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

UDC 612.017.2 + 612.2 + 612.766.1:796

Olena Lysenko¹, Tomasz Tomiak²

¹ National University of Physical Education and Sport, Kiev, Ukraine,
² Gdansk Academy of Physical Education and Sport, Gdansk, Poland

Abstract. The purpose of the study was to determine differences in the fast kinetics of O₂ consumption, CO₂ 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 T₅₀, «breath-by-breath» method). Sensitivity to CVS hypercapnia was determined by the «return» breathing method. Results. It was revealed that the fast kinetics of VO₂ and Vₑ, when performing work of average aerobic power at VO₂ 53.5 % of VO₂max was higher in sprinters as compared to long-distance runners. For «critical» power at VO₂ 93.4 % of VO₂max the characteristics of reaction kinetics were higher in long-distance runners. The findings suggest an association between differences in CVS sensitivity to CO₂ in sprinters, middle and long distance runners, and differences in the kinetics of fast reactions of CVS in athletes. Conclusions. The findings indicate the differences in CVS sensitivity to CO₂ 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 VCO₂ 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 O₂, виділення CO₂, 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 T₅₀, метод «breath-by-breath»). Чутливість до гіперкапнії КРС визначали методом «зворотнього» дихання. Результати. Виявлено, що швидка кінетика VO₂ і Vₑ під час виконання роботи середньої аеробної потужності при VO₂ 53,5 % від VO₂max була вищою у спринтерів порівняно з бігунами на довгі дистанції. Для роботи «критичної» потужності при VO₂ 93,4 % від VO₂max характеристики кінетики реакцій були вищі у бігунів на довгі дистанції. Отримані дані свідчать про наявність взаємозв’язку між відмінностями в чутливості КРС до CO₂ у спринтерів, у бігунів на середні та довгі дистанції, і відмінностями швидкої кінетики реакції КРС у спортсменів. Значення AP_CO₂/ΔVₑ було достовірно вищим у спринтерів порівняно з бігунами на довгі і середні дистанції. Висновки. Отримані дані свідчать про відмінності в чутливості КРС до CO₂ у спринтерів, у бігунів на середні та довгі дистанції, а також відмінності швидкої кінетики реакції КРС у спортсменів, відмінності у ступені залучення анаеробного метаболізму і кінетики VCO₂.
Останинє було пов’язано з дихальною компенсацією метаболічного ацидозу, що й забезпечувало найбільш виражені відмінності між бігунами на діагові та середні дістанції, а також спринтерами.

**Keywords:** sportsmen, sportive specialization, reactivity, cardiopulmonary system.

**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-anerobic 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 O2 uptake, CO2 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 ± 1.1 kg), 800 m running (n = 15; 75.1 ± 1.2 kg) and 5000 m running (n = 16; 70.6 ± 0.9 kg) were examined. The next exercise tests have been performed on treadmill: incremental (10–14 min), work an average aerobic power at VO2 53.5 % of VO2max (12 min) and work of «critical» power at VO2 93.4 % of VO2max (5 min). Peak responses and fast kinetics (half-period – T50, «breath-by-breathe» method, transition from 6 km·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 400x») and heart rate (Polar Electro Inc.) to maximum and standard physical loads were continually obtained. Treadmill LE2000CE («Jager», Germany) and «Monark824E» cycle ergometer («Monark», Sweden) was used.
The lung ventilation ($V_E$) was higher in long distance runners (22.8 ± 2.5 sec) as compared to long and middle distance runners (11.90 ± 0.76 sec). The studies have demonstrated that at incremental load the peak of $V_E$ and $VO_{2}\max$ was higher in sprinters as compared to long distance runners (11.90 ± 0.76 sec and 28.9 ± 2.1 sec, respectively; $p < 0.05$). Besides, sprinters have also been characterized by a higher peak value of $VCO_{2}/VO_{2}$ than middle and long distance athletes. The sensitivity of CRS responses to CO$_2$ was reliably higher in sprinters as compared to long and middle distance runners. According to lung ventilation level at $P_{ACO_2} = 50$ mm Hg reliable differences were

<table>
<thead>
<tr>
<th>Indices</th>
<th>Groups of athletes</th>
<th>p (t-test) &lt; 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta V_E/\Delta P_{ACO_2}$, L·min$^{-1}$·mm Hg$^{-1}$</td>
<td>short (1)</td>
<td>middle (2)</td>
</tr>
<tr>
<td>$V_E$ at 50 mm Hg, mL·kg$^{-1}$·min$^{-1}$</td>
<td>535 ± 43</td>
<td>295 ± 40</td>
</tr>
<tr>
<td>HR at 50 mm Hg, b·min$^{-1}$</td>
<td>74.4 ± 2.8</td>
<td>70.8 ± 3.2</td>
</tr>
</tbody>
</table>

Runners of different specialization differed in sensitivity of CRS responses to CO$_2$ (table 2, fig. 1).

The $\Delta V_E/\Delta P_{ACO_2}$ value was reliably higher in sprinters as compared to long and middle distance runners. According to lung ventilation level at $P_{ACO_2} = 50$ mm Hg reliable differences were

![Lung Ventilation and Heart Rate](image-url)

**Figure 1** – The lung ventilation ($V_E$, L·min$^{-1}$) and $P_{ACO_2}$ (mm Hg) relationship for increcent hypercapnia in short (100 m), middle (800 m) and long (5000 m) distance runners.

**Results and Discussion.** The studies have demonstrated that at incremental load the peak of lung ventilation ($V_E$) was higher in long distance runners as compared to sprinters (22.8 ± 2.5 sec and 1.57 ± 0.12 sec; $p < 0.05$). Blood lactate after the above load was higher in sprinters as compared to long distance runners (11.90 ± 0.76 and 8.10 ± 0.91 mmol·L$^{-1}$, respectively). Besides, sprinters have also been characterized by a higher peak value of $VCO_{2}/VO_{2}$ during recovery period (1.45 ± 0.12 and 1.18 ± 0.08, respectively; $p < 0.05$) (table 1).

![Indices Table](image-url)

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

<table>
<thead>
<tr>
<th>Indices</th>
<th>Groups of athletes</th>
<th>p (t-test) &lt; 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Power at VO_{2}\max$, W·kg$^{-1}$</td>
<td>short (1)</td>
<td>middle (2)</td>
</tr>
<tr>
<td>$V_{max}$ (peak), L·kg$^{-1}$·min$^{-1}$</td>
<td>1.57 ± 0.12</td>
<td>1.87 ± 0.12</td>
</tr>
<tr>
<td>$VO_{2}\max$, mL·kg$^{-1}$·min$^{-1}$</td>
<td>42.97 ± 3.36</td>
<td>50.11 ± 3.20</td>
</tr>
<tr>
<td>$VCO_{2}\max$, mL·kg$^{-1}$·min$^{-1}$</td>
<td>56.9 ± 3.7</td>
<td>52.0 ± 3.0</td>
</tr>
<tr>
<td>HRmax, b·min$^{-1}$</td>
<td>191.0 ± 4.5</td>
<td>186.5 ± 4.5</td>
</tr>
<tr>
<td>$V_E/VO_{2}$ at $VO_{2}\max$</td>
<td>29.97 ± 1.84</td>
<td>30.50 ± 2.43</td>
</tr>
<tr>
<td>$V_E/VCO_{2}$ at $VO_{2}\max$</td>
<td>26.92 ± 3.18</td>
<td>32.71 ± 1.36</td>
</tr>
<tr>
<td>$VCO_{2}/VO_{2}$ at $VO_{2}\max$</td>
<td>1.17 ± 0.14</td>
<td>1.07 ± 0.12</td>
</tr>
<tr>
<td>$VCO_{2}/VO_{2}$ peak at recovery</td>
<td>1.45 ± 0.12</td>
<td>1.22 ± 0.11</td>
</tr>
<tr>
<td>HLa immediately after, mmol·L$^{-1}$</td>
<td>11.90 ± 0.7</td>
<td>8.96 ± 0.86</td>
</tr>
</tbody>
</table>

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

**Figure 1** – The lung ventilation ($V_E$, L·min$^{-1}$) and $P_{ACO_2}$ (mm Hg) relationship for increcent hypercapnia in short (100 m), middle (800 m) and long (5000 m) distance runners.
| Indices | Groups of athletes | p (t-test) < 0.05 |
|---------|-------------------|-----------------
| Max level of RSA (RSA max), % | short (1) | middle (2) | long (3) |
| P<sub>CO₂</sub> at RSA max (P<sub>CO₂</sub> RSAmax), mm Hg | 49.67 ± 1.12 | 51.48 ± 1.17 | 53.81 ± 0.96 | 1–2 |
| RSA at P<sub>CO₂</sub> 50 mm Hg (RSA<sub>50</sub>), % | 12.30 ± 1.01 | 14.29 ± 0.82 | 18.73 ± 1.04 | 1–2; 2–3 |
| P<sub>CO₂</sub> max onset decrease of RSA, mm Hg | 49.91 ± 0.98 | 53.04 ± 1.08 | 56.18 ± 1.18 | 1–2; 2–3 |

observed between long and middle distance runners. In middle distance runners individual differences in Т₉₀₋₅₀ and VCO₂ 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 increments 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 CO₂ - drive. P<sub>CO₂</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 (VCO₂/VO₂) after progressively increased load was related to VO₂ sensitivity to CO₂ (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 CO₂ 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 VCO₂ 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 VO₂, VCO₂ 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 VO₂ max higher response kinetics has been noted in long and short distance athletes.

References

Спортивна медицина і фізична реабілітація, № 2, 2016

23


lysenkoolena9@gmail.com

Надійшла 26.07.2016