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Changes in Cerebral Hemodynamics and Hematological Aspects Following Scuba Diving at 5 Meters of Seawater

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The present study was designed to clarify whether scuba diving at 5 meters of seawater influences cerebral hemodynamics, hematological and biochemical variables. Twenty healthy young men well trained scuba diving participated in this study. The blood flow velocity in the right and left middle cerebral arteries (L-MCAV and R-MCAV), blood pressure (BP), heart rate (HR), CBC and differential count, prothrombin time (PT), activated partial thromboplastin time (aPTT), biochemical variables, D-dimer and interleukin-8 (IL-8) levels were determined before, immediately after scuba diving for 30 min, and after 30 min of rest (Pre-scuba, Scuba and R-30m, respectively). L-MCAV and R-MCAV tended to increase, but the only significant increase was in L-MCAV in Scuba. SBP and HR significantly declined in R-30m compared with those of Pre-scuba and the Scuba. IL-8 levels were elevated in Scuba and R-30m compared with that of Pre-scuba. In Scuba and R-30m, hematological variables except PT and biochemical parameters excluding glucose and lactic acid did not significantly changed in comparison with those of Pre-scuba. PT level at Scuba and glucose level at R-30m significantly declined in Scuba, while lactate level at R-30m increased compared with each in Pre-scuba. However, PT level at Scuba was within a normal range. These results suggest that scuba diving at 5 m of seawater for 30 min has no adverse effects, is safe and useful for improving health. However, further study must be performed to clarify the mechanism of elevated IL-8 level following scuba diving.

Key Words: Scuba Diving, Cerebral Hemodynamics, Hematology, Biochemistry, Interleukin-8

INTRODUCTION

Science the development of self-contained underwater breathing apparatus (scuba) by Emile Gagnon and Jacques Cousteau in 1943, diving with scuba (scuba diving) has become a popular leisure-sport worldwide and its popularity is still increasing. The increase in travel to more distant resorts, often resorts where a combination of clear warm water and colourful marine life make the entry into the subaquatic world enticing, has led to many of qualified divers travelling abroad to dive. Within Korea there are an estimated 480 thousands active recreational divers, and within the USA perhaps as many as 8.5 million people (House et al., 2001). Although those who do not practice this sport consider it a high-risk activity, the danger generated by scuba diving is very low (with a mortality rate of 0.4/1,000 participants) compared with other sports such as hang gliding and skydiving (Szasz and Cooper, 1982). However,

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scuba diving has potential risks. Diving accidents are mostly described as acute events related to decompression or barotraumatism. Numerous studies have reported decompression illness (DCI). It is well known that diving causes DCI. The term DCI encompasses both decompression sickness (DCS), which is generated by tissue bubble formation attributable to inert gas supersaturation, and arterial gas embolism. Nevertheless, most of the studies have focused on the DCI, and thus the effects of scuba diving on the cerebral hemodynamics, hematology, cardiac, biochemical and immunological variables are poorly understood.

The present study was designed to investigate the influences of scuba diving in a shallow seawater (5 meters) on the cerebral hemodynamics and cardiac, hematological, biochemical and immunological variables in young men.

MATERIALS AND METHODS

1. Study population

The subjects included in this study were healthy young men with about 19.05 months of scuba diving experience (Table 1). We explained the aim of the study and interviewed them for any medication, disease history and so forth. The criteria of exception in the study were subjects with cardiovascular, hematological, immunological, liver, or renal disorders. They were practiced for 10 days until this study is performed.

Table 1. Demographic characteristics of study population

Characteristics	Values
Total case number	20
Gender ratio (male : female)	20 : 0
Age (years)	21.95±0.43
Weight (kg)	62.85±3.19
Height (cm)	175.50±0.96
Body mass index	22.78±0.44
Scuba career (month)	19.0 5±5.30

Data are expressed as mean ± standard error (SE)

2. Methods

1) Study protocol

For all subjects, systolic and diastolic blood pressure (SBP and DBP, respectively), heart pressure (HR), blood flow velocity in the right and left middle cerebral arteries (R-MCV and L-MCV, respectively), ear temperature and blood collection were taken at the rest (Pre-scuba). They put on the scuba diving equipment including oxygen tank and practiced at 5 m of seawater for 30 min. Under the sea, they undertook light walking. Immediately after scuba diving (Scuba) and 30 min of recovery (R-30 m), above mentioned procedures were carried out.

2) Variable and analysis

On the three sampling periods (Pre-CPB, Scuba and R-30 m), other parameters except free radical were analyzed. R-MCV and L-MCV were detected by transcranial Doppler sonography (TCD) (ReMed Co., Israel) with a 2-MHz pulse Doppler prove. The sampling position and measurement depth (range, 50 to 55 mm) were applied on the temporal region at which maximal value with minimal noise was obtained. SBP, DBP, HR and RPP (heart rate-systolic blood pressure production were determined by autoanalyzer (Green-Cross Co., Korea). CBC and diff-count were measured with 2 ml of blood using coulter cell count (Coulter LH750, Backman Coulter, USA). 4 ml of blood with 3.8% sod-citrate was used for measuring prothrombin time (PT) and activated partial thromboplastin time (aPTT). For PT and aPTT, appropriate kit, Thromborel S and Dade actin (Dade Behring, Germany), and instrument, Sysmex CA-1500 (Germany), were used. Biochemical factors in serum were measured by Autohumalyzer 900S (Human Lab, Germany). Plasma with 3.8% sod-citrate was analyzed by Immunoterbidmetric method with Hisens D-dimer reagent (HBI Co., Ltd, Korea) and Hitachi 7600 (Hitach Co., Japan) for detecting D-dimer. Serum level in interleukin-8 (IL-8) was determined by microplate reader (in 405 nm) with commercial ELISA immunoassay kit (Quantikine immunoassay human IL-8, R&D system, USA).

3) Statistical analysis

Data are presented as mean ± SE (standard error). All parameters were statistically analyzed by ANOVA with Scheffe test (SAS program). Statistical significance was accepted with $P \leq 0.05$.

Table 2. Aspects in cerebral hemodynamics following scuba diving

Period \ Variable	P-MCAV (cm/s)	M-MCAV (cm/s)	D-MCAV (cm/s)	PI (cm/s)	RI (cm/s)
Pre-scuba					
R-MCA	99.00±5.60	71.89±4.23	45.44±2.96	0.75±0.02	0.54±0.01
L-MCA	96.42±5.60	68.79±3.96	42.58±2.67	0.77±0.03	0.55±0.02
Scuba					
R-MCA	103.39±7.51	74.22±5.54	46.17±3.76	0.77±0.03	0.55±0.02
L-MCA	110.17±6.13*	79.83±4.03*	50.28±2.29	0.73±0.03	0.53±0.02
R-30 m					
R-MCA	106.44±5.73	77.00±4.21	47.94±2.63	0.75±0.03	0.04±0.01
L-MCA	101.17±5.46	73.11±3.91	45.83±2.59	0.75±0.03	0.54±0.01

Data are expressed as mean ± SE

*, $P<0.01$ (compared with Pre-scuba or R-30 m)

Abbreviations: Scuba, immediately after scuba diving; R-30 m, 30 min of recovery after scuba diving; R-MCA, right middle cerebral artery; L-MCA, left middle cerebral artery; P-MCAV, peak blood flow velocity in MCA; M-MCAV, mean blood flow velocity in MCA; D-MCAV, blood flow velocity in MCA; PI, pulsatility index; RI, resistance index

Table 3. Changes in cardiac factors following scuba diving

Period \ Variable	SBP (mmHg)	DBP (mmHg)	HR (beat/min)	RPP
Pre-scuba	127.60±2.00	68.45±1.82	63.53±2.89	8,105.96±112.46
Scuba	125.95±2.03	64.50±3.14	66.56±2.93	8,382.73±112.83
R-30 m	119.60±2.51*	64.40±1.85	59.50±2.73*	7,116.20±130.38*

Data are expressed as mean ± SE

*, $P<0.01$ (compared with Pre-scuba or Scuba)

Abbreviations: SBP, systemic blood pressure; DBP, diastolic blood pressure; HR, heart rate; RPP, heart rate-systolic blood pressure production

RESULTS AND DISCUSSION

1. Cerebral hemodynamics

As shown in Table 2, Peak, mean and diastolic R-MCV and L-MCV were elevated in Scuba compared with each of the Pre-scuba, but statistically significant only in L-MCV (P=0.014, P=0.003 and P=0.018, respectively). This increase emerges due to the exercise effect of scuba diving, suggesting that cerebral hemodynamics is normally maintained at 5 m of seawater. PI and RI in right and left cerebral arteries were not changed during and after scuba diving, indicating that scuba diving in shallow sea did not adversely affect cerebral hemodynamics in young men. Slosman et al. (2004) described change in cerebral blood flow (CBF) following scuba diving, which divers in a cold lake showed a significant reduction in global CBF compared with divers in a warm sea. Their results indicate that frequent scuba diving at deep sea leads to negative neurofunctional effects. There was different protocol between our and their study. We performed the experiment at 5 m of seawater with a 24℃ of temperature, whereas they carried out the test in a cold lake and under 40 m of warm sea.

2. Cardiac factor

Table 3 shows changes in cardiac factors following scuba diving. Temperature significantly decreased in Scuba compared to Pre-scuba or R-30 m (P=0.000). SBP (P=0.003 and P=0.03), HR (P=0.005 and P=0.012) and RPP (heart rate-systolic blood pressure production) (P=0.02 and P= 0.012) on R-30 m were significantly lower than those on Pre-scuba or Scuba. However, DBP in Scuba and R-30 m did not significantly change when compared with that of Pre-scuba. These data imply that scuba diving at 5 m of sea and do not give load may have a positive effect on the cardiovascular system. On one hand, a study by Boussuges et al. (2006), which was performed at about 35 m of sea water for 25 min, suggested that scuba diving causes microbubble formation in the right heart chamber, decreases in left atrial and left ventricular diameter, decreased HR, and

Table 4. Changes in hematological aspects following scuba diving

Variable \ Period	Pre-scuba	Scuba	R-30 m
T-WBC ($\times 10^3/\mu l$)	6.77±0.31	7.17±0.42	7.29±0.35
Neutrophil (%)	74.97±1.51	76.34±1.32	78.24±1.33
Lymphocyte (%)	18.34±1.15	17.59±0.90	15.14±0.99
Monocyte (%)	2.70±0.31	2.86±0.27	3.45±0.40
RBC ($\times 10^6/\mu l$)	5.09±0.07	5.07±0.07	5.07±0.08
Platelet ($\times 10^3/\mu l$)	248.00±10.99	255.05±11.28	229.31±10.31
Hematocrit (%)	48.38±0.43	48.02±0.41	47.64±0.47
Hemoglobin (g/dl)	15.46±0.18	15.46±0.16	15.47±0.17
PT (sec)	12.90±0.18	11.92±0.12*	12.95±0.21
aPTT (sec)	33.19±0.90	33.00±0.70	32.48±0.78
D-dimer ($\mu g/ml$)	0.37±0.03	0.37±0.04	0.31±0.02

Data are expressed as mean ± SE
*, $P<0.01$ (compared with Pre-scuba or R-30 m)
Abbreviations: T-WBC, total white blood cell; RBC, red blood cell; PT, prothrombin time; aPTT, activated partial thromboplastin time

Table 5. Changes in biochemical variables following scuba diving

Variable \ Period	Pre-scuba	Scuba	R-30 m
GOT (U/L)	24.80±1.66	29.45±2.20	24.60±1.61
GPT (U/L)	24.00±3.39	24.304±3.33	23.05±3.28
Glucose (g/dl)	86.25±2.47	83.45±1.44	74.85±1.89*
BUN (mg/dl)	14.48±0.64	13.88±0.60	13.59±0.58
Creatinine (mg/dl)	1.03±0.02	0.98±0.03	0.96±0.02
Cholesterol (mg/dl)	162.45±5.05	176.30±7.46	174.05±9.96
Triglyceride (mg/dl)	78.20±8.30	74.75±8.18	74.20±8.55
CPK (U/L)	340.65±93.61	352.90±92.20	343.10±92.98
Lactate (mmol/L)	1.35±0.13	2.10±0.16†	1.23±0.07

Data are expressed as mean ± SE
*, $P<0.01$ (compared with Pre-scuba or Scuba)
†, $P<0.01$ (compared with Pre-scuba or R-30 m)
Abbreviations: GOT, glutamic oxaloacetic transaminase; GPT, glutamic pyruvic transaminase; BUN, blood urea nitrogen; CPK, creatine phosphate kinase

stroke volume and unchanged SBP/DBP. These few discrepancies between the two studies may be attributable to different test protocol and/or condition.

3. Hematological parameters

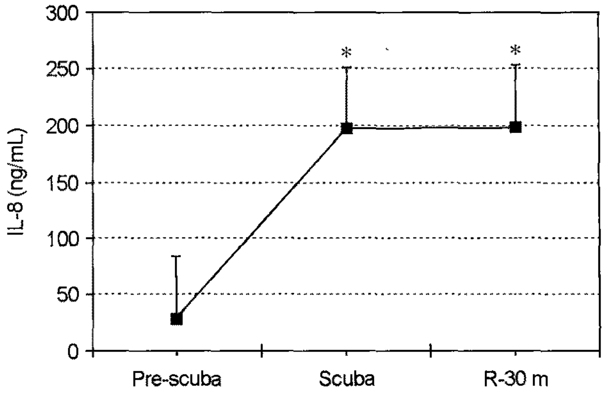

Fig. 1. Changes in serum interleukin-8 (IL-8) following scuba diving. IL-8 levels were elevated in the Scuba and R-30 m compared with that in the Pre-scuba (*, $P<0.05$). Scuba, immediately after scuba diving; R-30 m, 30 min of recovery after scuba diving.

All parameters were not significantly changed by scuba diving (Table 4). These findings suggest that scuba diving protocol at 5 m of seawater do not give rise to harmful influence on the hematological aspects. The PT level, which represents activation of extrinsic coagulation system, fell during scuba (11.92±0.12, $P=0.002$) and recovered to Pre-scuba level (12.90±0.18) 30 min after the end of scuba. aPTT and D-dimer levels did not change (Table 5). These results imply that our scuba diving protocol does not adversely affect coagulation and fibrinolytic system because PT level at Scuba was within a normal range.

4. Biochemical marker

The lactate level in venous blood was significantly elevated during scuba diving ($P=0.001$ and $P=0.001$, respectively) and recovered to Pre-scuba level 30 min of rest after the end of scuba diving. The glucose concentration in R-30 m was lower than those in Pre-scuba and Scuba ($P=0.002$ and $P=0.026$, respectively) (Table 5). Our observation is supported by a previous report in which Lormeau et al. (2005) demonstrated that scuba diving attenuates blood glucose level. These findings indicate that scuba diving in shallow seawater may improve health with exercise and calorie consumption.

5. Interleukin-8

Serum levels in IL-8 raised in the Scuba (195.65±39.09 pg/ml, $P=0.014$) and reached their peak in the R-30 m (197.15±45.11, $P=0.013$) (Fig. 1). IL-8 is a cytokine with 69~79 amino acid and is released by various cells such as neutrophils, endothelium, astrocytes and microglia (Yamasaki et al., 1997; Ehrlich et al., 1998; Croitoru-Lamoury, 2003). We report for the first time an increased IL-8 level following scuba diving, but can not explain the mechanism for such elevation. Several studies of traumatic brain injury (TBI) have reported that IL-8 is considered to be one of the crucial cytokines associated with the pathophysiology of TBI (Matsumoto et al., 1997; Zhang et al., 1999; Gopcevic et al., 2007). However, no all subjects complained any headache. Thus, the mechanism for elevation in IL-8 level following scuba diving and its physiological effect should be investigated in the future.

In conclusion, the scuba diving at 5 meters of seawater for 30 min has no adverse effects, is safe and useful for improving health. However, further study must be performed to clarify the mechanism of elevated IL-8 level following scuba diving.

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