



Original Article

# The relationship between changes in deoxy Hb and body composition before and after cycling exercise during unilateral lower extremity occlusion

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**Abstract.** [Purpose] To clarify the relationship between changes in deoxygenated hemoglobin level due to cycling exercise and body composition in healthy participants with unilateral lower-limb obstruction. [Participants and Methods] The height, weight, body mass index, and body composition (skeletal muscle mass, body water content, and body fat percentage) of nine healthy males were measured along with the anaerobic threshold. The protocol consisted of 7 minutes of rest followed by 4 minutes of cycling exercise (anaerobic threshold level) with unilateral lower extremity occlusion. After exercise, ischemia was released, and the participants was allowed rest for 5 minutes. Deoxygenated hemoglobin levels before and after the exercise and the relationship between the level of variation and each index were examined. [Results] Body water content and skeletal muscle mass showed a significant negative correlation with changes in deoxygenated hemoglobin level; however, no correlation was found for the other indices. Body water content and skeletal muscle mass were found to be significantly positively correlated. they showed a significant positive correlation with deoxygenated hemoglobin levels. [Conclusion] Our study indicates that body water content and skeletal muscle mass play a significant role in the recovery of blood flow following exercise.

**Key words:** Cycling exercise, Deoxy Hb, Body composition

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## INTRODUCTION

Primary symptoms of arteriosclerosis obliterans (ASO or peripheral arterial/artery disease [PAD]) are diverse, including pain, pallor, paresthesia, and motor palsy. The diagnosis of ASO has been made in a variety of ways including tests such as limb blood pressure measurements and angiography<sup>1)</sup>. Moreover near-infrared spectroscopy (NIRS) is one of the useful methods for physical therapists. With this method, muscular oxygenation of the motor limb has been found as a factor affecting the symptoms of intermittent claudication in vascular diseases<sup>2)</sup>. It was also proved by this method that blood fluidity of the motor limb is the cause of intermittent claudication. In addition, various blood flow biomarkers, such as hematocrit and plasma viscosity, are known to determine blood flow. For human beings exercise induces hemoconcentration by transferring intravascular water to the interstitial space due to thermoregulation and metabolic regulation during exercise<sup>3)</sup>. In other words, fluid management during exercise was an important method to predict the symptom of intermittent claudication in blood vessel. Conversely, ASO is strongly associated with atherosclerosis because of the presence of risk factors associated

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with lifestyle-related diseases, such as aging, obesity, and diabetes<sup>4</sup>). Vascular endothelial damage may be the starting point for impaired blood flow, which may lead to more severe symptoms. Arterial stiffness has been reported to be related to body composition such as body fat, body mass index and skeletal muscle mass<sup>5</sup>). As a result, the body composition changes of the patient should be understood in order to implement exercise therapy. Therefore, if the relationship between changes in kinetic muscular oxygenation and body composition including water content can be clarified, that might be a useful and effective therapeutic method to alleviate symptoms of intermittent claudication. To obtain basic knowledge on the possibility of alleviating symptoms, this study employed a method of the shut off of lower limb blood flow during an cycling exercise in healthy participants. A previous study<sup>2</sup>) reported that deoxygenated hemoglobin (deoxy Hb), an indicator of muscular oxygenation dynamics, increased with exercise in patients with vascular disease and deviated from the baseline in deoxy Hb. In other words, according to symptoms of intermittent claudication decrease after exercise, the difference in the mean value (amount of change) of deoxy Hb at rest in intermittent claudication between before and after exercise is defined as the ability to recover blood flow. Therefore, this study aimed to clarify the relationship between the amount of deoxy Hb changes in body composition before and after exercise and to investigate the effects at the same time.

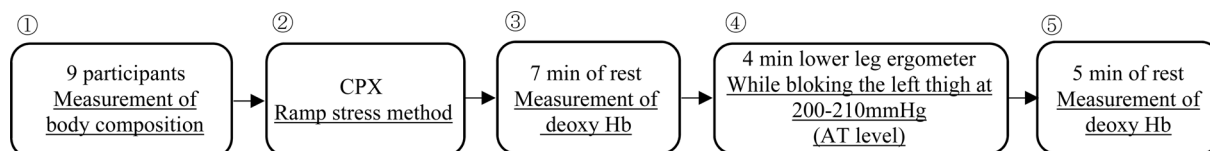
## PARTICIPANTS AND METHODS

Nine healthy males were included in this study. Participants were fully explained on the research, and their signatures were obtained in a consent form with an understanding of the research purpose. Participants performed a cardiopulmonary exercise test (CPX) using the exhaled gas analyzer AE-300S (AE-300S, Minato Medical Sciences) and recorded the anaerobic threshold (AT) using the ramp stress method proposed by Whipp BJ et al<sup>6</sup>). Next, the protocol consisted of 7 minutes of rest and cycling was performed at 50–60 rpm for 4 minutes at 200–210 mmHg in the left thigh using a blood tourniquet. After the end of the cycling, the patient was allowed to rest for 5 minutes, and then deoxy Hb was measured using NIRS (Omega Wave BOM-L1TRW) and the deoxy Hb obtained were averaged over 5 minutes (Fig. 1). The averaged values were expressed as the difference between pre- and post-exercise, which was defined as the amount of change ( $\Delta$ deoxy Hb). The probe was placed on the medial side of the gastrocnemius muscle, where blood flow tends to stagnate due to the vein anatomy<sup>7</sup>), and the measurement depth was set to 2–4 cm. Body composition was determined by measuring the skeletal muscle mass, body water content, and body fat percentage using a body composition analyzer (Inbody: Inbody 270).

IBM® SPSS® Statistics 19 was used for statistical analysis. The Shapiro-Wilk test was used for each index, and the normality test was performed. Partial correlation analysis was performed for the relationship between changes in deoxy Hb and each index (skeletal muscle mass, body water content, body fat percentage, and BMI), using age as a control variable. Means  $\pm$  standard deviation and  $p < 0.05$  were set as significant. This study was conducted with the approval of the ethics committee of the University of Seirei Christopher (approval No. 14066) (Table 1).

## RESULTS

The results of partial correlation analysis between  $\Delta$ deoxy Hb and skeletal muscle mass, body water content, body fat percentage, and BMI before and after cycling exercise with age as a control variable are shown below. The indices showing a significant negative correlation with  $\Delta$ deoxy Hb were body water content ( $n=9$ ,  $r=-0.82$ ,  $p < 0.05$ ) and skeletal muscle mass ( $n=9$ ,  $r=-0.77$ ,  $p < 0.05$ ). No correlation was found for the other indices. Body water content and skeletal muscle mass were found to be significantly positively correlated ( $n=9$ ,  $r=0.98$ ,  $p < 0.05$ ) (Table 2).



**Fig. 1.** Experimental protocols.  
A graphical representation of the protocols.

**Table 1.** Characteristics data for the participants

Characteristics	Age (years)	Height (m)	Weight (kg)	AT (ml/kg/min)
Value	24.4 $\pm$ 4.0	1.7 $\pm$ 0.1	62.4 $\pm$ 6.8	7.2 $\pm$ 1.1

Data are mean  $\pm$  standard deviation.

**Table 2.** Partial correlation coefficient for each indicator

Control Variables	Variables	Mean $\pm$ SD	Partial correlation coefficient			
			Skeletal muscle mass	Body water quantity	Body fat rate	BMI
Age	$\Delta$ deoxy Hb ( $10^4$ unit/mm <sup>3</sup> )	0.09 $\pm$ 2.9	-0.77*	-0.82**	0.21	-0.04
	Skeletal muscle mass (kg)	47.7 $\pm$ 4.2	-	-	-	-
	Body water quantity (kg)	37.1 $\pm$ 3.5	0.98**	-	-	-
	Body fat rate (%)	15.2 $\pm$ 3.8	-0.56	-0.47	-	-
	BMI (kg/m <sup>2</sup> )	21.4 $\pm$ 2.4	-0.15	-0.05	0.98*	-

\* $p < 0.05$ , \*\* $p < 0.01$ .

Data are mean  $\pm$  standard deviation.

Partial correlation analysis.

deoxy Hb: deoxygenated hemoglobin; BMI: body mass index.

## DISCUSSION

This study primarily aimed to clarify the relationship between deoxy Hb changes and body composition (skeletal muscle mass, body water content, body fat percentage and BMI) before and after cycling exercise in healthy participants. Results showed that body water content and skeletal muscle mass were a correlated indicator with deoxy Hb changes.

Water is a major component of the human body which accounts for approximately 60% of the body weight in adult males and 50–55% in females due to a higher body fat percentage (water content of the adipose tissue is approximately 10%) when compared with males. It would be up to 75% in newborns<sup>8</sup>). Besides, the lean body mass decreases with age, and water content is lower in females and obese individuals because of a higher fat mass percentage<sup>9</sup>). Muscle tissues have been shown to account for >40% of the body weight, and the water content in muscle is approximately 43% of the total water content<sup>10</sup>). Besides, water has varied roles, including metabolic functions, transport functions for electrolytes and metabolites, temperature control functions, structural functions of water bound to the cytoplasm to determine cell and plasma volumes and tissue reflux, and mechanical functions for joint protection such as the synovial fluid<sup>11</sup>). In this study, we found the relationship between the skeletal muscle mass and body water content was very important for the human body. In For adults, the blood weight is approximately 8% of the body weight, and the total body volume is approximately 5.0 L. The water content of the whole blood is approximately 70–80%, and plasma comprised 90% of water<sup>12</sup>). In other words, the water content played an important role in the structural function of the blood as described above. When a patient becomes dehydrated, the blood cell concentration relatively increases, and the hematocrit value is high due to decreased water content in the body. These have been reported to be strongly associated with blood viscosity<sup>13</sup>). In this study, the blood flow in healthy participants was passively limited, and deoxy Hb changes before and after exercise reflected their ability to recover the blood flow. In other words, the effects of blood viscosity likely affect the ability of blood flow to recovering, even in healthy individuals. Although skeletal muscle mass indeed declines with age, skeletal muscle mass was indirectly related to age or body water content in this study, the mean age of participants in this study was  $24.4 \pm 4$  years and the effects of aging were relatively absent. ASO is caused by risk factors for lifestyle-related diseases<sup>3</sup>). However, as for individuals with stroke and cardiovascular disease, increased blood viscosity may contribute to the disease onset because it increases the risk of thrombosis<sup>14</sup>). ASO is often associated with vascular endothelial damage, which can cause blood flow stagnation. Adequate body water content might be one of the factors that reduced the symptoms of intermittent claudication caused by stagnant blood flow.

In conclusion, effects of body water content and skeletal muscle mass in the amount of deoxy Hb changes before and after exercise were significant and it is essential to be aware of the overall water content and skeletal muscle mass during exercise, regardless of age for the treatment of intermittent claudication. Moreover, understanding body water content and skeletal muscle mass in exercise prescriptions can lead to symptom relief and improved exercise capacity, and interventions such as tracking changes in mealtime, fluid intake, and muscular blood flow over time for these can lead to improved exercise capacity.

Future perspectives are needed to increase the number of participants and clarify the degree of influence of factors affecting deoxy Hb.

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### Conflict of interest

None.

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