Available online at www.sciencedirect.com
ScienceDirect
Respiratory Physiology & Neurobiology 157 (2007) 348–359
RESPIRATORY PHYSIOLOGY & NEUROBIOLOGY
www.elsevier.com/locate/resphysiol

Insufficient ventilation as a cause of impaired pulmonary gas exchange during submaximal exercise

H.-C. Holmberg [a,b,*], José A.L. Calbet [c,d]

[a] Department of Physiology and Pharmacology, Karolinska Institutet, Stockholm, Sweden
[b] Department of Health Sciences, Mid Sweden University, Östersund, Sweden
[c] The Copenhagen Muscle Research Centre, Rigshospitalet, Copenhagen, Denmark
[d] Department of Physical Education, University of Las Palmas de Gran Canaria, Spain

Accepted 20 December 2006

Abstract

Pulmonary ventilation and gas exchange were determined during prolonged skiing (∼76% of $\dot{V}_{O_2,max}$; cardiac output = 26–27 L min^{-1}) using diagonal technique (DIA) for 40 min followed by 10 min of double poling (DPOL) and 10 min of leg skiing (LEG). Exercise caused ∼2–5% reduction of arterial oxygen saturation (Sa_{O_2}). For a given cardiac output and $\dot{V}_{O_2}$, DPOL presented higher $\dot{V}_E$, lower Pa_{CO_2} and a more efficient pulmonary gas exchange, revealed by higher PA_{O_2} and Pa_{O_2} and lower A–aD_{O_2}. The A–aD_{O_2} widened 2 mmHg L^{-1} of cardiac output increase. However, for a given cardiac output and $\dot{V}_{O_2}$, exercise mode had an important influence on pulmonary ventilation and gas exchange. Highly trained cross-country skiers' present about 2 units reduction in Sa_{O_2} from resting values during submaximal exercise at 76% of $\dot{V}_{O_2,max}$. Half of the reduction in saturation is accounted for by the rightward-shift of the oxygen dissociation curve of the haemoglobin. The exercise duration has almost no repercussion on pulmonary gas exchange in these athletes, with the small effect on Sa_{O_2} associated to the increase in body core temperature.
© 2007 Elsevier B.V. All rights reserved.

Keywords: Desaturation; Elite; Fatigue; Lung; Performance

1. Introduction

About 50 years ago Holmgren and Linderholm (1958) showed that the Pa_{O_2} and the O_2 saturation of haemoglobin (Sa_{O_2}) is reduced during exercise in endurance-trained individuals, a phenomenon called exercise-induced arterial hypoxemia (EIAH) (Dempsey and Wagner, 1999). In an earlier study where pulse-oximetry was used on elite cross-country skiers, we found that the majority of them desaturated at maximal exercise (Holmberg et al., 2006). However, the magnitude of the desaturation was mild and much less than previously reported in rowing (Nielsen, 2003). Since metabolic acidosis may worsen pulmonary gas exchange by increasing pulmonary artery pressure (Loeppky et al., 1992), one explanatory factor could be a lesser drop in pH during cross-country skiing than during rowing (Nielsen, 1999; van Hall et al., 2003). Pulse oximetry data suggest that during skiing exercise with the double poling technique (predominantly upper body exercise) the degree of desaturation is lower than during either running or skiing with the diagonal technique (Holmberg et al., 2006). Thus, these findings indicate that the exercise mode may influence the ventilatory response and the pulmonary gas exchange. In fact, EIAH has been reported to be more common during running than during cycling (Hopkins et al., 2000; Rice et al., 2000). However, Laursen et al. (2005) reported a similar reduction in Sa_{O_2} during cycling and running in triathletes.

A critical factor to compare pulmonary gas exchange during different exercise modes is to match the exercise conditions for cardiac output and $\dot{V}_{O_2}$. Previously, only Hopkins et al. (2000) have compared the ventilatory and pulmonary gas exchange response to running and cycling in the same subjects accounting for the effects of cardiac output, which has been suggested to be a contributing factor in EIAH (Hopkins et al., 1996). However, the influence of a high involvement of arm muscles in pulmonary gas exchange during whole body exercise has not yet been specifically addressed.

Cross-country skiers have a very high maximal oxygen uptake and have equally trained upper and lower body muscles

* Corresponding author at: Åstrand Laboratory of Work Physiology, Department of Physiology and Pharmacology, Karolinska Institutet, Box 5626, S-114 86 Stockholm, Sweden. Tel.: +46 70 3799040; fax: +46 8 4026818.
E-mail address: hc.holmberg@sok.se (H.-C. Holmberg).

1569-9048/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.resp.2006.12.013

(Saltin, 1997). Thus, they are able to perform submaximal exercise at a rather high metabolic rate and with cardiac output levels similar or higher than achieved by untrained humans at maximal exercise. Moreover, they are skilled in combining arms and leg exercise while skiing, and in addition they can ski at high intensities with either the upper body or the legs (Saltin, 1997), as well. Thus, a comprehensive study of cross-country skiers performing the various cross-country skiing techniques could shed some new light on the causes of EIAH.

The main hypothesis in the present study was that, for a given cardiac output, Sa_{O_2} and the efficiency of pulmonary gas exchange will be lower for exercise modes eliciting a higher degree of acidosis and blood lactate concentration (Loeppky et al., 1992). The rational for this hypothesis is mainly based on a study by Rasmussen et al. (1991) showing a negative relationship between capillary blood lactate and arterial saturation, and a positive relationship between pH and saturation during arm cranking, running and rowing, exercise modes that elicited rather different $\dot{V}_{O_2}$. However, in this study arterial Pa_{O_2} was higher in the condition that produced the highest desaturation (Rasmussen et al., 1991). Another hypothesis to be tested was if pulmonary ventilation and gas exchange are affected by the exercise modality during cross-country skiing at the same $\dot{V}_{O_2}$ and cardiac output.

Therefore, the purpose of this study was first to determine if for a given cardiac output and $\dot{V}_{O_2}$ the degree of exercise-induced impairment of pulmonary gas exchange is mainly determined by the exercise mode and the level of ventilation achieved. Another aim was to quantify to what extent exercise-induced reduction of Sa_{O_2} can be ascribed to imperfect pulmonary gas exchange or to a rightward-shift of the oxygen dissociation curve of the haemoglobin.

2. Methods

2.1. Subjects

Six Swedish elite cross-country skiers (mean ± S.E.: age 24 ± 2 years, height 180 ± 3 cm and body mass 74 ± 2 kg) volunteered and gave written consent to participate in this study, which was carried out according to the Declaration of Helsinki, and approved by the Ethical Committee of the Karolinska Institute, Stockholm, Sweden. The subjects had a maximal oxygen uptake ($\dot{V}_{O_2,max}$) of 5.1 ± 0.3 L min^{-1} (range 4.8–6.2 L min^{-1}) corresponding to 72 ± 2 mL kg^{-1} min^{-1} (range 64–75 mL kg^{-1} min^{-1}), assessed during an incremental test to exhaustion 1 week before the experimental day. The incremental exercise test was performed using the diagonal stride technique while skiing uphill with roller skis (PRO-SKI C2, Nyhammar, Sweden) on a modified treadmill (Refox, Falun, Sweden). All subjects frequently used roller-skis as a part of their normal training and were familiar with using them for training and testing on the treadmill. The participants were all informed about the possible risks and discomfort involved before given their written consent to participate in the study. All six skiers performed the submaximal exercises and three of them also finished the maximal effort. In the planning of an experiment as complex as this one, the feasibility of including a maximal effort after the submaximal exercises was questionable. The concerns were related to the safety of the skiers and whether it would be possible to obtain blood samples and perform proper measurements over such a long period of time. The experience from the first experiments was very positive. The subjects handled the submaximal exercise well and the planned measurements could be made in an adequate manner. In this light, the maximal exercise using the diagonal technique was added to the protocol and the last three subjects successfully managed to handle both the submaximal and the maximal parts of the experiment. The two groups of three subjects were similar in regard to body size and aerobic exercise capacity (72.9 mL kg^{-1} min^{-1} versus 72.0 mL kg^{-1} min^{-1}). Moreover, their pulmonary gas exchange responses to the submaximal exercise were very close (Fig. 1D–F).

2.2. Exercise protocol

The protocol consisted of 40 min of continuous diagonal stride technique (DIA, combined upper and lower body exercise), followed by 10 min of double poling (DPOL, predominantly upper body exercise), 10 min of diagonal and 10 min of leg skiing (LEG, predominantly lower body exercise). Then, the speed of the treadmill was reduced and the subjects had 3 min of active recovery, while skiing with the diagonal technique at 30–40% of $\dot{V}_{O_2,max}$, before the maximal exercise test was performed. The maximal test started with 2 min of diagonal stride technique at ∼75% of $\dot{V}_{O_2,max}$. Thereafter, the speed and inclination of the treadmill were elevated every minute to increase the oxygen demand by ∼0.25 L min^{-1} until exhaustion, which occurred after 6–8 min. The first 40 min of diagonal exercise were used to study the influence of prolonged submaximal exercise on pulmonary gas exchange in cross-country skiing at an intensity commonly used in training. Following the double poling we included again a 10 min bout with the diagonal stride technique to rule out a carry-over effect, i.e. to have the same kind of exercise preceding the next technique that was leg skiing. Since the values obtained in the second diagonal stride bout were comparable to those obtained during the first 40 min of diagonal stride, this bout of exercise is omitted. This combination of different submaximal exercise modes ending with an incremental exercise test allow to reproduce in the laboratory an exercise session close to that usually performed by these athletes during training and competition.

2.3. Experimental preparation

The present study is part of a larger study and the methods used are described in detail elsewhere (van Hall et al., 2003; Calbet et al., 2004, 2005). This study is focusing on the pulmonary gas exchange effects which we have not been addressed in the previous papers (van Hall et al., 2003; Calbet et al., 2004, 2005). Here follows a summary of the relevant parts for the present study. One catheter (18-G Hydrocath, Ohmeda, Wiltshire, UK) was inserted using the Seldinger technique into the right femoral artery. Another catheter was inserted in the left

Download English Version:

https://daneshyari.com/en/article/2848344

Download Persian Version:

https://daneshyari.com/article/2848344

Daneshyari.com