Pharmacological Reports 67 (2015) 719–727

Contents lists available at ScienceDirect

Pharmacological Reports

journal homepage: www.elsevier.com/locate/pharep

Review article

Coronary and muscle blood flow during physical exercise in humans; heterogenic alliance

Jerzy A. Zoladz [a,*], Joanna Majerczak [a], Krzysztof Duda [a], Stefan Chlopicki [b,c]

[a] Department of Muscle Physiology, Chair of Physiology and Biochemistry, Faculty of Rehabilitation, University School of Physical Education, Kraków, Poland
[b] Jagiellonian Center for Experimental Therapeutics (JCET), Jagiellonian University, Kraków, Poland
[c] Department of Experimental Pharmacology, Chair of Pharmacology, Jagiellonian University Medical College, Kraków, Poland

ARTICLE INFO

Article history:
Received 18 February 2015
Received in revised form 8 May 2015
Accepted 2 June 2015
Available online 15 June 2015

Keywords:
Coronary blood flow
Exercise
Muscle blood flow
Muscle oxygen uptake
Myocardial oxygen uptake

ABSTRACT

In this review, we present the relation between power generation capabilities and pulmonary oxygen uptake during incremental cycling exercise in humans and the effect of exercise intensity on the oxygen cost of work. We also discuss the importance of oxygen delivery to the working muscles as a factor determining maximal oxygen uptake in humans. Subsequently, we outline the importance of coronary blood flow, myocardial oxygen uptake and myocardial metabolic stability for exercise tolerance. Finally, we describe mechanisms of endothelium-dependent regulation of coronary and skeletal muscle blood flow, dysregulation of which may impair exercise capacity and increase the cardiovascular risk of exercise.

© 2015 Institute of Pharmacology, Polish Academy of Sciences. Published by Elsevier Sp. z o.o. All rights reserved.

Contents

Abbreviations: ADP, adenosine diphosphate; ATP, adenosine triphosphate; CO, carbon monoxide; COX, cyclooxygenase; EDHF, endothelium-derived hyperpolarizing factors; eNOS, endothelial nitric oxide synthase; FMD, flow-mediated dilatation; K_{IR}, inwardly rectifying potassium channel; LT, lactate threshold; MET, metabolic equivalent; NADH, reduced nicotinamide adenine dinucleotide; Na^+/K^+-ATPase, sodium-potassium adenosine triphosphatase; NO, nitric oxide; NO_2^-, nitrite; NO_3^-, nitrate; NOS, nitric oxide synthase; PCr, phosphocreatine; PGI_2, prostacyclin; P_i, inorganic phosphate; PO, power output; ROS, reactive oxygen species; TRPV4, transient receptor potential channel 4; $\dot{V}O_2$, oxygen uptake; $\dot{V}O_{2max}$, maximal oxygen uptake.

* Corresponding author.
E-mail address: jerzy.zoladz@awf.krakow.pl (J.A. Zoladz).

http://dx.doi.org/10.1016/j.pharep.2015.06.002
1734-1140/© 2015 Institute of Pharmacology, Polish Academy of Sciences. Published by Elsevier Sp. z o.o. All rights reserved.

Introduction

In physiological conditions, muscle energy homeostasis during exercise of moderate intensity is well preserved [1]. This is due to simultaneous resynthesis of ATP at the rate of its utilization via three main energy pathways: creatine kinase reaction, anaerobic glycolysis and oxidative phosphorylation, with the majority of the resynthesis of ATP supplied by oxidative phosphorylation [2]. Strenuous physical exercise, however, leads to disturbances in muscle metabolic stability and to fatigue [3–5]. In the case of sustained physical exercise, oxidative phosphorylation plays a key role in cardiac and skeletal muscle energy homeostasis [see *e.g.* 6,7]. The rate of oxidative phosphorylation depends on oxygen delivery, which is regulated by blood flow. Here, we review determinants of $\dot{V}O_{2max}$ and the importance and mechanisms of endothelium-dependent regulation of coronary and skeletal muscle blood flow during exercise. In particular, we examine whether coronary or skeletal muscle blood flow increase is a major determinant limiting $\dot{V}O_{2max}$.

Pulmonary $\dot{V}O_2$

The rate of oxidative phosphorylation at rest and during whole body exercise in humans can be well expressed by the measurement of pulmonary oxygen uptake ($\dot{V}O_2$). At rest, pulmonary $\dot{V}O_2$ in humans amounts to about 250 and 200 mL min^{-1} in men and women, respectively (*i.e.* about 3.6 mL O_2 kg body $mass^{-1}$ min^{-1}), also called MET (being defined as a multiple of the resting metabolic rate) [8]. Increased exercise intensity enhances pulmonary oxygen uptake, which during moderate-intensity cycling exercise increases linearly with power output at the rate of about 10 ml O_2 per W ("gain") [5,9–12]. Therefore, an increase in power output in this exercise domain by 50 W requires an increase of $\dot{V}O_2$ by ~500 mL O_2 min^{-1}. Exercise of higher intensities (above the lactate threshold [LT]) requires about 20% more oxygen uptake per W of generated power output than below the LT [5,9–12]. Accordingly, an increase in power output above the LT by 50 W requires an increase of $\dot{V}O_2$ by ~600 mL O_2 min^{-1}. This additional oxygen uptake is known in literature as "$\dot{V}O_2$ excess", and it generates another challenge to the cardio-pulmonary system by decreasing the magnitude of power output to be reached at maximal oxygen uptake (see Fig. 1). In other words, the presence of the "$\dot{V}O_2$ excess" above the LT decreases the power output reached at $\dot{V}O_{2max}$ by about 20% in relation to the expected power output, based on the linear relationship between the $\dot{V}O_2$ and power output below the LT (see Fig. 1). The reason for the observed decreases in muscle efficiency occurring above the LT are not fully understood, but there is a growing body of evidence that they are related to disturbances in muscle metabolic stability [4] and muscle fatigue [for a review, see 5]. Indeed, recent studies in this area provide strong evidence that muscle fatigue might play an important role in the origin of an increase of the oxygen cost of work, as shown both in an isolated *in situ* dog muscle preparation [4], as well as in human studies [13]. Therefore, maintaining the highest possible power output at the LT and high muscle metabolic stability during exercise [5,14,15] constitutes a strategy for preserving high mechanical efficiency and exercise tolerance in humans. Preserving a high mechanical efficiency of work seems to be especially important in cases of patients suffering from cardio-pulmonary insufficiency as well as in aged people where the maximal oxygen uptake ($\dot{V}O_{2max}$) is much lower than in young, healthy individuals (for an overview, see below). The low power output at the lactate threshold occurring in untrained subjects and in elderly people could also be at least partly related to the endothelial dysfunction which could limit oxygen delivery to the working muscles. Inadequate O_2 availability could affect muscle metabolite concentrations, including an increase in ADP_{free} and P_i, as well as a decrease in PCr [16,17] and an increase in metabolic acidosis at lower power outputs. Interestingly, training-induced increase in exercise tolerance in cardiac patients was accompanied by an improvement of their endothelial function [18,19].

Maximal pulmonary $\dot{V}O_2$ in humans

The maximal pulmonary oxygen uptake ($\dot{V}O_{2max}$), which is considered an index of cardio-pulmonary capacity in humans [for an overview of $\dot{V}O_{2max}$ see *e.g.* 8,20], varies among subjects from ~10 mL kg body $mass^{-1}$ min^{-1} in the case of elderly people [21] to more than 80 mL kg body $mass^{-1}$ min^{-1} in the case of some elite endurance athletes [22,23]. The lowest $\dot{V}O_{2max}$ allowing for

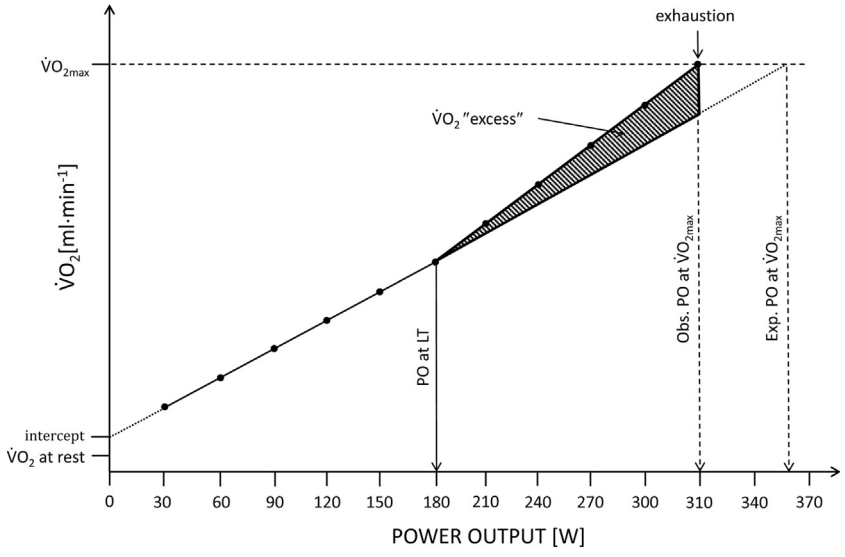

Fig. 1. Oxygen uptake–power output relationship during incremental cycling exercise in humans. A schematic presentation of the relationship between oxygen uptake ($\dot{V}O_2$) and power output during the incremental exercise test in humans (an increase of power output by 30 W every 3 min) – based on data from Zoladz et al. [9]. See also [5,10–12]. Note the difference in the slope in $\dot{V}O_2$ – the power output relationship below and above the PO at the LT (the power output at the lactate threshold), resulting in about 20% difference between the power output observed at the $\dot{V}O_{2max}$ (Obs. PO at $\dot{V}O_{2max}$) and the power output expected at $\dot{V}O_{2max}$ (Exp. PO at $\dot{V}O_{2max}$).

Download English Version:

https://daneshyari.com/en/article/2011791

Download Persian Version:

https://daneshyari.com/article/2011791

Daneshyari.com