 10.06.2024

Abstract

Objective of the study was to identify the features of the parameters of bioelectric activity of muscles that characterize the pedaling technique using the electromyography method.

Methods and structure of the study. A pilot study was organized with the participation of 2 athletes who had experience competing in major international cycling competitions. Each athlete performed a task during a standardized 30-second anaerobic test (Wingatetest) on a Cyclus 2 bicycle ergometer, recording the bioelectrical activity of the leading muscle groups of the legs.

Results and conclusions. Analysis of electromyograms made it possible to identify the individual characteristics of the implementation of the motor potential of each athlete according to parameters characterizing the contribution to the work of the leading muscle groups, the asymmetry of the manifestation of muscle activity on the left and right, as well as the ratio of muscle activity in the bench press and pull-up phases. The presented approach made it possible to clearly reflect the features of the pedaling technique of two athletes with a comparable level of preparedness and to form an objective idea of the mechanisms of involvement of the leading muscle groups in the work of the pedaling phases. A promising direction for further research is the use of electromyography as a means of biofeedback to optimize pedaling technique.

Keywords: *electromyography, bioelectrical muscle activity, cycling, pedaling.*

Introduction. The basis of a cyclist's pedaling, from a mechanical point of view, is the creation of a torque on the carriage axis to move the cranks along a circle. This process is cyclical and consists of movements repeated in a certain sequence. In the cycle of one revolution of the crank, two main parts are distinguished: pressing and pulling. During the cycle of the crank revolution, the thigh and shin produce a pendulum-like movement, transmitted through the foot into a rotational movement. During pedaling, movement occurs in three joints - the hip, knee and ankle, but the muscles involved in this can perform different work depending on the skill of the athlete. A cyclist comprehends the art of pedaling faster and better if he specially trains the extensor muscles that ensure the active transfer of the pedal through the upper position, and the flexors involved in pulling the pedal during the completion of this movement [4]. However, it is visually impossible to understand to what extent the muscles key to this motor action are involved in the work, and what is the amplitude of their work. Meanwhile, the study of this process is of great importance for assessing pedaling technique and improving the athlete's performance by optimizing it [4].

Methods and structure of the study. In order to develop an approach to assessing pedaling technique in terms of the involvement of the leading muscle groups of the legs, a pilot study was organized with the participation of two cyclists with experience of performing in major international competitions. The testing program included performing a standardized anaerobic test (Wingatetest) on a Cyclus 2 bicycle ergometer, lasting 30 s, with recording the bioelectrical activity of the leg muscles. This test task is specific to cycling and is regularly used to assess the level of athletes' fitness. To record muscle bioelectrical activity signals, a mobile hardware and software complex Delsystrignoavanti (Delsys, Inc., Massachusetts, U.S.A) with wireless skin electrodes with a built-in inertial unit was used.

Results of the study and discussion. The total EMG analysis was performed based on amplitude characteristics. A 6th-order Butterworth bandpass filter with a pass frequency in the range from 30 to 600 Hz was used to filter out various motor artifacts that distort the quality of the original signal. For the purpose of comparative analysis, two pedaling phases were distinguished in each data set characterizing the athlete's work during the test task: pressing and pulling up. This is due to the need to perform active muscle work not only in the pressing phase, but also in the pulling up phase, in order to achieve maximum movement performance by distributing the load in each cycle between the two limbs. The phase boundaries were determined by regular changes in the synchronously recorded gyroscope signal from the rectus femoris muscle (Biceps femoris). The gyroscope signals were preliminarily filtered using a median filter with a window width of 0.05 seconds.

The resulting files were exported for further analysis to Microsoft Excel, where the developed automated analysis template was used to automate the computational processes. Automation of a number of operations was implemented using macros. Using a template, the boundaries of the pressing and pulling phases were identified, the identification criterion of which is the intersection of the gyroscope signal with the isoline (in this case, the zero line). Depending on the polarity of the gyroscope signal, each pedaling phase was identified (the

Table 1. Results of the analysis of electromyography data of the leg muscles of athlete 1 during pedaling (front view)

Muscles	R Rectusfemoris	L Rectusfemoris	R Vastuslateralis	L Vastuslateralis	R Vastusmedialis	L Vastusmedialis	R Tibialisanterior	L Tibialisanterior
Parameters characterizing muscle work in the bench press phase								
A±σ, mkV	151,3±41,4	165,1±27,4	497,3±119,3	466,0±97,5	326,6±82,1	280,8±54,8	178,0±84,9	83,5±43,4
CW, %	5,2	5,6	17,0	15,9	11,2	9,6	6,1	2,9
ASI, %	8,7		6,5		15,1		72,2	
R/L, %	47,8	52,2	51,6	48,4	53,8	46,2	68,1	31,9
Parameters characterizing muscle work in the pull-up phase								
A±σ, mkV	50,0±15,4	59,3±19,1	138,4±52,5	139,7±60,6	97,7±29,8	76,8±22,0	82,1±38,0	83,7±21,5
CW, %	3,8	4,5	10,6	10,7	7,5	5,9	6,3	6,4
ASI, %	16,9		0,9		24,0		1,9	
R/L, %	45,8	54,2	49,8	50,2	56,0	44,0	49,5	50,5

Table 2. Results of the analysis of electromyography data of the leg muscles of athlete 1 during pedaling (rear view)

Muscles	R Bicepsfemoris	L Bicepsfemoris	R Gastrocnemiuslateral	L Gastrocnemiuslateral	R Gastrocnemiusmedial	L Gastrocnemiusmedial
Parameters characterizing muscle work in the bench press phase						
A± , mkV	100,9±43,7	76,8±22,2	127,3±80,3	140,0±61,0	165,9±73,5	164,0±57,8
CW, %	3,5	2,6	4,4	4,8	5,7	5,6
ASI, %	27,2		9,5		1,2	
R/L, %	56,8	43,2	47,6	52,4	50,3	49,7
Parameters characterizing muscle work in the pull-up phase						
A± , mkV	72,1±35,2	74,3±25,6	142,9±86,1	85,2±44,3	107,7±43,9	92,9±44,2
CW, %	5,5	5,7	11,0	6,5	8,3	7,1
ASI, %	3,0		50,5		14,7	
R/L, %	49,2	50,8	62,6	37,4	53,7	46,3

area of positive values corresponds to the pressing phase, and negative values - to the pulling phase).

Based on the functional purpose of the muscle groups that were studied, the peak activity of almost all of them falls on the press phase, with the exception of the anterior tibial muscle (Tibialis anterior).

Based on the initial data of the bioelectrical activity of the muscles, the parameter - contribution to work (CW, %) was calculated, characterizing the contribution of each muscle to the overall performance of movements, expressed as a percentage of the total activity of all muscles [1]. To assess the asymmetry of muscle work on the left and right, a parameter widely used in sports research - ASI [2, 3] was used. The indicators of this parameter characterize the percentage difference between the right and left parts of the athlete's body when performing motor actions.

The parameters analyzed based on the results of electromyogram patterns are of high practical value for a deep understanding of the mechanisms of realizing the motor potential of cyclists when pedaling, characterizing the internal form of this process.

For a visual representation of the dominant side in the analysis of the asymmetry of muscle work, the ratio between them was calculated (hereinafter in the tables it is designated - R/L, %). The results of the electromyography data analysis for the athletes who took part in the study are presented in Tables 1-4.

Based on the results of the data analysis, the following conclusions can be drawn:

With varying degrees of severity, both athletes are characterized by a predominance of muscle activity in the pressing phase during the pedaling process compared to the pulling phase. The most significant predominance of pressing efforts is observed on the part of the leading limb.

Both athletes have a high level of asymmetry in the work of individual muscle groups (ASI index over 15%). This feature is a reflection of unbalanced work and has a negative impact on the efficiency of pedaling. This logically correlates with the results of the test, where athlete 2 has a lower indicator: 1298 W versus 1345 W for athlete 1. The

Table 3. Results of the analysis of the electromyography data of the leg muscles of athlete 2 during pedaling (front view)

Muscles	R Rectusfemoris	L Rectusfemoris	R Vastuslateralis	L Vastuslateralis	R Vastusmedialis	L Vastusmedialis	R Tibialisanterior	L Tibialisanterior
Parameters characterizing muscle work in the bench press phase								
A±σ, mkV	136,0±29,3	80,5±13,9	151,9±28,6	128,9±20,6	114,2±21,6	109,8±21,1	116,2±31,1	58,7±14,3
CW, %	10,1	5,9	11,2	9,5	8,4	8,1	8,6	4,3
ASI, %	51,3		16,4		3,9		65,6	
R/L, %	62,8	37,2	54,1	45,9	51,0	49,0	66,4	33,6
Parameters characterizing muscle work in the pull-up phase								
A±σ, mkV	45,0±9,1	32,0±12,0	44,4±13,5	63,1±29,2	37,1±12,7	46,5±17,4	98,5±15,2	60,0±8,2
CW, %	5,7	4,0	5,6	8,0	4,7	5,9	12,4	7,6
ASI, %	34,0		34,8		22,7		48,5	
R/L, %	58,5	41,5	41,3	58,7	44,3	55,7	62,1	37,9

Table 4. Results of the analysis of electromyography data of the muscles of the back legs of athlete 2 during pedaling (rear view)

Muscles	R Bicepsfemoris	L Bicepsfemoris	R Gastrocnemiuslateral	L Gastrocnemiuslateral	R Gastrocnemiusmedial	L Gastrocnemiusmedial
Parameters characterizing muscle work in the bench press phase						
A±σ, mkV	53,9±9,1	66,6±9,7	98,0±21,8	69,1±11,6	78,5±16,9	90,8±14,8
CW, %	4,0	4,9	7,2	5,1	5,8	6,7
ASI, %	20,9		34,6		14,5	
R/L, %	44,8	55,2	58,7	41,3	46,4	53,6
Parameters characterizing muscle work in the pull-up phase						
A±σ, mkV	35,1±6,2	54,4±10,7	68,8±15,8	57,7±16,3	76,5±17,5	72,5±14,9
CW, %	4,4	6,9	8,7	7,3	9,7	9,2
ASI, %	43,2		17,7		5,3	
R/L, %	39,2	60,8	54,4	45,6	51,3	48,7

same trend is in the ratio of muscle activity in the press and pull-up phases (unequally for the left and right legs), as well as in the average ASI index for all muscles studied: 29,5 versus 18,0. Based on the initial results of the study, it is impossible to assess to what extent these features affect the technique of athletes' movements, however, it is known from earlier publications that the presence of equal efforts when pedaling on both sides is an important condition for highly efficient work [2, 3].

Conclusions. The presented approach allows to visually reflect the total bioelectrical activity of the left and right leg muscles during pedaling, compare the results of different athletes with each other and form an objective idea of the mechanisms of involvement of the leading muscle groups in the work by the phases of movements. With a proportionate total ratio of muscle activity in the phases of the press and pull-up, different athletes may have significant differences in the composition of the activity distribution between the leading muscle groups, the degree of asymmetry of the left and right legs, and, as a consequence, in the nature of pedaling with visually identical work. A promising direction for further research is the use of the electromyography method as a means of biological feedback to optimize the pedaling technique of cyclists.

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