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Development of a Real-Time Evaluation System for Exercise Effectiveness and Safety in Normobaric Hypoxic Environments: A Preliminary Study

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***Abstract*—The effectiveness of exercise can be optimized using a normobaric hypoxic environment. However, the safety and effectiveness of exercise in such an environment have rarely been investigated in nonathlete subjects. In this study, we clarify the safety of normobaric hypoxic exercise and evaluate useful measurement indices for a real-time monitoring system. The results of this study suggest that the proposed system is capable of real-time monitoring of hypoxic load during normobaric hypoxic exercise and may contribute to achieving safe exercise.**

I. INTRODUCTION

For people with low physical fitness and those suffering from obesity, exercising under hypoxic conditions is more effective than under normal oxygen, even with a lower exercise load [1][2]. In addition, the risk of headache and dizziness under normobaric normoxia is lower than that experienced at high altitudes. However, for nonathletes, the safety and ideal exercise load in such conditions are still unclear. Therefore, developing a system that determines the exercise load and hypoxic stress, by measuring biological indices in real-time, may contribute to ensuring safety in exercising in a hypoxic environment and clarify the appropriate atmospheric oxygen concentration for individuals. Accordingly, this study aims to develop a system for real-time monitoring of physiological indices during hypoxic exercise and evaluate the validity of the measured values to monitor hypoxic load and safety.

II. METHODS & RESULT

40 healthy nonathletes between the ages of 20 and 59 participated in the experiment. Subjects whose measurement data contained a lot of noise were excluded, and thus the number of analyzed subjects was 24. All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Clinical Research Ethics Committee of Kumamoto University Hospital.

The exercise was performed according to the procedure shown in Fig. 1. The electrocardiogram (ECG) in standard lead II from chest electrodes (BS-3400, Nihon Kohden) and arterial oxygen saturation (SpO_2) from an ear clip sensor (MLT332, AD Instruments) were simultaneously collected by a digitizer (PowerLab 8/35, ADInstruments) at 1-kHz sampling frequency, while the exercise heart rate (HR) was continuously calculated from the ECG. Further, blood pressure was measured seven times at the points indicated by the blue arrows in Fig. 1. The measurement data of the last minute of Epoch 4 were used for statistical tests.

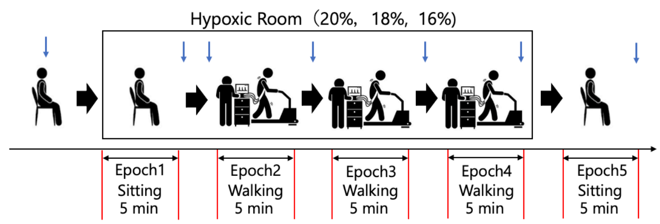

Figure 1. Experimental Procedure

The results of one-way ANOVA showed no significant difference in the HR between each oxygen concentration ($P > 0.05$). As in previous studies, the results indicated that ageing and resting HR can be used to properly assess the exercise load tailored to an individual, even in a hypoxic environment [3]. The results of Steel-Dwass test in the age group of 20–39 years showed a significant difference in SpO2 both between 20% and 16% and between 18% and 16% oxygen concentrations ($P < 0.05$). This result suggested that using a normobaric hypoxic environment with an oxygen concentration of 16% is sufficient for those in the 20–39 age group. The results of Tukey's HSD test in the 40– 59 age group showed no significant difference in the oxygen concentrations of 20% and 18% ($P > 0.05$); however, the results of Student's t-test showed that SpO_2 values at 20% oxygen were significantly lower than those in the 20–39 age group. Therefore, from the viewpoint of safety, the use of a normobaric hypoxic environment with an oxygen concentration of 18% is considered sufficient for the 40 – 59 age group.

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