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Original Article

Improvement of cyclists' pedaling technique by studying their individual differences

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Abstract:

The paper dwells upon the study of pedaling types in highly skilled track cyclists. The study involved 18 skilled cyclists. Kinematic, dynamic and integral indices of pedaling technique were examined. The studies revealed three types of pedaling according to the character of effort distribution. The first type is characterized by cyclist using the increased values of efforts of the vertical components of both legs at the distance. The second type includes pedaling technique variants that are based upon different degree of exceeding the values of mean group model characteristics of motion structure at the distance in terms of the efforts of all zones of right or left foot pedaling. The third type of motion structure is distinguished by high values of efforts of right foot pushing through and pushing down and left foot following through and pulling up, or vice versa – left foot pushing through and pushing down and right foot following through and pulling up. Pedaling technique is recommended to improve depending on its type. Moreover, one should pay attention at the development of the "leading" zones of pedaling cycle rather than the "lagging" ones.

Key words: cycling, biomechanics, pedaling, cyclists, technical preparation.

Introduction

Technical preparation represents an important part of sports training. It is one of the main areas of sports perfection in elite sport (Golovachev & Krylatyh, 1982; Umberto at al., 2011).

The external form of cyclist movements during a competitive distance covering gives only a superficial idea about his technical fitness (Lukes at al., 2006; Theurel at al., 2011; Tkachenko, 2012). The variability of the internal mechanisms of sports technique is covered up from the observer. In the long run, the technique efficiency is determined by athlete's ability to stably maintain its individual components (Yanaki at al., 2012). High sports mastery is determined by the ability of an athlete to consciously control his motor activity rather than to preserve the basic temporal, spatial and dynamic characteristics of sports technique throughout the competitive distance. This means efficient changing these or those technique details, depending on his functional capacities and the degree of fatigue, in order to achieve maximum results (Lepine at al., 2012; Olds, 2001; Sigrist at al., 2014).

Highly skilled pursuit cyclists have significant individual differences from the average statistical norm in individual indices of pedaling techniques (Kolumbet, 2018; Wangerin at al., 2017).

All athletes cannot have exactly the same motion structure during covering the competitive distance. While improving the pedaling technique of cyclists, it is advisable to identify types of motion structure. When developing typical models of motion structure of cyclists, we proceeded from the following. Each athlete has significant deviations, which are manifested in the unequal participation of individual zones of the pedaling cycle, while trying to ensure high distance speed and high sports result at a competitive distance. Compensation of some characteristics by others allows athletes with completely different motion structure to achieve the same sports results. This predetermines the need to take into account the peculiarities of cyclist's pedaling techniques in managing the process of technical preparation. For cycling coach it is rather difficult to plan preparation and monitor the execution of training loads by each athlete separately. This necessitates combining similar individual aspects of pedaling technique into separate types in order to train cyclists using typical model characteristics of motion structure.

The solution to the problem of the expediency of rearrangements in the motion system of highly skilled cyclists at a competitive distance permits not only to obtain new information about the pedaling technique. This also allows to design specific ways to improve the technical skills of athletes.

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Objective of study – to determine experimentally the cyclists' pedaling types and to conduct training process on this basis.

Materials, methods and organization of studies

Participants

The study involved 18 skilled cyclists (members of the Ukrainian national team in track cycling: 12 Masters of Sport of International level, 6 Merited Masters of Sport).

Organization of study

A complex method was used to conduct biomechanical studies both in a laboratory experiment simulating an individual 4km pursuit race, and in the natural conditions of sports training. The dynamics of the kinematic and dynamic characteristics of the horizontal and vertical components of efforts applied by the cyclist to the pedals was studied. In addition, indices of efficiency and economy of motor activity were calculated, the variability of studied characteristics of movements was determined. Control for the speed of pedaling was made by means of the developed electronic leader of pedaling speed (Kolumbet, 2017).

The total duration of the pedagogical experiment was six months. Athletes were divided into three groups. This division corresponded to the identified types of cyclists' motion structure.

During the first period of preparation (November-January), the process of technical preparation was designed in such a way as to provide the increase of the effectiveness of the efforts of the "lagging" elements of the pedaling technique. Cyclists with the structure of movements of the first type devoted more time to training horizontal zones of the pedaling cycle. Athletes with the structure of movements of the second type mainly practiced the symmetry of foot work. The third type cyclists improved individual zones of the pedaling cycle.

During the second period (January-April), training sessions were focused on the development of those elements of motion structure that had the prospect of preferential development in each particular cyclist. For athletes with a predominant development of the efforts of the vertical zones of the pedaling cycle the volume of load was increased in order to improve the marked zones. Cyclists with the dominant development of the efforts of all zones of the pedaling cycle of one of the legs paid more attention at the strongest extremity. Athletes with the structure of movements of the third type improved the right leg pushing through and pushing down, and the left leg following through and pulling up, or vice versa – the right foot following through and pulling up, and the left foot pushing through and pushing down. In addition, these athletes also practiced circular pedaling.

Special exercises traditionally used in the practice of cyclist training were applied to improve the strength of muscles of definite zones of the pedaling cycle.

Statistical analysis

During experimental data processing, we determined the average values of indices and their errors (X ± m), the degree of difference of averages and the significance of differences (t, p), the dispersion value of variants around the average (σ, CV) as well as the degree of relationship between the studied parameters (r). While conducting complex pedagogical, biomechanical and biological surveys with the participation of athletes, the legislation of Ukraine on health care, the 2000 Helsinki Declaration, Directive No. 86/609 of the European Society regarding people's participation in biomedical research were adhered to.

Results

Three types of motion structure of highly skilled pursuit cyclists were identified according to the character of effort distribution within pedaling cycle. The first type of pedaling technique is characterized by cyclist using the increased values of efforts of the vertical components of both legs at the distance. The second type includes pedaling technique variants that are based upon different degree of exceeding the values of mean group model characteristics of motion structure at the distance in terms of the efforts of all zones of the right or the left foot pedaling. The third type of motion structure is distinguished by high values of efforts of the right foot pushing through and pushing down and the left foot following through and pulling up, or vice versa – the left foot pushing through and pushing down and the right foot following through and pulling up.

Tables 1-3 present individual data of the pedaling technique of three highly skilled pursuit cyclists in accordance with identified types of motion structure.

Table 1. Pedaling technique indices of cyclist V.Kup-c at a model pursuit race (I-st type of pedaling)

Indices	Starting section	Distance segment			Finishing section
		Initial segment	Middle segment	Final segment	
Strength efficiency coefficient (SEC), %	76	77	82	74	75
Expended efforts, H	360.0	355.0	353.0	357.0	381.0
Useful efforts, H	282.0	269.0	283.0	274.0	272.0
Right leg relative momentum of pushing down, %	31.0	40.4	46.1	39.1	46.3

Left leg relative momentum of pushing down, %	38.2	44.3	48.0	42.9	40.5
Right leg relative momentum of pulling up, %	27.7	23.9	19.1	54.3	16.3
Left leg relative momentum of pulling up, %	38.9	24.1	21.9	28.6	34.6
Right leg relative momentum of pushing through, %	21.1	13.3	12.4	36.5	17.1
Left leg relative momentum of pushing through, %	16.9	21.0	23.4	19.4	23.8
Right leg relative momentum of following through, %	20.2	22.5	22.4	24.3	20.4
Left leg relative momentum of following through, %	16.0	10.6	16.8	18.9	11.0
Right leg maximum effort of pushing down, H	348.0	411.0	427.0	326.0	445.0
Left leg maximum effort of pushing down, H	250.0	254.0	274.0	274.0	308.0
Right leg maximum effort of pulling up, H	150.0	190.0	158.0	235.0	194.0
Left leg maximum effort of pulling up, H	182.0	144.0	133.0	152.0	113.0
Right leg maximum effort of pushing through, H	164.0	159.0	146.0	146.0	206.0
Left leg maximum effort of pushing through, H	101.0	103.0	120.0	81.0	100.0
Right leg maximum effort of following through, H	130.0	129.0	136.0	181.0	103.0
Left leg maximum effort of following through, H	111.0	71.0	43.0	64.0	102.0

In the process of managing preparation of cyclists, a distinction should be made between initial and subsequent examinations of athletes. The initial testing was conducted to determine the development level of cyclists' special physical qualities and their technical fitness. The study allowed to create individual models of athletes. Testing results were compared with analogous indices of mean group model characteristics of highly skilled cyclists, and permitted to determine the type of motion structure.

Table 2. Pedaling technique indices of cyclist V.Mov-n at a model pursuit race (II-nd type of pedaling)

Indices	Starting section	Distance segment			Finishing section
		Initial segment	Middle segment	Final segment	
Strength efficiency coefficient (SEC), %	91.0	89.0	84.0	85.0	88.0
Expended efforts, H	243.0	236.0	233.0	251.0	229.0
Useful efforts, H	225.0	208.0	197.0	218.0	202.0
Right leg relative momentum of pushing down, %	16.4	21.7	14.2	13.3	16.2
Left leg relative momentum of pushing down, %	23.0	39.0	54.1	13.3	39.7
Right leg relative momentum of pulling up, %	14.0	39.6	22.3	29.7	23.2
Left leg relative momentum of pulling up, %	35.0	27.2	10.3	53.6	23.4
Right leg relative momentum of pushing through, %	14.8	18.0	12.1	24.0	11.1
Left leg relative momentum of pushing through, %	23.0	21.1	15.7	19.6	16.6
Right leg relative momentum of following through, %	54.7	20.7	51.4	33.0	49.5
Left leg relative momentum of following through, %	19.0	12.7	19.3	23.4	20.3

Right leg maximum effort of pushing down, H	113.0	124.0	106.0	92.0	107.0
Left leg maximum effort of pushing down, H	135.0	128.0	165.0	168.0	130.0
Right leg maximum effort of pulling up, H	54.0	117.0	101.0	128.0	96.0
Left leg maximum effort of pulling up, H	204.0	139.0	107.0	171.0	134.0
Right leg maximum effort of pushing through, H	159.0	155.0	146.0	178.0	152.0
Left leg maximum effort of pushing through, H	74.0	48.0	47.0	49.0	68.0
Right leg maximum effort of following through, H	285.0	313.0	316.0	223.0	289.0
Left leg maximum effort of following through, H	95.0	59.0	85.0	83.0	85.0

After an athlete assigning to this or that group, his training process was carried out according to the plan of the corresponding type of pedaling. Based on the pedaling technique indices, the cyclist was informed about deviations from the model and given pedagogical instructions for its operative correction.

Table 3. Pedaling technique indices of cyclist Yu.Lus-ko at a model pursuit race (III-rd type of pedaling)

Indices	Starting section	Distance segment			Finishing section
		Initial segment	Middle segment	Final segment	
Strength efficiency coefficient (SEC), %	86.0	84.0	89.0	88.0	88.0
Expended efforts, H	302.0	321.0	314.0	299.0	325.0
Useful efforts, H	277.0	288.0	286.0	269.0	290.0
Right leg relative momentum of pushing down, %	54.6	71.9	41.0	43.1	47.8
Left leg relative momentum of pushing down, %	20.9	36.7	32.3	21.1	28.9
Right leg relative momentum of pulling up, %	22.5	25.3	32.0	26.2	35.1
Left leg relative momentum of pulling up, %	29.0	23.7	27.8	35.0	17.2
Right leg relative momentum of pushing through, %	15.2	10.1	19.9	11.6	11.0
Left leg relative momentum of pushing through, %	29.3	21.4	17.8	28.3	27.4
Right leg relative momentum of following through, %	17.7	12.7	23.0	29.1	17.2
Left leg relative momentum of following through, %	20.8	18.3	22.0	15.6	26.4
Right leg maximum effort of pushing down, H	435.0	293.0	294.0	333.0	414.0
Left leg maximum effort of pushing down, H	118.0	266.0	112.0	112.0	160.0
Right leg maximum effort of pulling up, H	176.0	121.0	228.0	189.0	242.0
Left leg maximum effort of pulling up, H	100.0	93.0	115.0	110.0	79.0
Right leg maximum effort of pushing through, H	74.0	74.0	62.0	46.0	34.0
Left leg maximum effort of pushing through, H	169.0	162.0	127.0	142.0	117.0
Right leg maximum effort of following through, H	112.0	117.0	141.0	158.0	168.0
Left leg maximum effort of following through, H	107.0	131.0	110.0	84.0	111.0

During subsequent examinations (along with the assessment of cyclist special and technical fitness) the degree of changes in pedaling technique indices was determined on the basis of mean group model characteristics. Obtained data were taken as a basis for planning further pedagogical impacts and the process of technical preparation of each specific athlete. The direction and character of impact upon motion structure were determined for each cyclist individually.

Table 4. Characteristics of the final testing results in laboratory conditions of athletes, who participated in pedagogical experiment (n=18)

	Indices	Experimental group		Control group	
		X	m	X	m
1	Cadence, number of revolutions	54,9	0,3	55,2	0,4
2	Speed component of speed strength, number of revolutions	46,1	0,5	45,3	0,4
3	Strength component of speed strength, number of revolutions	38,7	1,3	36,5	0,9
4	Strength endurance, number of revolutions	127,6	1,2	125,8	1,3
5	Strength efficiency coefficient (SEC), %	81,9	1,1	77,9	1,2
6	Useful efforts, H	276,0	12,0	233,0	13,3
7	Expended efforts, H	296,0	13,1	325,0	11,2
8	Total momentum, Hxc	255,0	9,6	214,0	9,7
9	Symmetry index according to SEC, %	88,3	1,9	84,7	1,9
10	Symmetry index according to expended efforts, %	81,1	3,3	76,2	4,2
11	Maximum efforts of right leg pushing down, H	266,0	18,0	234,0	18,3
12	Maximum efforts of right leg pulling up, H	181,0	12,4	126,0	12,2
13	Maximum efforts of right leg pushing through, H	135,0	12,4	117,0	11,8
14	Maximum efforts of right leg following through, H	157,0	12,2	102,0	10,3
15	Maximum efforts of left leg pushing down, H	246,0	14,9	199,0	13,1
16	Maximum efforts of left leg pulling up, H	179,0	9,8	163,0	12,9
17	Maximum efforts of left leg pushing through, H	126,0	10,7	108,0	10,6
18	Maximum efforts of left leg following through, H	105,0	7,7	89,0	10,2

While considering the efficiency of the use of typical model characteristics of cyclists' motion structure in order to form competitive pedaling techniques, one should not focus only on the obtained results of studies. The quality and effectiveness of technical preparation process are influenced by many factors. This is not only the improvement of the accuracy of diagnosing the motion structure at a distance or highlighting the factors that provide a high distance speed, but the direction of corrections in the process of training cyclists, which are made after this or that result during evaluation of athletes' pedaling technique. The training process, which is aimed at the harmonious development of all physical qualities of athletes and the improvement of "lagging" links of physical or technical fitness, does not provide the desired results.

Table 5. Validity of changes in characteristics of physical and technical fitness of cyclists throughout pedagogical experiment (n=18)

	Indices	Experimental group		Control group	
		t	P	t	P
1	Cadence, number of revolutions	5,7	$<0,05$	3,7	$<0,05$
2	Speed component of speed strength, number of revolutions	2,7	$<0,05$	5,4	$<0,05$
3	Strength component of speed strength, number of revolutions	2,9	$<0,05$	3,6	$<0,05$
4	Strength endurance, number of revolutions	2,7	$<0,05$	3,7	$<0,05$
5	Strength efficiency coefficient (SEC), %	4,0	$<0,05$	0,7	$>0,05$
6	Useful efforts, H	3,3	$<0,05$	0,8	$>0,05$
7	Expended efforts, H	2,4	$<0,05$	2,9	$<0,05$
8	Total momentum, Hxc	3,3	$<0,05$	1,3	$>0,05$
9	Symmetry index according to SEC, %	1,2	$>0,05$	0,5	$>0,05$
10	Symmetry index according to expended	0,5	$>0,05$	0,2	$>0,05$

	efforts, %				
11	Maximum efforts of right leg pushing down, H	2,5	<0,05	0,5	>0,05
12	Maximum efforts of right leg pulling up, H	2,5	<0,05	0,4	>0,05
13	Maximum efforts of right leg pushing through, H	2,5	<0,05	0,9	>0,05
14	Maximum efforts of right leg following through, H	2,5	<0,05	0,2	>0,05
15	Maximum efforts of left leg pushing down, H	3,0	<0,05	1,4	>0,05
16	Maximum efforts of left leg pulling up, H	3,1	<0,05	0,6	>0,05
17	Maximum efforts of left leg pushing through, H	2,4	<0,05	0,6	>0,05
18	Maximum efforts of left leg following through, H	2,5	<0,05	0,2	>0,05

While planning the training process, we proceeded from the fact that its effectiveness depends on the orientation of cyclist technical preparation in accordance with the typical features of motion structure. At the preliminary stages of preparation, this orientation should envisage the improvement of “lagging” elements of pedaling technique, whereas at the final stages the attention must be paid at the dominant elements of motion structure.

The initial testing of technical fitness of cyclists showed that all members of the experimental and control groups had low indices of the efficiency and economy of footwork in the pedaling cycle at the beginning of the experiment. The control of technical and tactical skills demonstrated that the indicated characteristics of the pedaling technique decreased at the finish of the distance, thus reducing the distance speed of pedaling. By the end of the finishing segment of the distance, the athletes also showed pronounced asymmetry in the work of the extremities in the direction of increasing the proportion of the right leg efforts.

Subsequent tests showed a systematic increase in physical qualities in both groups in accordance with the regularities of the formation of the competition form under the influence of applied physical loads. However, the growth of technical fitness indices in the experimental group occurred at a higher rate, and already in April a significantly greater increase in results was noted as compared to the initial ones. Indices of effort efficiency and economy have increased in athletes of the experimental group by 8.8-24.3% and by 17.0-26.9%, respectively. In the control group, the increase in these characteristics constituted 1.4-6.9% and 9.2-16.5%, respectively. Experimental group athletes have noticeably decreased asymmetry of footwork in terms of efficiency and economy. In addition, they had a higher rate of increase in the maximum strength of individual zones of the pedaling cycle (Table 4).

In the experimental group cyclists significant changes in the characteristics of motion structure were observed (Table 5). Indices of pedaling techniques of the control group athletes did not have significant differences for the most part (Table 5). Comparison of groups by the method of conjugated pairs and comparison of the results of the control showed higher efficiency of preparation of the experimental group athletes.

Discussion

Pedaling technique of cyclists has been studied for over 50 years. Scientists, however, have not come to a common definition of the types of technique. Some authors believe that there are "circular" and "impulse" pedaling (Baechle at al., 2008; Dahmen, 2012; Wilson, 2004 et al.). Other researchers think differently (Alexandrov & Mikhaylova, 2015; Crouch at al, 2014).

Under the conditions of the current level of sports achievements, highly skilled athletes are not able to maintain the same motor characteristics during the entire duration of the race. Martynov G.M. & Abrosimov V.V. (1970), Erdakov S.V. (1972), Mihaylov V.V. & Levenko N.A. (1975) pointed out the difference in the energy cost of different methods of pedaling. The authors indicate that the work in impulse mode contributes to more economical energy expenditure. According to Mihaylov V.V., Levenko N.A. (1975), in practice the most natural should be considered the intermediate between “circular” and “impulse” type of pedaling.

An important point in the distribution of muscular efforts at a particular point of covering the distance is the ability of athletes to correlate sports technique with the body functional capacities.

Scientists (Dorel at al., 2009; Kolumbet at al., 2017; Mornieux et al., 2010; Turpin at al., 2011) found that in highly skilled cyclists during cycle ergometry under conditions of regulated cadence, the speed in the period of fatigue is mainly maintained by compensatory changes in muscle contractility. At the same time, the kinematic and dynamic characteristics of the main components of pedaling remain unchanged (Brocker at al., 2009; Erik at al., 2005; Wangerin at al., 2017). This is primarily manifested in the involvement of additional (previously not functioning) motor units with a higher threshold of excitability in the active state. During the period of fatigue, a redistribution of muscle activity occurs. The spatial and temporal characteristics of bioelectric activity tend to change as well (Bini at al., 2014; Castronovo at al., 2012; Thomas at al., 2007).

We have proved for the first time that there are many variants of pedaling techniques that can be combined into three types. The training process of highly skilled athletes should be carried out with due account for these provisions.

Conclusions

In the initial testing during the model pursuit race, the decrease in the indices of economy, work efficiency and pedaling speed was observed by the end of the distance. Experimental training was aimed at developing adaptive mechanisms in the technique of pedaling, which occur in highly skilled cyclists at a competitive distance. By the end of the pedagogical experiment, it allowed the experimental group cyclists to raise the total level of all studied parameters and stabilize the dynamics of biomechanical characteristics. Efficiency, economy, symmetry of the work of legs of cyclists and speed at the finishing segment of the distance increased.

The effectiveness of the process of technical training of cyclists of the experimental group is significantly higher than that of the athletes of the control group. It should be borne in mind that the experiment involved athletes, whose technical skill was somewhat stabilized. However, in a relatively short time, it was possible to achieve significant changes in the technique of pedaling and an increase in sports results. This is an additional factor that testifies to the effectiveness of the suggested experimental program.

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Conflict of interest

The authors declare that there is no conflict of interests.

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