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Assessment of the acute impact of normobaric hypoxia as a part of an intermittent hypoxic training on heart rate variability

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ABSTRACT

Aim: To assess the dynamics of the autonomic nervous system (ANS) by means of heart rate variability (HRV) during and after acute exposure to normobaric hypoxia, representing a single session of an intermittent hypoxic training protocol.

Material and methods: Twenty four healthy males aged 28.0 ± 7.2 (mean ± SD) breathed hypoxic air (FIO2 = 12.3 ± 1.5%) for one hour delivered via hypoxicator (AltiPro 8850 Summit+, Altitude Tech, Canada). Pulse oximetry and HRV were measured before, during and after the hypoxic exposure.

Results: At the end of the hypoxic session all of the tested subjects had higher low frequency (lnLF) (6.9 ± 1.1 ms^2 vs. 7.5 ± 1.1 ms^2; $p = 0.042$), LF/HF (1.5 ± 0.8 vs. 3.3 ± 2.8; $p = 0.007$) and standard deviation 2 of the Poincaré plot (SD2) (92.8 ± 140.0 ms vs. 120.2 ± 54.2 ms; $p = 0.005$) as well as increase in the Total power (7.7 ± 1.1 ms^2 vs. 8.1 ± 1.2 ms^2; $p = 0.032$) and the Standard deviation of normal-to-normal interbeat intervals (SDNN) (57.3 ± 31.0 ms vs. 72.3 ± 41.1 ms; $p = 0.024$) but lower Sample entropy (SampEn) (1.6 ± 0.2 vs. 1.4 ± 0.2; $p = 0.010$). Immediately after the hypoxic exposure LF/HF lowered (3.3 ± 2.8 vs. 2.2 ± 1.8; $p = 0.001$) but lnHF significantly increased (6.6 ± 1.4 ms^2 vs. 7.1 ± 1.3 ms^2; $p = 0.020$).

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Conclusion: Acute normobaric hypoxia as a part of a single session of an intermittent hypoxic training protocol leads to changes in the activity of the ANS. The sympathetic tone prevails during hypoxic exposure and parasympathetic tone increases immediately after the hypoxic factor is withdrawn.

Introduction

Intermittent hypoxic training (IHT) has become a very popular method nowadays, enhancing exercise performance, working ability or as a pre-acclimatization alpine technique [1]. It refers to the discontinuous use of normobaric or hypobaric hypoxia, in an attempt to reproduce some of the key features of altitude acclimatization [2]. Prolonged hypoxic exposure for one to several hours a day as a part of the intermittent hypoxic training leads to a number of adaptations in the physiological systems that transport and utilize oxygen [3]. Most of the initial adaptations are related to alterations in the activity of the autonomic nervous system (ANS), such as acceleration of heart rate (HR) almost immediately after hypoxic stimulation [4,5]. Heart rate variability (HRV) is the variation in the beat-to beat intervals and is commonly used to evaluate the autonomic modulation of the heart, especially sympathetic/parasympathetic interaction.

HRV has been used in the assessment of initial adaptations to hypoxic exposure at high altitude [6–9]. Acute exposure to high altitude has been shown to lead to a decrease in Total power (TP) and standard deviation of normal-to-normal inter-beat intervals (SDNN) that indicates a reduction in the overall HRV associated with an increase in LF/HF ratio, suggesting sympathetic predominance [10–13]. However, in most of the studies in humans, the effect of hypobaric, high altitude hypoxia has been evaluated which is not the case with IHT which is accomplished by means of normobaric hypoxia. Additionally, at high altitude the influence of various ambient factors such as temperature, humidity, sensory stimulation and radiation should be taken into account [14]. Furthermore, there are no studies regarding the ANS immediately after the hypoxic exposure. This article presents our pilot study in this field.

Aim

To assess the dynamics of ANS by means of heart rate variability during and after acute exposure to normobaric hypoxia, representing a single session of intermittent hypoxic training protocol.

Material and methods

Twenty four healthy non-smoker males aged 28.0 ± 7.2 (mean ± SD) were included in the study. The subjects received all the relevant information about the study, regarding aim, protocol, included tests. A signed informed consent was received from all the subjects prior to inclusion in the study and a questionnaire about their physical status was filled in. During the experiment and the preceding day, the participants did not take any medications, drink coffee or alcohol. A physical examination, including an electrocardiogram (ECG) reviewed by a cardiologist to exclude cardiovascular abnormalities or any rhythm or conductive disorders was carried out. No side effects or complaints were reported during the protocol.

The subjects were situated in supine position in a comfortable bed, placed in a quiet, well aerated room with constant light and ambient temperature and absence of any distracting factors. They were instructed to keep calm without excessive voluntary movement or speaking.

During the first 10 min of the visit the participants breathed ambient air, i.e. at altitude of 130 m (Plovdiv, Bulgaria). Subsequently, air with an oxygen concentration of 12.3 ± 1.5% corresponding to altitude of 4200 m was administered for one hour via full-facemask, using a hypoxicator (AltiPro 8850 Summit+, Altitude Tech, Canada). This protocol did not include any change in the barometric pressure (normobaric hypoxia). After the end of the hypoxic session the mask was removed and the subject breathed ambient air for 10 min.

Four-channel ECG (H3+, Mortara Instruments, Milwaukee, USA), pulse oximetry (CMS50F, Contec Medical Systems, Qinhuangdao, China) were recorded during the whole protocol. Blood pressure was manually measured on every 10 min (Boso, Bosch and Sohn, Germany).

ECG recordings were reviewed, R–R intervals were extracted automatically by H-Scribe 5 software (Mortara Instruments, Milwaukee, USA). Five-minute samples were selected from the end of the pre-hypoxic period; the beginning of hypoxia the end of hypoxia and immediately after the hypoxic exposure for the subsequent analysis. After removing trends, data were analyzed using Kubios HRV software [15] by which both time and frequency domain parameters were calculated. Prior to the spectral estimation by Fast Fourier Transform, beat-to-beat RR time series were transformed to evenly sampled time series using a cubic spline interpolation.

The following parameters were derived from the RR data: Total Power (TP) and SDNN as measures of overall autonomic regulation; absolute and normalized (nu) powers of high frequency (HF; 0.15–0.40 Hz) and low frequency (LF; 0.04–0.15 Hz) spectral components, respectively reflecting parasympathetic nervous system (PNS) activity and combined sympathetic (SNS) and PNS activities. The ratio LF/HF was also calculated as an index of sympatho-vagal balance. Root mean square of successive RR interval difference (RMSSD) is a time domain parameter associated with the parasympathetic activity [16]. In addition to linear methods described above, three commonly used nonlinear parameters were computed.