

# МЕДИКО-БІОЛОГІЧНІ ПРОБЛЕМИ СПОРТУ ВИЩИХ ДОСЯГНЕНЬ

## Reactivity of cardiorespiratory system and manifestations of fast kinetics responses in athletes of different sports specialization

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**Abstract.** The purpose of the study was to determine differences in the fast kinetics of  $O_2$  consumption,  $CO_2$  release, pulmonary ventilation and heart rate, as well as differences in sensitivity of the cardiorespiratory system (CVS) to hypercapnia in athletes of various sports specializations. *Methods.* In three groups of elite runners (19–24 years old) at a distance of 100, 800 and 5000 m peak responses and their fast kinetics were studied (half cycle  $T_{50}$ , «breath-by-breath» method). Sensitivity to CVS hypercapnia was determined by the «return» breathing method. *Results.* It was revealed that the fast kinetics of  $\dot{V}O_2$  and  $\dot{V}_E$ , when performing work of average aerobic power at  $\dot{V}O_2$  53.5 % of  $\dot{V}O_{2max}$  was higher in sprinters as compared to long-distance runners. For «critical» power at  $\dot{V}O_2$  93.4 % of  $\dot{V}O_{2max}$  the characteristics of reaction kinetics were higher in long-distance runners. The findings suggest an association between differences in CVS sensitivity to  $CO_2$  in sprinters, middle and long distance runners, and differences in the kinetics of fast reactions of CVS in athletes. The value of  $\Delta P_A CO_2 / \Delta \dot{V}_E$  was significantly higher for sprinters as compared to long and middle distance runners. *Conclusions.* The findings indicate the differences in CVS sensitivity to  $CO_2$  in sprinters, middle and long distance runners, as well as differences in the kinetics of fast reactions of CVS in athletes, differences in the degree of involvement of anaerobic metabolism and  $\dot{V}CO_2$  kinetics. The latter has been associated with respiratory compensation of metabolic acidosis, which provided the most pronounced differences between long and middle distance runners, as well as sprinters.

**Keywords:** athletes, specialization, reactivity, cardiovascular system.

**Резюме.** Мета дослідження полягала у визначенні відмінностей швидкої кінетики споживання  $O_2$ , виділення  $CO_2$ , легеневої вентиляції і частоти серцевих скорочень, а також відмінностей чутливості кардіореспіраторної системи (КРС) до гіперкапнії у спортсменів різних спортивних спеціалізацій. *Методи.* У трьох груп елітних бігунів (віком 19–24 роки) на дистанціях 100, 800 і 5000 м було досліджено пік реакцій і швидку їх кінетику (напівперіод  $T_{50}$ , метод «breath-by-breath»). Чутливість до гіперкапнії КРС визначали методом «зворотнього» дихання. *Результати.* Виявлено, що швидка кінетика  $\dot{V}O_2$  і  $\dot{V}_E$  під час виконання роботи середньої аеробної потужності при  $\dot{V}O_2$  53,5 % від  $\dot{V}O_{2max}$  була вищою у спринтерів порівняно з бігунами на довгі дистанції. Для роботи «критичної» потужності при  $\dot{V}O_2$  93,4 % від  $\dot{V}O_{2max}$  характеристики кінетики реакцій були вищі у бігунів на довгі дистанції. Отримані дані свідчать про наявність взаємозв'язку між відмінностями в чутливості КРС до  $CO_2$  у спринтерів, у бігунів на середні та довгі дистанції, і відмінностями швидкої кінетики реакцій КРС у спортсменів. Значення  $\Delta P_A CO_2 / \Delta \dot{V}_E$  було достовірно вищим у спринтерів порівняно з бігунами на довгі і середні дистанції. *Висновки.* Отримані дані свідчать про відмінності в чутливості КРС до  $CO_2$  у спринтерів, у бігунів на середні та довгі дистанції, а також відмінності швидкої кінетики реакцій КРС у спортсменів, відмінності у ступені залучення анаеробного метаболізму і кінетики  $\dot{V}CO_2$ .

Останнє було пов'язано з дихальною компенсацією метаболічного ацидозу, що й забезпечувало найбільш виражені відмінності між бігунами на довгі та середні дистанції, а також спринтерами.

**Ключові слова:** спортсмени, спортивна спеціалізація, реактивність, кардіореспіраторна система.

**Резюме.** Цель исследования заключалась в определении различий быстрой кинетики потребления  $O_2$ , выделения  $CO_2$ , легочной вентиляции и частоты сердечных сокращений, а также различий чувствительности кардиореспираторной системы (КРС) к гиперкапнии у спортсменов различных спортивных специализаций. **Методы.** У трех групп элитных бегунов (19–24 лет) на дистанциях 100, 800 и 5000 м были исследованы пик реакции и быстрая их кинетика (полупериод  $T_{50}$ , метод «breath-by-breath»). Чувствительность к гиперкапнии КРС определяли методом «возвратного» дыхания. **Результаты.** Выявлено, что быстрая кинетика  $\dot{V}O_2$  и  $\dot{V}_E$  при выполнении работы средней аэробной мощности при  $\dot{V}O_2$  53,5 % от  $\dot{V}O_{2max}$  была выше у спринтеров по сравнению с бегунами на длинные дистанции. Для работы «критической» мощности при  $\dot{V}O_2$  93,4 % от  $\dot{V}O_{2max}$  характеристики кинетики реакции были выше у бегунов на длинные дистанции. Полученные данные свидетельствуют о наличии взаимосвязи между различиями в чувствительности КРС к  $CO_2$  у спринтеров, у бегунов на средние и длинные дистанции, и различиями в быстрой кинетике реакций КРС у спортсменов. Значение  $\Delta P_A CO_2 / \Delta \dot{V}_E$  было достоверно выше у спринтеров по сравнению с бегунами на длинные и средние дистанции. **Выводы.** Полученные данные указывают на различия в чувствительности КРС к  $CO_2$  у спринтеров, у бегунов на средние и длинные дистанции, а также различия в быстрой кинетике реакций КРС у спортсменов, различия в степени вовлечения анаэробного метаболизма и кинетики  $\dot{V}CO_2$ . Последнее было связано с дыхательной компенсацией метаболіческого ацидоза, которая и обеспечивала наиболее выраженные различия между бегунами на длинные и средние дистанции, а также спринтерами.

**Ключевые слова:** спортсмены, спортивная специализация, реактивность, кардиореспираторная система.

## Background

Strenuous sports training is characterized by significant hypoxic and acidosis events in the body of athletes. They are some of the most important factors limiting the work capacity. Their expressiveness is related to both cardiorespiratory system (CRS) functional capacities and intensity-duration of executed training and competitive loads as well as to the kinetics of aerobic energy-supply responses [1–4, 7, 10, 13, 15, 16]. Regular repetition of uniform character of several years' endurance sports training provides an increase in both specific metabolic capacities and responsiveness optimization of cardiorespiratory system (CRS) relative to specific conditions of athletes' energy potential utilization. The specific metabolic capacities usually are related to aerobic potential realization during loads of different power and specific of athletes' aerobic-anaerobic energy potential utilization for sports event [2, 6, 8–10, 17]. There is quite contradictory data about differences in fast kinetics and sensitivity of CRS responses in athletes of different specialization [5, 8–14, 17]. We have proceeded from the fact that during specific training one may observe also definite changes of not only the limits of work aerobic energy-supply responses but sensitivity and fast (initial) kinetics of CRS responses, i.e. character of aerobic potential realization during loads of different power. Expressiveness of these changes should be connected with specifics of the demands of competitive distance of sprinters or long distance runners, and thus, reflect adaptation specificity.

The aim of the study was to determine the differences in fast kinetics of  $O_2$  uptake,  $CO_2$  elimination, lung ventilation and heart rate as well as sensitivity of CRS responses to hypercapnia in athletes of different sport specialization – of short, middle and long duration.

**Material and methods.** Three groups of runners (19–24 years old) who have been training for 5–8 years in 100 m running ( $n = 17$ ; body mass  $77.6 \pm 1.1$  kg), 800 m running ( $n = 15$ ;  $75.1 \pm 1.2$  kg) and 5000 m running ( $n = 16$ ;  $70.6 \pm 0.9$  kg) were examined. The next exercise tests have been performed on treadmill: incremental (10–14 min), work an average aerobic power at  $\dot{V}O_2$  53.5 % of  $\dot{V}O_{2max}$  (12 min) and work of «critical» power at  $\dot{V}O_2$  93.4 % of  $\dot{V}O_{2max}$  (5 min). Peak responses and fast kinetics (half-period –  $T_{50}$ , «breath-by-breath» method, transition from  $6 \text{ km}\cdot\text{hour}^{-1}$ ) were determined. Capillary blood lactate was measured after incremental load. CRS response sensitivity to hypercapnia was determined by the re-breathing method under standard resting conditions. The lung ventilation, heart rate and respiratory sinus arrhythmia (RSA) responses were measured, by mean of values of inter-beat interval for 10 sec in percent of mean R–R interval.

During testing, «breath-by-breath» gas exchange data («Oxycon Pro», Jager), acid-base balance of blood («Dr Lange LP 400») and heart rate (Polar Electro Inc.) to maximum and standard physical loads were continuously obtained. Treadmill LE200CE («Jager», Germany) and «Monark824E» cycle ergometer («Monark», Sweden) was used

TABLE 1 – Cardiorespiratory responses to incremental (10–14 min) treadmill exercise test of short, middle and long distance athletes, mean ± SD

Indices	Groups of athletes			p (t-test) < 0.05
	short (1)	middle (2)	long (3)	
Power at $\dot{V}O_2$ max, W·kg <sup>-1</sup>	3.18 ± 0.17	3.57 ± 0.15	4.82 ± 0.22	1–2,3; 2–3
$\dot{V}_E$ max (peak), L·kg <sup>-1</sup> ·min <sup>-1</sup>	1,57 ± 0,12	1,87 ± 0,12	2,22 ± 0,10	1–2,3; 2–3
$\dot{V}O_2$ max, mL·kg <sup>-1</sup> ·min <sup>-1</sup>	42.97 ± 3.36	50.11 ± 3.20	61.0 ± 2.3	1–2,3; 2–3
$\dot{V}CO_2$ max, mL·kg <sup>-1</sup> ·min <sup>-1</sup>	56.9 ± 3.7	52.0 ± 3.0	55.1 ± 2.41	
HRmax, b·min <sup>-1</sup>	191.0 ± 4.5	186.5 ± 4.5	184.3 ± 5.6	
$\dot{V}_E/\dot{V}O_2$ at $\dot{V}O_2$ max	29.97 ± 1.84	30.50 ± 2.43	29.89 ± 0.70	
$\dot{V}_E/\dot{V}CO_2$ at $\dot{V}O_2$ max	26.92 ± 3.18	32.71 ± 1.36	36.67 ± 2.23	1–2,3; 2–3
$\dot{V}CO_2/\dot{V}O_2$ at $\dot{V}O_2$ max	1.17 ± 0.14	1.07 ± 0.12	0.98 ± 0.09	1–3
$\dot{V}CO_2/\dot{V}O_2$ peak at recovery	1.45 ± 0.12	1.22 ± 0.11	1.18 ± 0.08	1–2,3; 2–3
HLa immediately after, mmol·L <sup>-1</sup>	11.90 ± 0.7	8.96 ± 0.86	8,10 ± 0,91	1–2,3

Indices	Groups of athletes			p (t-test) < 0.05
	shortn (1)	middle (2)	long (3)	
$\Delta\dot{V}_E/\Delta P_A CO_2$ , L·min <sup>-1</sup> ·mm Hg <sup>-1</sup>	2.27 ± 0,16	1.59 ± 0,11	1.09 ± 0,14	1–2, 3
$\dot{V}_E$ at 50 mm Hg, mL·kg <sup>-1</sup> ·min <sup>-1</sup>	535 ± 43	295 ± 40	209 ± 28	1–2,3; 2–3
HR at 50 mm Hg, b·min <sup>-1</sup>	74.4 ± 2.8	70.8 ± 3.2	67.1 ± 2.1	1–3

TABLE 2 – The lung ventilation and heart rate responses to hypercapnia in short, middle and long distance runners, mean ± SD

during this study. Statistics 5.0 PL in Excel 97 packet was used.

**Results and Discussion.** The studies have demonstrated that at incremental load the peak of lung ventilation ( $\dot{V}_E$ ) was higher in long distance runners as compared to sprinters ( $2.22 \pm 0.10$  and  $1.57 \pm 0.12$  L·min<sup>-1</sup>·kg<sup>-1</sup>; p < 0.05). Blood lactate after the above load was higher in sprinters as compared to long distance runners ( $11.90 \pm 0.76$  and  $8.10 \pm 0.91$  mmol·L<sup>-1</sup>, respectively). Besides, sprinters have also been characterized by a higher peak value of  $\dot{V}CO_2/\dot{V}O_2$  during recovery period ( $1.45 \pm 0.12$  and  $1.18 \pm 0.08$ , respectively; p < 0.05) (table 1).

It was revealed that fast kinetics  $\dot{V}O_2$  and  $\dot{V}_E$  during the average aerobic power at  $\dot{V}O_2$  53.5 % of  $\dot{V}O_2$ max were higher in sprinters as compared to long distance runners. For instance,  $T_{50} \dot{V}O_2$  constituted  $25.5 \pm 1.81$  sec and  $28.9 \pm 2.1$  sec, whereas  $T_{50} \dot{V}_E$  ( $38.6 \pm 2.91$  sec and  $45.9 \pm 3.3$  sec, respectively; p < 0.05). Just the opposite was observed for work of «critical» power at  $\dot{V}O_2$  93.4 % of  $\dot{V}O_2$ max – fast kinetics was the lowest in the group of sprinters and the highest in long and middle distance runners. For instance,  $T_{50} \dot{V}O_2$  constituted  $29.8 \pm 3.0$  sec in sprinters and  $24.4 \pm 2.9$  sec – in long distance runners (p < 0.05).  $T_{50} \dot{V}O_2$  was  $22.8 \pm 2.5$  sec in middle distance runners. The above value was the lowest in middle distance runners ( $22.8 \pm 2.5$  sec).

Runners of different specialization differed in sensitivity of CRS responses to CO<sub>2</sub> (table 2, fig. 1).

The  $\Delta\dot{V}_E/\Delta P_A CO_2$  value was reliably higher in sprinters as compared to long and middle distance runners. According to lung ventilation level at  $P_A CO_2 = 50$  mm Hg reliable differences were

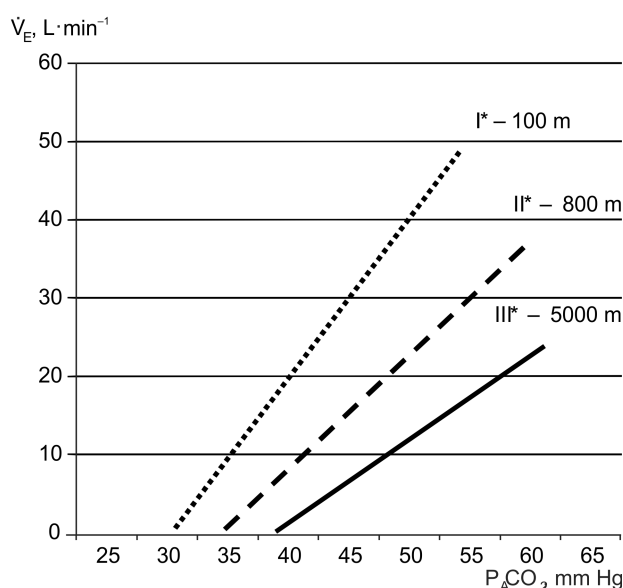


Figure 1 – The lung ventilation ( $\dot{V}_E$ , L·min<sup>-1</sup>) and  $P_A CO_2$  (mm Hg) relationship for increscent hypercapnia in short (100 m), middle (800 m) and long (5000 m) distance runners

Indices	Groups of athletes			p (t-test) < 0.05
	short (1)	middle (2)	long (3)	
Max level of RSA (RSA max), %	14.13 ± 2.24	19.51 ± 2.24	22.08 ± 2.96	1–2,3
P <sub>A</sub> CO <sub>2</sub> at RSA max (P <sub>A</sub> CO <sub>2</sub> RSAmax), mm Hg	49.67 ± 1.12	51.48 ± 1.17	53.81 ± 0.96	1–2
RSA at P <sub>A</sub> CO <sub>2</sub> 50 mm Hg (RSA <sub>50</sub> ), %	12.30 ± 1.01	14.29 ± 0.82	18.73 ± 1.04	1–2,3; 2–3
P <sub>A</sub> CO <sub>2</sub> max onset decrease of RSA, mm Hg	49.91 ± 0.98	53.04 ± 1.08	56.18 ± 1.18	1–2,3; 2–3

TABLE 3 – Indices of respiratory sinus arrhythmia (RSA) for increscent hypercapnia in short, middle and long distance runners, mean ± SD

observed between long and middle distance runners. In middle distance runners individual differences in T<sub>50</sub>,  $\dot{V}_E$  and  $\dot{V}CO_2$  were related to lung ventilation response sensitivity to hypercapnia (r = -0.67 and r = -0.65, respectively; p < 0.05).

Heart rate response to hypercapnia was also higher in sprinters than long distance runners. Increasing of parasympathetic activity, measured by respiratory sinus arrhythmia changes for increscent hypercapnia, to some extent also reflected specific endurance training status (table 3).

The onset of abrupt sympathetic modulation of cardiac activity increase took place at high level of CO<sub>2</sub>-H<sup>+</sup>-drive. P<sub>A</sub>CO<sub>2</sub>max decrease of RSA was related to the stability such modulation of cardiac activity. This level was related to athletes' specific training status and was higher in long distance athletes.

The analysis of all runners has shown that the peak of gas exchange ratio ( $\dot{V}CO_2/\dot{V}O_2$ ) after progressively increased load was related to  $\dot{V}_E$  sensitivity to CO<sub>2</sub> (r = 0.59; p < 0.05) and showed

different levels of respiratory compensation of metabolic acidosis in short, middle and long distance athletes.

**Conclusions.** The data indicate a relationship between the differences in sensitivity to CO<sub>2</sub> in sprinters, middle and long distance athletes and the differences in fast kinetics of CRS response in athletes as well as degree of anaerobic metabolism involvement and  $\dot{V}CO_2$  kinetics. The latter was related to metabolic acidosis respiratory compensation. Its expressiveness provides the most distinction of long and middle distance athletes as well as sprinters.

We have observed dependence of fast kinetics  $\dot{V}O_2$ ,  $\dot{V}CO_2$  and cardiorespiratory peak responses in sprinters and long distance runners upon the load intensity. Under submaximal power sprinters demonstrated higher response kinetics as compared to long distance runners. For power at  $\dot{V}O_2$ max higher response kinetics has been noted in long and short distance athletes.

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