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Original Article

Energy supply during cyclist muscular activity

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Abstract:
The paper discusses the studies of energy expenditure dynamics in cyclists during performance of maximal muscular work of relative power. Fourteen athletes of the I category aged 16 years participated in the studies. During the main study, each athlete was asked to perform maximal load with voluntary distribution of efforts within 15 minutes in order to achieve maximal efficiency. Athletes performed this exercise 13 times, but only one load was used up to the end. In all other cases, work was interrupted after an unknown time for the subject since the beginning of the exercise. Interruptions were made after 30 s, 1, 1,5, 2, 2,5, 3, 4, 5, 7, 8, 10, 13 and 14 min. of work. Loads were performed in accordance with the established procedure with a sufficient rest interval within 4 days. The intensity of initial work was proved to be dependent on the power and the velocity of phosphagen and lactacid systems.
Key words: cyclists, testing, energy supply mechanisms.

Introduction

Intensive muscular work is provided by total contribution of three major energy systems: oxidative, phosphagen and lactacid (Kots, 1982; Plowman & Smith, 2007). Each of them is characterized by power, capacity and efficiency (Manier & Pugh, 1968; Tesch & Karlsson, 1979). The limiting factor of energy formation through oxidation at the beginning of exercise performance is its inertia (Ahlborg et al., 1972; Mornier et al., 2006, 2010). Oxygen deficiency at the beginning of work is compensated at the expense of energy formation in anaerobic processes (phosphagen and lactacid). However, while determining the dynamics of energy expenditures the researchers have mainly used the measurement of oxygen consumption rate during the work. In some cases, they took into account the rate of energy formation by glycolytic pathway (Wasserman, Van Kessel & Burtong, 1967). The power of phosphagen energy system was measured by special Margaria test (Margaria R, 1963).

Based on experimental studies (Castronovo et al., 2012, Sundstr□ et al., 2013, Turpin et al., 2011), it has become possible to calculate the power of phosphagen energy formation during short-term maximal work according to alactate fraction of oxygen debt. Such an approach of calculating during maximum exercises of high relative power has never been used. Total energy expenditures were calculated without the contribution of the phosphagen system.

Objective of work – studying the dynamics of total energy expenditures during performance of maximal muscular work of relative power with account for the major energy systems.

Material and methods

Fourteen athletes of the I category aged 16 years participated in the studies. Before the beginning of studies, their level of functional fitness was tested on the basis of performing the load of stepwise incremental power to exhaustion.

During the main study, each athlete was asked to perform maximal load with voluntary distribution of efforts within 15 minutes in order to achieve maximal efficiency. Athletes performed this exercise 13 times, but only one load was used up to the end. In all other cases, work was interrupted after an unknown time for the subject since the beginning of the exercise. Interruptions were made after 30 s, 1, 1,5, 2, 2,5, 3, 4, 5, 7, 8, 10, 13 and 14 min. of work. Loads were performed in accordance with the established procedure with a sufficient rest interval within 4 days. The same way of load setting for all subjects was used. The resistance on flywheel of cycle ergometer constituted 2.5 kgm; load performance was controlled every 30 s of work by means of counter device.

Pulse was recorded by electrocardiograph; samples of exhaled air were taken. Samples of peripheral blood were taken every minute to determine the lactate concentration. "*Specol-10*" spectrocolorimeter was used for blood test. The analysis of exhaled air was carried out by means of "*Beckman*" gas analyzer (to determine O_2 and CO_2 content). During the first 2 min of recovery, exhaled air was taken to determine the alactate fraction of

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the oxygen debt and the phosphagen system contribution to total energy expenditures (according to Fox, 1974). The main peculiarity of our study was that during the recovery period at 1, 3, 5 and 7 min peripheral blood samples were taken to determine the maximum lactate concentration after each load.

Results and analysis

Obtained data allow to determine the change in the rate of energy formation by three mechanisms. In order to determine the contribution of each energy system to the performance of maximal muscular work, the obtained data were reduced to the same units of measurement - watts. The rate of energy formation at the expense of the oxidative system (*O_2*) at each segment was calculated as the arithmetic mean of all oxygen consumption values (*Vo_{2R}*) recorded at this segment minus the initial level (*Vo_{2S}*):

$$O_2\ [W] = 21 \times (VO_{2R} - VO_{2S})\ [ml] : \Delta t\ [s]$$

The rate of energy formation at the expense of lactacid system was presented as the ratio of blood lactate concentration between two interruptions to the given time interval:

$$L\ [W] = \Delta\ La\ [mM/l] \times 0{,}0624 \times P\ [kg] : \Delta t\ [s]$$

where 0,0624 – scaling ratio according to Margaria et al. (1963);

P – weight of athlete.

Only the highest values of lactate concentration registered after each interruption were taken into account. In a similar way the rate of energy formation at the expense of phosphagen system was determined (the difference in measured alactate oxygen debt between interruptions to the time interval between them):

$$F\ [W] = \Delta\ VO_{2a}\ [J] : \Delta t\ [s]$$

Relative contribution of each of the studied energy formation mechanisms was calculated for all work intervals. It appeared that the above ratio tended to vary throughout the entire work (Table 1). For all studied time intervals of work the relative contribution of each energy system was not the same. This ratio tended to vary throughout the entire work (Table 1, Fig. 1).

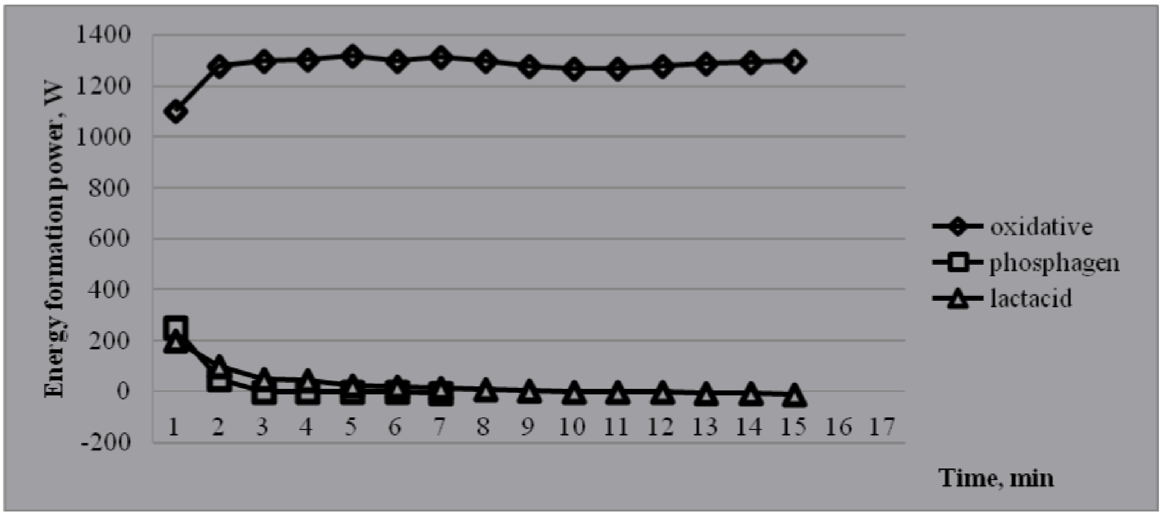

Fig. 1. Change of energy formation rate by oxidative, phosphagen and lactacid systems during work of relatively high power

It is expedient to divide the graph of changing performed work power into three phases in order to conduct more detailed analysis of findings. The first one is the starting phase or the phase of warming-up that is characterized by adaptation of all body systems of athletes to loads. Its duration constitutes 2 minutes. During the first 30 s of work (Table 1) 64.5 % of energy is provided by anaerobic systems with preferential contribution of phosphagen system (50.5 %). Simultaneous increase of the rate of energy formation by glycolytic pathway (its contribution constitutes 14 %) is observed. It is important to note individual differences in time of achieving the maximal rate of energy formation by lactacid system, which is most frequently found in athletes in time interval from 60 to 90 s. The rate of energy formation by phosphagen pathway drops sharply by the 2^{nd} min of work, achieving the value of 53.9 W, which constitutes 3 % of total energy expenditures. The rate of energy formation by glycolytic pathway decreases to a lesser extent (110 W and 10.7 % of total energy expenditures). The rate of oxygen consumption rapidly increases by this time. At the end of the first phase, it reaches 90 % of contribution to total energy expenditures. The most distinctive feature of this phase is its high initial intensity that is due to developed anaerobic energy power.

The second phase (distance power maintenance) lasts from 2 to 10 minutes. During this phase, the processes of energy formation by anaerobic systems are terminated. Oxygen consumption reaches its working level. This phase is characterized by preferential energy formation at the expense of oxidative system. Its contribution constitutes 95-99 % of total energy expenditures. The dynamics of mechanical power is determined by the power of oxidative system. It has close to uniform character of effort distribution.

Table 1. Relative contribution of the major energy formation systems to total energy expenditures during maximal work of high relative power

Duration of work, min.	Energy formation system, % oxidative	lactacid	phosphagen	Total energy expenditures, W	Muscular work efficiency factor, %
0,5	36,40	14,04	50,48	1487,40	18,10
1,0	74,50	12,60	13,00	1489,70	17,70
1,5	84,00	10,70	5,20	1450,20	17,90
2,0	89,20	7,70	3,50	1449,70	17,90
2,5	95,20	3,60	1,20	1359,00	18,30
3,0	96,60	3,50	1,20	1381,90	17,90
4,0	97,00	2,30	0,70	1408,20	17,60
5,0	98,20	1,90	0,40	1382,20	17,80
7,0	98,40	1,30	0,40	1360,30	17,50
8,0	98,90	1,00	0,06	1392,60	16,90
10,0	99,20	0,80	0,05	1318,90	18,10
12,0	99,70	1,20	0,08	1303,20	17,70
15,0	100,00	0,04	0,05	1295,60	17,70

The third finishing· phase (10-15 min) is characterized by energy formation at the expense of oxidative system only. However, there are cases when anaerobic energy potential is not fully exhausted. Then the realization of its leftovers during this phase allows the athletes to increase the work intensity, i.e., to accelerate at the finish.

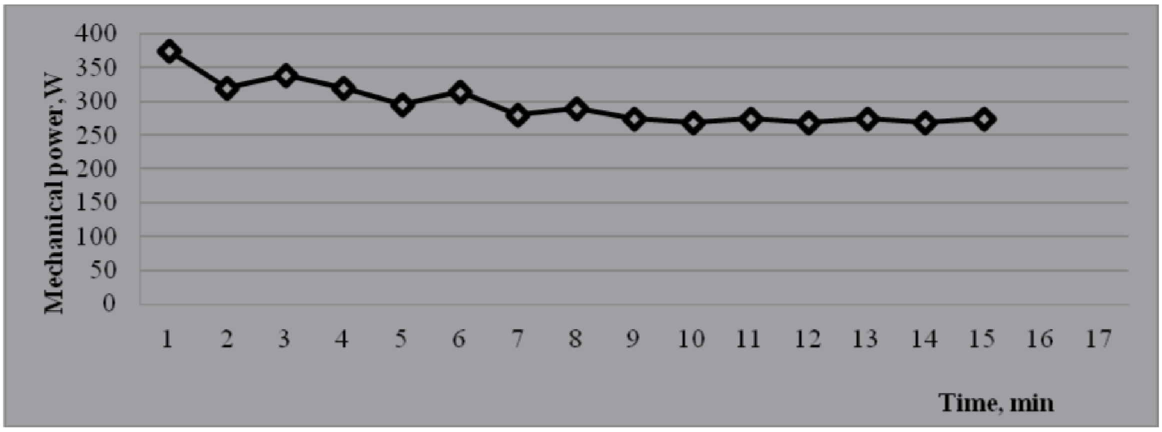

Fig. 2. Change of metabolic energy expenditures depending on the duration of maximal exercise of high relative power

The findings demonstrated the possibility of practical assessment of energy formation rate (oxidative, lactacid, phosphagen) on the basis of maximal work performance with multiple interruptions (cross-sections).

Mechanical efficiency coefficient was calculated as the ratio of performed mechanical work to metabolic expenditures at each segment.

Dynamics of total energy expenditure change during work (Fig. 2), that of mechanical power (Fig. 3) and changes of muscular work efficiency coefficient (Fig. 4) are presented. Change of mechanical power corresponds to alteration of metabolic energy expenditures. Efficiency coefficient is constant during the whole of exercise (Table 1).

It appears that the process of anaerobic system energy formation has no influence on the efficiency of performance of maximal muscular work of high relative power. This should be underscored as many scientists have reported the decrease of the work mechanical efficiency along with the increase of exercise power (Asmussen, 1981; Dahmen, 2012; Olds, 2001). They argue that the reason consists in involvement of inefficient anaerobic systems in the process of energy formation (Pahud et al., 1980; Whipp et al., 1970, 1983). There are, however, experimental data demonstrating that the economy of work performance during combined aerobic-anaerobic regime of energy supply does not decrease as compared to work performed at the expense of oxidative phosphorylation. In this case, the value of muscle contraction mechanical efficiency is considered to be a constant that does not depend on the working conditions (Tallarida et al., 1981; Wiley & Lind, 1975).

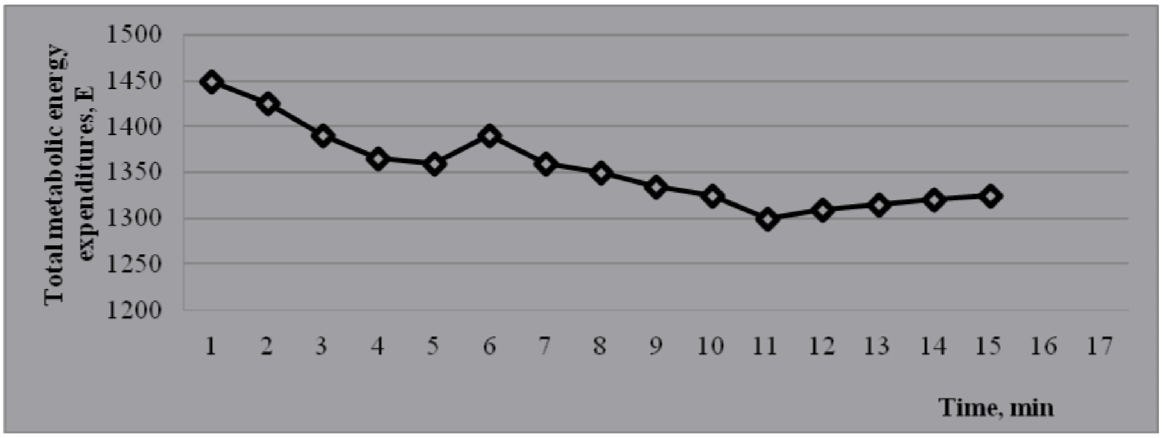

Fig. 3. Change of mechanical power depending on the duration of maximal exercise of high relative power

Conclusion

While performing maximal work of high relative power for up to 15 min, anaerobic systems (phosphagen and lactacid) do not influence the efficiency of muscular work performance. Coefficient of muscular work efficiency remains practically constant. Initial intensity of work depends on the power and velocity of phosphagen and lactacid systems. It represents an individual value for each athlete. This fact should be taken into consideration during preparation of athletes for 1000 m standing start heat as well as 4 km individual and team pursuits.

At 1000 m standing start, the athlete should gain maximal speed as soon as possible, and try to keep it up to the end of the distance. In this type of races, the overall result depends on the start. A good start, in its turn, depends on individual peculiarities of athletes as well as power and velocity of phosphagen and lactacid energy supply system switching on.

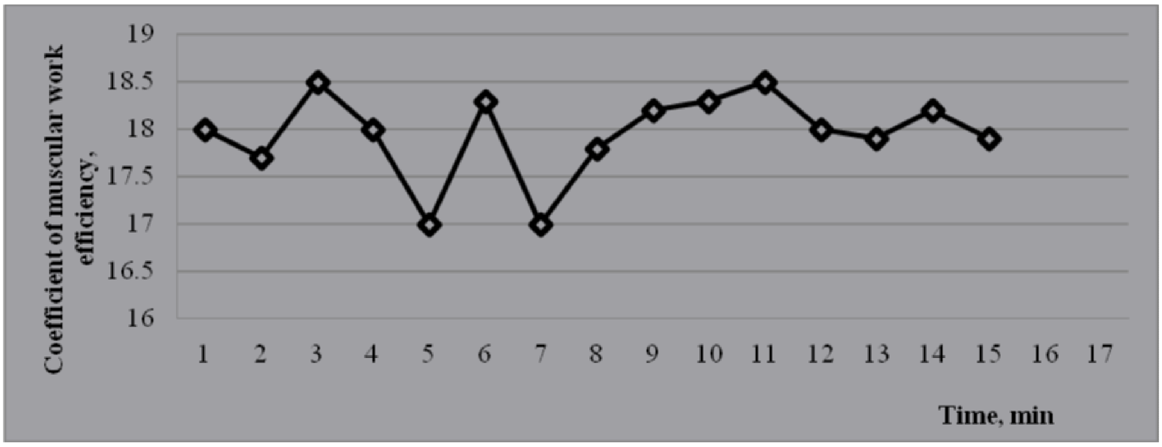

Fig. 4. Change of muscular work efficiency coefficient depending on the duration of maximal exercise of high relative power

A good start is also needed for cyclists-pursuers. It is important in team pursuit, where the racer starting at the first position is tasked to accelerate to distance speed as soon as possible. Due account of individual potential of oxidative system work power will allow the coaches to more precisely determine each racer's position in the team.

Conflict of interest

The authors declare that there is no conflict of interests.

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