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□RESERCH MATERIALS□

Breathing and buoyancy regulation and autonomic nervous activity during diving in recreational divers with different experiences

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【Abstract】
This study examined changes in the respiratory rate, depth, and autonomic nervous activity during swims of five divers with different experiences (instructor and novice) to investigate measures for reducing accidents and challenges during recreational diving. The results revealed that the instructors could consciously control their breathing and had less depth variation during submerging. However, novices revealed greater depth variation during submerging, and some of them could not take slow and deep breaths as recommended by regulator breathing. The autonomic nervous activity of divers, except for one instructor, resulted in a slight increase in sympathetic activity and suppression of parasympathetic activity in underwater conditions requiring to regulate more neutral buoyancy than that at rest.

Key Words: SCUBA diving, Recreational diving, Respiratory control, Buoyancy adjustment, Autonomic nervous activity.

I. Introduction

Self-contained underwater breathing apparatus (SCUBA) diving is an underwater activity performed while breathing in water using SCUBA. Based on the attendance certification of private education organizations, SCUBA divers are classified as nationally licensed divers and recreational divers[1,2]. Recreational diving can be experienced in Japan and abroad under a diving instructor's supervision, regardless of their age or physical fitness, as long as the diver is in good health. Furthermore, divers who have completed a scuba diving certification course are awarded a certification card (C-card) and are eligible to dive for fun (FUN diving services)[3]. The knowledge and diving skills acquired by divers in the certification course are the minimum requirements for enjoying recreational diving safely.

SCUBA diving is performed underwater in a hyperbaric environment, involves more risks than activities on land, and can lead directly to death[1,2,4]. Regarding diving accidents in Japan, the years of diving experience of accident victims were as follows: no previous experience (27%), <1 year (15%), and >10 years (29%). Furthermore, the proportion of accidents was higher in middle-aged and older people than in other populations[5,6]. Shibayama (2011) investigated the frequency of diving disabilities among experienced divers aged over 15 years and reported that 2% of them experienced decompression sickness, regardless of age, even when the dive computer carrying rate was ≥90%[7]. The primary causes of diving accidents are self-negligence due to a lack of diving skills and inattention to health conditions. In FUN diving, the reasons for accidents are as follows: (1) inability of some participants to control their buoyancy, (2) inability of some participants to recover the regulator that has come off their mouths, (3) poor physical condition of some participants, (4) forceful participation in diving despite being aware of the dangerous sea conditions, and (5) diving without having the ability to set up their equipment. This knowledge and diving skills should be acquired in the certification course. Diving skills are essential for air consumption during ocean SCUBA diving[8]. Body size affects air consumption, but air consumption by inexperienced beginners may occur due to a combination of factors, such as insufficient skills in breathing control and buoyancy adjustment (neutral buoyancy), underwater environmental conditions, and psychological effects due to divers' age and experience[3,6,8].

Furthermore, it is helpful to acquire diving skills and basic knowledge of diving physiology, which are covered in certification courses, to prevent accidents during recreational diving. Respiratory movement is closely related to autonomic nervous activity, although it can be consciously regulated. During diving, breathing must be consciously regulated by taking slow and deep breaths. Sasaki et al.[9] examined changes in cardiovascular physiological indices while diving due to different breathing methods. They reported the possibility of suppressing blood pressure elevation during diving by taking deeper breaths than normal to relax. The sympathetic and parasympathetic nerves are antagonistically involved in respiratory regulation, with the sympathetic nerves predominating during inhalation and parasympathetic

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nerves predominating during exhalation. Additionally, it is well known that deep breathing affects autonomic nervous activity[10,11]. The relationship between autonomic nervous activity and emotions, such as anxiety and tension, has also been clarified[12-14]. Chouchou et al.[15] reported that diving increases parasympathetic activity and suppresses sympathetic activity. However, Schipke and Pelzerm[16] used heart rate variability (HRV) to assess autonomic nervous activity during pool diving and found that head out immersion into the pool increased sympathetic and parasympathetic activities, whereas whole body submersion and SCUBA diving increased parasympathetic activity. Nevertheless, novices are often found to be nervous during SCUBA diving. Hence, a better understanding of respiration and autonomic nervous activities involved in respiratory control might prevent diving accidents.

This study aimed to perform preliminary experiments with divers having different experiences (instructor and novice) to better understand the relationships among breathing control, buoyancy adjustment, and autonomic nervous activity during diving. In addition, it provided directions for future research that could contribute to preventing accidents during recreational diving and improving certification course programs.

II. Materials and Method

1. Participants

This study included five healthy people (one man and four woman) with no illnesses who were certified with recreational diving C-cards (Table 1).

Table 1. Characteristics of participants

Characteristics	Participants				
	A	B	C	D	E
Gender	Male	Female	Female	Female	Female
Age	49	36	22	21	20
Height（cm）	167	164	151	162	152
Weight（kg）	69	53	56	58	50
SCUBA Diving Level	instructor	instructor	O/W	O/W	O/W
Diving experience (years)	20 over	15	3	2	2
Number of tanks (bottles)	5000 over	5000 over	10	7	7

Participants A and B were instructors with >15 years of experience, whereas participants C, D, and E were open-water divers with <3 years of experience. The SCUBA diving level was specified on each participant's license card. The years of diving experience and number of tanks were collected from each participant's logbook. The years of diving experience (number of tanks) was ≥15 years (5000) for participants A and B, whereas those for participants C, D, and E were 3 (10), 2 (7), and 2 years (7), respectively. After obtaining approval from the ethical review of Kansai University (approval number 2021-17), the participants received a verbal explanation of the study; subsequently, written informed consent was obtained from the participants.

2. Procedure

Participants were instructed to pay attention to the effects of body position, exercise, diet, sleep, time of day, smoking, and other factors regarding autonomic nervous activity and take thorough care of their physical condition 1 week before the experiment. On the day of the experiment, measurements were recorded in a dedicated indoor diving pool with stable environmental conditions. The pool's maximum depth was 5 m, and the vertical and horizontal distances were 10 and 5 m, respectively. The room and water temperatures were kept constant at 27°C. The measurement period was the same for all five participants (10:00–12:00). Hydration was prohibited for 30 min before the measurement. Additionally, participants were instructed to urinate before the measurement. Each participant wore a wetsuit over a swimsuit.

Measurements were recorded under the following six conditions in the particular order (Figure 1):

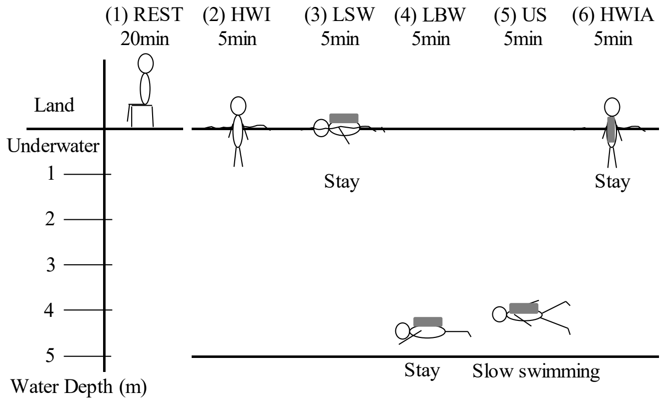

Figure.1 Experimental Protocol

(1) Sitting and resting for 20 min (REST)
(2) Maintaining a standing position with the water surface reaching the heart level for 5 min (head out water immersion [HWI])
(3) Attaching SCUBA equipment and floating horizontally on the water surface for 5 min (lying surface water [LSW])
(4) Diving to the bottom of the water and maintaining a horizontal position for 5 min (lying bottom water [LBW])
(5) Maintaining neutral buoyancy at a constant and swimming as slowly as possible at a depth of 3–4 m for 5 min (underwater swimming [US])
(6) Maintaining a standing position with the water surface reaching the heart level with equipment attached for 5 min (HWI with apparatus [HWIA]).

Participants could easily move to the next step. Respiratory measurements were performed via natural respiration under REST, HWI, HWIA, and regulator breathing (RB). Respiratory measurements were also performed using SCUBA under LSW, LBW, and US while being aware of each participant's respiratory rhythm and skill.

3. Measurement item

The measurement items were respiratory rate, water depth, and the time interval between adjacent normal R waves in the ECG (RR interval). Spontaneous expiration and inhalation were recorded for determining respiratory rate on land (REST, HWI, and HWIA) using a thermistor attached to the nostrils.

Exhalations expelled as bubbles were counted for the RB in the water (LSW, LBW, and US). The respiratory rate was calculated every minute for each condition. Diving depth variations were continuously monitored using a dive computer (AIR DIVER, D202-Q00117, CITIZEN, Tokyo, Japan). Electrocardiograms were obtained using a Holter electrocardiograph (Cardio Memory, RAC-3103, NIHON KOHDEN, Tokyo, Japan) via the chest bipolar induction method. The electrocardiograph was fitted with a custom-made (manufactured by DIV Co., Ltd) pressure-resistant housing for waterproofing.

4. Data processing

Respiratory rate, RR interval, and heart rate calculated from the RR interval were determined as number of times per min, and the mean and standard deviation (SD) were calculated for the last 3 min under resting condition and for 5 min under other conditions. Depth data obtained via the dive computer was transferred to PC via the communication unit (COMMUNICATION UNIT, CMUT-01, CITIZEN, Tokyo, Japan) using a USB cable (HYPER AQUALAND USB CABLE, 400-0270, CITIZEN, Tokyo, Japan). The water depths under US conditions were determined every 5 s and were averaged every minute. HRV analysis was conducted using the time series data of RR intervals to evaluate autonomic function. This study used time (time-domain method) and frequency (frequency-domain method) domain analyses, which can be performed noninvasively and are recommended for use by the Special Technical Committees of the European and American Heart Associations[17,18].

In the time-domain analysis, RR50 and %RR50 were calculated from the RR interval data. RR50 indicates the number of occurrences of RR intervals per unit time (60 s in this study), where the absolute value of the difference between two consecutive RR intervals exceeds 50 ms. %RR50 indicates the percentage of RR50 divided by the total RR interval within a specific period; it was first established by Ewing et al.[19]. %RR50 is an index that mostly reflects parasympathetic function and is suitable for capturing variations in short-term regulatory function (s to min)[20,21]. In this measurement, %RR50 was calculated every minute and was averaged over the last 3 min under REST and over 5 min under other conditions.

Frequency-domain analysis was performed to corroborate the time-domain analysis using the dedicated software (MemCalc/Tonam software, GMS, Tokyo, Japan) and spectral analysis using the maximum entropy method. Analysis was performed based on 5-min RR interval data for each condition with a frequency resolution of 1/3–0.5 Hz. Among the spectral components, 0.04–0.15 Hz were separated and quantified as the low-frequency (LF) component and 0.15–0.4 Hz as the high-frequency (HF) component. The HF spectral power value was calculated as an index of parasympathetic activity, whereas LF/ (HF + LF) was calculated as an index of sympathetic activity per minute[18,22]. Among the calculated data, the 1-min average value from 2 min before the end of each condition was used as the representative value.

5. Statistics

The respiratory rate, heart rate, %RR50, and LF/ (HF + LF) were calculated for each condition relative to the REST. To examine the variability in heart rate for each condition or among participants, the coefficient of variation (CV) was calculated using the mean heart rate and SD for 3 min under REST and 5 min under other conditions. CV was calculated using the average depth and SD for 5 min to compare variability in depth among participants under US condition. A scatter plots was constructed to examine the association of depth variation as a measure of diving skill with respiratory rate and autonomic nervous activity under US condition.

III. Results

1. Respiratory rate

The respiratory rates of instructors A and B and novices D and E were lower under LSW, LBW, and US conditions during RB than under REST and HWI conditions. However, the respiratory rate of novice C was higher under all other conditions than under REST. Only novice D and the instructors could breathe slowly and deeply with the regulator in the mouth. The respiratory rates of instructors A and B and novice D under US condition were 30%–60% of those on REST, whereas novice E showed 80% of respiratory rates on REST, and novice C had higher respiratory rates under US condition than on REST (Table 2).

Table 2. Respiratory rate of participants in each condition

Condition	Participants				
	A	B	C	D	E
REST	18.3 (1.00)	13.3 (1.00)	14 (1.00)	12.3 (1.00)	13.7 (1.00)
HWI	18.8 (1.03)	13.8 (1.04)	15.2 (1.09)	11.8 (0.96)	13.8 (1.01)
LSW	6.0 (0.33)	9.2 (0.69)	16.2 (1.16)	5.0 (0.41)	11.4 (0.82)
LBW	3.4 (0.19)	7.4 (0.56)	15.4 (1.10)	4.4 (0.36)	11.4 (0.83)
US	6.0 (0.33)	7.8 (0.59)	15 (1.07)	5.2 (0.42)	11.4 (0.83)
HWIA	18.0 (0.98)	13.7 (1.03)	15.3 (1.09)	12.0 (0.98)	13.7 (1.00)

The values in parentheses show relative to the REST condition.
The unit is breaths/min.

2. Water depth variation (buoyancy adjustment)

Table 3 shows the mean depth and SD per min and for 5 min as well as CV of depth (maintained constant) for 5 min under US condition. The mean and SD of 5-min depths for instructors A and B and novices C, D, and E were 2.9 ± 0.2, 3.4 ± 0.2, 2.5 ± 0.3, 2.9 ± 0.5, and 3.6 ± 0.3 m, respectively. Depth variation (CV) calculated from the mean and SD of 5 min depths was smaller for instructors than for novices.

Table 3. Mean depth and SD per min and for 5 min and CV for 5 min in US condition

Time	Participants				
	A	B	C	D	E
1min.	3.2 ± 0.1	3.4 ± 0.3	2.5 ± 0.3	3.1 ± 0.8	3.7 ± 0.3
2min.	3.0 ± 0.2	3.5 ± 0.2	2.8 ± 0.2	3.3 ± 0.2	3.7 ± 0.1
3min.	2.9 ± 0.2	3.5 ± 0.1	2.6 ± 0.2	2.9 ± 0.5	3.5 ± 0.4
4min.	3.0 ± 0.4	3.4 ± 0.1	2.4 ± 0.2	3.2 ± 0.4	3.4 ± 0.7
5min.	2.4 ± 0.3	3.2 ± 0.1	2.2 ± 0.9	2.2 ± 0.5	3.9 ± 0.2
5 minute avg.	2.9 ± 0.2	3.4 ± 0.2	2.5 ± 0.3	2.9 ± 0.5	3.6 ± 0.3
5 minute CV	0.079	0.048	0.138	0.166	0.085

The unit of depth is meters

3. RR interval

In a previous study, the reference value (REST) of the participants' RR interval in this study was close to its normal value according to age [18,19]. The heart rate calculated from the RR interval, in most participants, showed a decrease under LSW and LBW conditions compared with that under REST and HWI conditions. Heart rate under US condition was higher than that at REST and under other conditions in all participants, and the CV of heart rate was greater in novices than in instructors (Table 4).

Table 4. Mean heart rate and CV for participants in each condition

Condition	Participants A		B		C		D		E	
	Heart rate	CV	Heart rate	CV	Heart rate	CV	Heart rate	CV	Heart rate	CV
REST	68.3 (1.00)	0.019	65.7 (1.00)	0.032	63.8 (1.00)	0.034	66.5 (1.00)	0.026	90.0 (1.00)	0.071
HWI	69.0 (1.01)	0.012	60.8 (0.93)	0.063	55.8 (0.87)	0.141	58.8 (0.88)	0.020	77.6 (0.86)	0.022
LSW	66.1 (0.97)	0.039	65.5 (1.00)	0.047	62.8 (0.98)	0.045	57.6 (0.87)	0.062	83.7 (0.93)	0.043
LBW	67.9 (0.99)	0.049	70.3 (1.07)	0.057	57.6 (0.90)	0.041	51.8 (0.78)	0.050	75.5 (0.84)	0.030
US	73.2 (1.07)	0.026	72.0 (1.10)	0.022	74.4 (1.16)	0.098	68.4 (1.03)	0.069	97.8 (1.09)	0.038
HWIA	71.4 (1.05)	0.059	63.9 (0.97)	0.044	56.5 (0.89)	0.096	60.2 (0.91)	0.123	74.5 (0.83)	0.101

The values in parentheses show as relative to REST condition.
The unit of heart rate is beats/min.

4. Evaluation of autonomic nervous activity

When %RR50 is ≥5%, parasympathetic nerve function is enhanced[23]. In this study, %RR50 for instructor B and novices C, D, and E was >5% under all conditions. For instructor A, %RR50 was >5% under LBW, US, and HWIA conditions. Under US condition, instructor A showed the highest %RR50, whereas instructor B and novices C, D, and E showed the lowest value (Table 5).

Table 5. Mean %RR50 for 5 minutes of participants in each condition

Condition	Participants A	B	C	D	E
REST	1.5 (1.00)	14.6 (1.00)	41.0 (1.00)	35.7 (1.00)	7.7 (1.00)
HWI	0.3 (0.20)	41.8 (2.85)	59.1 (1.44)	64.6 (1.81)	37.0 (4.84)
LSW	1.5 (1.00)	39.5 (2.70)	43.7 (1.07)	37.7 (1.06)	11.4 (1.49)
LBW	9.3 (6.26)	15.5 (1.06)	61.2 (1.49)	39.0 (1.09)	22.3 (2.91)
US	20.2 (13.61)	5.0 (0.34)	9.7 (0.24)	21.3 (0.60)	6.3 (0.82)
HWIA	17.5 (11.81)	27.4 (1.87)	53.5 (1.30)	44.0 (1.23)	30.9 (4.03)

The values in parentheses show as relative to REST condition.

Table 6 shows representative values of LF/ (HF + LF) for participants in each condition. As a measure of sympathetic nervous activity, LF/ (HF + LF) was generally higher in the other four participants, except for instructor A, under LSW, LBW, and US conditions than that at REST (Table 6).

Table 6. Representative value of LF/(HF+LF) for participants in each condition

Condition	Participants A	B	C	D	E
REST	1.0 (1.00)	0.4 (1.00)	0.5 (1.00)	0.3 (1.00)	0.2 (1.00)
HWI	0.9 (0.92)	0.8 (1.81)	0.4 (0.82)	0.4 (1.27)	0.3 (1.47)
LSW	0.5 (0.53)	0.9 (2.11)	0.9 (1.68)	0.7 (1.87)	0.6 (2.74)
LBW	1.0 (1.00)	0.8 (1.99)	0.4 (0.71)	0.8 (2.29)	0.4 (1.94)
US	0.8 (0.86)	0.5 (1.10)	0.7 (1.47)	1.0 (2.81)	0.3 (1.19)
HWIA	0.8 (0.83)	0.8 (1.88)	0.7 (1.41)	0.6 (1.59)	0.6 (2.46)

The values in parentheses show as relative to REST condition.

Figure 2 shows scatter plots of the association of depth variation with respiratory rate and autonomic nervous activity under US condition. A trend toward greater sympathetic nervous activity was observed with a greater depth variation. No consistent trend was observed between depth variation and respiratory rate or between depth variation and parasympathetic nervous activity.

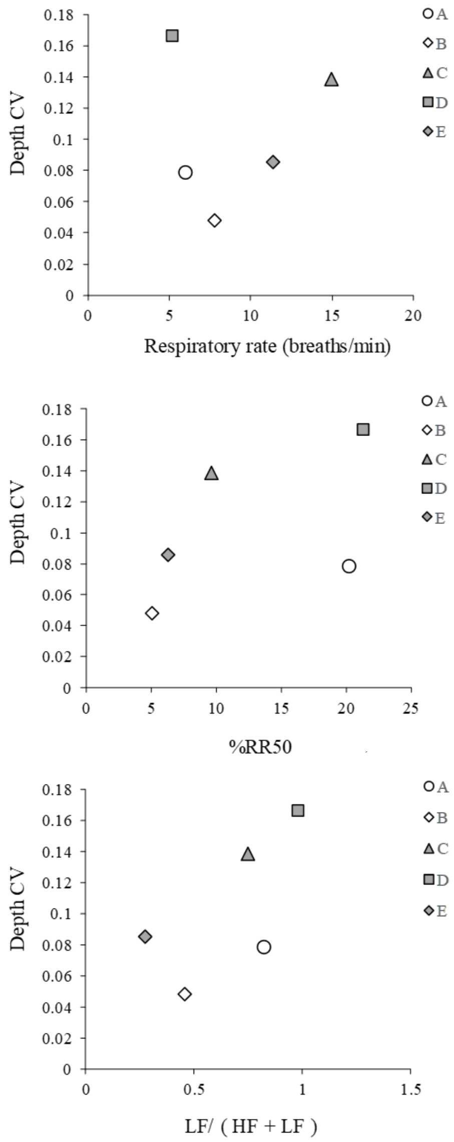

Figure 2. Scatter plots of the association of depth variation with respiratory rate and autonomic nervous activity in US condition

IV. Discussion

This study evaluated the association between diving skills and autonomic nervous system status in divers with different experiences using respiratory control, buoyancy adjustment, and autonomic nervous activity. This study hypothesized that experienced divers are more skilled and relaxed underwater, whereas novice divers are more nervous.

1. Respiratory control

The breathing resistance of the equipment affects the RB[24). Furthermore, respiratory control in the presence of increased respiratory resistance stresses the body, enhances sympathetic nerve activity, increases negative pleural pressure, promotes heart rate, and increases the venous return rate[25)]. Respiratory control creates a relaxed state and reduces anxiety[26)]. In this study, instructors A and B and novice D could perform <50% of RBs during submerging (LSW, LBW and US) than at REST, indicating that they have conscious respiratory control during diving. However, novice C showed an increase in RB during submerging compared with that at rest, and novice E only showed a decrease of approximately two breaths. Therefore, it is difficult to conclude that they have good respiratory control. The recommended breathing skill for RB is slow and deep for relaxation and safety. However, such breathing is challenging for beginners because they are not conscious regarding breathing daily. Furthermore, beginners may tend to breathe faster when extra effort is required to balance their bodies in the water, or they may take more breaths to stabilize neutral buoyancy.

2. Buoyancy adjustment (neutral buoyancy)

In recreational diving, buoyancy adjustment, the ability to swim without floating or sinking (neutral buoyancy), is a vital skill[8)]. In this study, depth while submerging varied more among novices than among instructors, indicating that diving skill influences buoyancy adjustment skills. However, novice D could control breathing intentionally, but depth variation while submerging was large, whereas novice E showed a small depth variation but a high respiratory rate. Regarding neutral buoyancy, the slow and deep breathing generally recommended for SCUBA diving results in large buoyancy changes; therefore, it is assumed that as novice D in this study, could control breathing but did not achieve stable buoyancy adjustment. The factors involved in adjusting neutral buoyancy are considered buoyancy compensator operation as buoyancy adjustment skills, balance of equipment settings including appropriate weights, and ventilation rate due to breathing control. Moreover, it is presumed that novice E attempted to increase his breathing rate (lower ventilation rate) and/or frequent buoyancy compensator operation to stabilize neutral buoyancy. Novice C probably had difficulty in achieving breathing control as well as buoyancy adjustment. Thus, the results indicate that respiratory and buoyancy adjustment skills do not necessarily correlate in novice divers. As novice divers and instructors likely use different buoyancy adjustment methods, it was also presumed that the evaluation of buoyancy adjustment skills should be examined separately for novice divers and instructors.

3. Assessment of relaxation in water

The RR interval is an index for determining the heart rate. A high RR interval value indicates a decrease in the heart rate, whereas a low value indicates an increase in the heart rate. It has been reported that water temperatures of ≥30°C increase the heart rate and cardiac output[27)]. However, the pool water temperature was 27°C in this study. Hence, it is not considered an effect of the increase in water temperature.

In this study, the CV of heart rate under US condition was greater in novice divers than in instructors and was more stable among instructors. In general, bradycardia (diving reflex) via the vagus nerve occurs in water due to the contact of water with the whole body and face. Bradycardia prolongs the vulnerable period of the ventricle. It has been reported that extrasystoles occurring during the vulnerable period can easily transform into lethal arrhythmias[28)]. In this study, a general trend was a decrease in heart rate under LSW and underwater conditions compared with resting conditions on land (REST) and in water (HWI), which was particularly clear in the three young novices. Higher variability in heart rate under US condition in younger novices compared with that in instructors suggests that the effect of aging is reflected in the variability of heart rate. Further, instructor A showed higher %RR50 under underwater conditions (LBW and US) than that under REST or standing condition on the water surface (HWI), whereas LF/ (HF + LF), a measure of sympathetic activity, showed no clear difference between the REST and underwater conditions, indicating a relaxed state in underwater activity. However, instructor B and novices C, D, and E showed the lowest %RR50 under US condition compared with the other conditions. Additionally, most of them showed increased LF/ (HF + LF) under underwater condition, including US, compared with REST and HWI. Thus, novices were more nervous underwater. Furthermore, instructor B's introspection that "it had been a long time since I had been diving" suggested that she was more nervous underwater, although not as much as the novices; the results did not fully support the hypothesis. The autonomic nervous activity during diving indicates that even instructors do not always exhibit a relaxed state.

Previous studies have reported that diving stimulates the autonomic nervous system, increasing parasympathetic activity and suppressing sympathetic nervous activity; furthermore, diving anxiety increases sympathetic activity[15,16)]. In this study, scatter plots of buoyancy adjustment skills and autonomic nervous activity during diving suggest that lower buoyancy adjustment skills tend to increase sympathetic nervous activity, although this trend was observed in a limited number of participants (n = 5). Low buoyancy adjustment skills may be a factor contributing to diving anxiety and vice versa.

Sasaki et al.[9)] reported that the relaxed state of deep breathing may be involved in suppressing blood pressure elevation during diving. Malinowski et al.[29)] indicated that the cardiac response to diving is strictly dependent on the autonomous control of resting heart rhythm. Schipke and Pelzerm[16)] suggested that if HRV is lower than normal under controlled conditions, such as sitting by the poolside, or if HRV is reduced after diving, it is assumed that there is some problem with the autonomic nervous system, which might be an indicator for evaluating the diver's physiological adequacy. This study suggests that some novice divers have difficulty with slow and deep breathing control recommended for SCUBA diving. Furthermore, despite having control over their breathing, buoyancy adjustment is not enough, and they are not always in a relaxed state. This suggests that even instructors with excellent breathing control and neutral buoyancy adjustment skills can become nervous during a dive due to various factors. From the perspective of ensuring safety while diving, instructors and guides during ocean SCUBA diving should be able to predict whether a diver is in a state of excitement (sympathetic nervous activity) based on the diver's respiratory status and depth variation, and should be very careful to ensure their safety. In addition to assessing the physical and mental conditions, knowledge and skills required for diving and the importance of monitoring the physical activity in real-time, such as measuring the heart rate during underwater activities, need to be emphasized. We believe that the data presented in this study will provide helpful information for considering safety management in recreational diving.

4. Research limits and prospects

The study limitations include the small sample size of leisure divers and a pool to measure underwater conditions. In the future, increasing the number of participants should be considered. In addition, instructors may be nervous during diving courses and ocean tours. Therefore, measuring and evaluating diving skills under conditions similar to the actual diving environment and understanding the state of nervousness before diving through subjective questionnaires would lead to improved diving instruction and safety management.

V. Conclusions

This study examined changes in the respiratory rate, depth, and autonomic nervous activity during swims of five divers with different experiences to investigate measures for reducing accidents and challenges during recreational diving. The results showed that the instructors could consciously control their breathing and had less depth variation during submerging. However, novices showed greater depth variation while submerging, and some of them could not take slow and deep breaths as recommended by RB. The results also indicate that buoyancy adjustment and breathing control skills are not necessarily correlated among novices. The autonomic nervous activity of divers, except for one instructor, resulted in a slight increase in sympathetic activity and suppression of parasympathetic activity under conditions requiring more neutral buoyancy than that at rest. It was suggested that beginners tend to become nervous underwater and even instructors do not always show a relaxed state while diving.

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□研究資料□

潜水経験の異なるレクリエーショナル・ダイバーにおける潜水中の呼吸および浮力の調整、自律神経活動

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【抄　録】
レクリエーショナル・ダイビングにおける事故やトラブルを減らす方策を検討するため、潜水経験の異なるダイバー5 名（インストラクターと経験の浅いダイバー）の潜水中の呼吸数、深度変化及び自律神経活動の変化を調べた。結果は、インストラクターでは、意識的に呼吸を調節でき、遊泳中の潜水深度の変動が小さかった。一方、経験の浅いダイバーでは、潜水深度の変動がより大きく、レギュレータ呼吸で推奨されるゆっくり大きく呼吸することが不十分な者もいた。自律神経活動は、インストラクター１名を除き、安静時よりも中性浮力を調節するスキルを要する水面下遊泳条件において、交感神経活動の若干の亢進と、副交感神経活動の抑制が示された。

キーワード：スクーバダイビング，レクリエーショナル・ダイビング，呼吸調節，浮力調整，自律神経活動.

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編集後記

第 12 巻第 1 号は、第 2 号（第 12 回学会大会号）と同時期の発行となり、学会大会に合わせた形で、皆さまに大変貴重な知見をお届けできることとなりました。

本号掲載の論文は、潜水中に生理学的データを収集したものであり、計測機器に防水処理を施したり、電極もシーリングが必要であったりと、実験系としては極めて困難なものです。実験系が困難であるがゆえに、サンプルサイズを確保することも難しく、さらに主なパラメーターのひとつである心拍変動解析により得られる自律神経系の評価は、個人間のバラツキが大きく、統計学的分析を実施しても、なかなか一定の傾向を導き出すことが難しいものです。本論文の知見は、このような数々の困難を乗り越えて得られた、大変貴重なものであると感じています。世界的に見ても、これまで同種の研究は数例しかなく、このように貴重な研究成果を本誌にご投稿頂きました著者の皆さまに敬意を表しますとともに、心から感謝申し上げます。

（松本　秀夫）

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海洋人間学雑誌　投稿規定

“海洋人間学雑誌”は日本海洋人間学会の機関誌であり、海洋における人間の健康と安全ならびに海洋スポーツ競技と海洋教育の進歩と発展に寄与することを目的とするものである。
本誌の英文名は“Japanese Journal of Maritime Activity”とし、略称は“Jpn J Marit Activity”とする。

Ⅰ．原稿の種類

1. 投稿原稿

投稿論文には以下の種類を設ける。1-①総説、1-②原著、1-③短報、1-④研究資料、1-⑤実践研究、1-⑥報告（事例、調査、視察、事業・活動等)、1-⑦その他（Letter to the Editor、学会大会抄録など)。

1-①総説：特定の研究領域に関する主要な文献内容の総覧として、その内容は、単なる羅列ではなく、特定の視点に基づく体系的なまとまりを持つことが必要となる。

1-②原著：科学論文としての内容と体裁を整えているもので、新たな科学的な知見をもたらすものである。

1-③短報：科学論文として単体で完結しており、学術的重要性が高く即時的に公表すべき最新の知見を提供しうるものである。

1-④研究資料：調査や実験の結果を主体にした研究資料であり、客観的な資料として価値が認められるものとする。

1-⑤実践研究：現場からの貴重な情報を基にした研究で、指導法に関する実用的研究や、総合的に分析した研究などが含まれる。

1-⑥事例報告：事例として、調査、視察、事業などを詳細に調査・研究し、その結果を報告する。

1-⑦その他：Letter to the Editor は本誌掲載の論文に関する質疑やコメントなどを編集委員会に寄せ、編集委員会が論文執筆者に回答を求めるものである。質疑やコメントと回答は合わせて同じ号に掲載する。質問者も回答者もすべて実名とし、また両者は相反する利益、業務に支障をきたすような利害関係がない事を条件とする。

2. 依頼原稿

学会の趣旨に関連した貴重性や有用性が高いと認められるテーマ、あるいは会員相互の連携や学会の発展に資するテーマについては編集委員会が論文執筆を依頼するものとし、以下の種類を設ける。2-①依頼総説、2-②依頼報告（事例、調査、視察、事業・活動等)、2-③教育講座、2-④その他（議事録、学会記、研究紹介、会報など)。

Ⅱ．投稿原稿および依頼原稿に関する一般規定

1. 投稿原稿と依頼原稿の共通項目

A. 原稿作成には和文（日本語）を用いることとする。他の言語を用いる場合は英語のみ可とする。

B. ヒトや実験動物を対象とした生理学的、心理学的研究など、または報告などにおいても、倫理上または個人情報上の特別な配慮が必要となる場合は、関係法令の遵守と文部科学省ならびに厚生労働省のガイドライン等をよく参照した実験遂行・原稿作成に十分留意し、大学、研究機関等における倫理審査において許可されていることが望ましく、承認の有無を本文に記述すること。また、利益相反については、適切な開示に努め記述すること。

D. 本学会誌はオンラインジャーナルであるため論文別刷りの作成は行わない。別刷り相当物が必要な場合は本学会ホームページなどのインターネット媒体より入手して頂きたい。

E. 本誌は、オンラインジャーナルであることから、1-④研究資料、1-⑤実践研究、1-⑥事例報告においては、動画の使用も認める。投稿にあたっては、編集委員会に事前に問い合わせること。

２．投稿原稿

A. 原稿は、他誌に未掲載かつ完結したもののみを受け付ける。また同時に他誌に投稿することはできない。

B. 筆頭者は本学会の会員に限るが、共著者についてはこの限りではない。入会手続きは学会事務局まで問い合わせのこと。

C. 原稿には表紙を添付すること。なお表紙には以下の内容を記載すること。原稿の種類：本投稿規定の「Ⅰ．原稿の種類」に準拠して表記する、タイトル：和文と英文で表記する。なお本学会ホームページから投稿原稿の見本がダウンロード出来るので参照のこと。

D. 本学会ホームページからダウンロードできる投稿連絡票に所定の事項を記入して原稿と一緒に送付すること。なおファイル名は以下の例を参照のこと。

　　例、投稿連絡票_海洋太郎

この投稿連絡票について、1-⑥報告、1-⑦その他（Letter to the Editor）のキーワードは不要とする。1-⑦その他（学会大会抄録）のキーワードについては大会案内号などにて別途定める。

E. 抄録は、本文とはページを変えて、和文 300 字以上 400 字以内および英文 200 語以上 300 語以内で各 1 枚ずつ添付すること。また、英文抄録はネイティブチェックを受けることが望ましい。

1-④研究資料、1-⑤実践研究、1-⑥報告、1-⑦その他（Letter to the Editor、学会大会抄録など）は、和文および英文抄録の添付は任意とする。

F. 章立ての構成、見出し等は、研究専門領域に応じて適切なものを使用するが、原則、以下の例に準拠すること

（例：「目的（※もしくは「はじめに」「緒言」)」「方法」「結果」「考察」「結論（※もしくは「結語」「まとめ」)」「引用文献」)。1-⑦その他（Letter to the Editor）は「編集委員長へ」「引用文献」とすること。ここで挙げた論文種別以外の章立てについては、専門研究領域の1-⑦その他（学会大会抄録など）は別途大会案内号などにて定めるが、原則として著者の意向どおりとする。

G. 原稿の長さは、1-①総説、1-②原著、1-④研究資料、1-⑤実践研究、1-⑥報告は、抄録（①・②のみ)、図表（縦 5 cm ×横 7 cm に縮小印刷が可能なもの１点を 400 字相当と換算する）および引用文献などを含めて刷り上がり８ページ（1200字/原稿１ページ×10枚）以内とし、1-③短報と1-⑦その他（Letter to the Editor）については同様に４ページ以内を基本原則とする。しかし、本学会誌はオンラインジャーナルであることから、事前に編集委員長に問い合わせること。また1-⑦その他（学会大会抄録）については大会案内号などにて別途定める。

H. 査読（1-⑥、1-⑦を除く）は、論文および報告の内容および体裁と必要書類の確認等を編集委員会で審査を行い、必要があれば編集委員会より筆頭者に修正を求める。査読者は、編集委員会が原稿の内容により適任者を本学会内外を問わず３名選定し依頼する。審査結果は、A: 受理（変更改訂の必要なし）B: 受理（多少修正の必要あり）C: 再投稿要請（大幅修正の必要あり、再査読）D: 掲載不可として、査読者からの指摘やコメントを、筆頭者に「査読結果通知書」として連絡する。修正要請等がある場合は通知書発信日より ２ ヶ月以内に修正した論文を提出すること。期限内に提出されなかった論文は不採択とする。査読は３名のうち２名のＡ判定で掲載可とする。1-⑥報告については原則査読を実施せず、編集委員会内での掲載審議により掲載を決定する。最終的な採否は編集委員会の審査によって決定し、その日をもって受理年月日とする。なお掲載は原則として総説、原著、短報、研究資料、実践研究、報告の順番とし、同種論文間では採択順とする。「掲載不可」の査読結果に異議がある場合、筆頭者はその反論を附して異議申し立てをすることができる。同一投稿に関する異議申し立ては１回とし、その期間は「掲載不可」の通知日より １ヶ月以内とする。異議申し立てがあった場合、編集委員会は合議のもとで、原則１ヶ月以内に異議申し立ての可否を決し筆頭者に通知する。再審査を行う場合の対象原稿は「掲載不可」確定時のものとする。この原稿に修正等を加えた場合は再審査の対象とはならず、再投稿として扱う。再審査は、新規投稿と同様な方法で行う。ただし、この原稿受付日は最初の原稿の原稿受付日とする。また、原則として最初の原稿の担当査読者を除く候補者の中から新たな査読者を選定する。

※ Letter to the Editorと学会大会抄録については、編集委員会において受理を検討し、不採択となる場合もある。

I. 投稿原稿および図表は、それぞれ別のファイルにして PDF 形式のファイルに変換し、これらを電子メールに添付して学会事務局メールアドレスに送信すること。なお、送信メールの「メール件名」および「ファイル名」はⅠ-1で示した論文種別を参照して必ず下記の例のようにすること。

　例１、メール件名　「原著投稿_海洋太郎」、「報告投稿_海洋次郎」

　例２、ファイル名　「原著投稿本文_海洋太郎」、「原著投稿図表_海洋太郎」

なお、掲載可となった原稿は、著者が学会誌用の定型フォームに割り付けを行い、編集委員会に提出すること。

J. 投稿料は、1-①総説、1-②原著、1-④研究資料、1-⑤実践研究、1-⑥報告（5 ページ以上）については 1 編あたり 10,000円とする。1-③短報、1-④研究資料、1-⑤実践研究、1-⑥報告の４ページ以内原稿については１編あたり 5,000円とする。1-⑦その他は無料とする。投稿料の支払いについては、学会事務局の郵便振込口座に振り込むこと。なお振込用紙には内訳（例：原著投稿料として）を記入すること。

３．依頼原稿

A. 他誌に未掲載の原稿であることを原則とする。

B. 筆頭者および共著者が、本学会の会員であるか否かは問わない。

C. 抄録は、2-①依頼総説、2-②依頼報告について和文もしくは英文で作成を依頼する場合もある。

D. 章立ては、Ⅱ-2-Fを参考とすること。

E. 原稿の長さは、基本的にⅡ-2-Gに準じる。

F. 原稿の郵送方法、著者校正、最終稿の提出等に関しては、依頼者へ個別に連絡する。

G. 投稿料は発生しない。

Ⅲ．原稿作成要項

1. 原稿はワードプロセッサなどによる機械仕上げのものとし、書式は下記の事項に準拠して作成すること。用紙：A4判、文字数/１頁：1200 字（40 字×30 行)、余白：上下端および左右端を広めにとること、図表位置の指定：右の余白に挿入位置を赤字で指定すること、行数：左の余白にページ毎に表示させること、ページ数：下端（フッター）中央に、表紙および和文、英文の抄録を除いた本文のみのページ数について記載すること。ランニングタイトル：上端（ヘッダー）右端に 20 文字以内で記載すること。以上、学会ホームページよりダウンロードできる投稿原稿の見本を参照のこと。

2. 日本語原稿は現代かなづかい、常用漢字とし、外国語、引用文献等の外国固有名詞はその言語を用いること。数字はアラビア数字を用いることを原則とし、単位符号はCGS単位（mm、sec、cm、ml、μgなど）を用いること。数式中の数、数値や量、統計法に用いられる記号、動物・植物の学名などはイタリック体を用い、それ以外、イタリック体は用いないこと。和文の句読点は「､」「｡」を用いること。

3. 引用については、本文中で文献の一部を直接引用する場合は、引用した語句または文章を、和文の場合は「 」、英文の場合には“ ”でくくること。引用文献は、番号を片括弧にて記載すること（例：単独の場合「篠宮[3)]によると…」、複数の場合「佐野ら[1)] Ferrigno ら[2)]」）。複数の文献を同一箇所に引用する場合は、連続の場合ハイフン「-」、連続でない場合はカンマ「,」でつなぐこと（例：「…一連の研究がある[2-4)]」「…などの報告がある[3,5,9)]」）。

4.文献表の作成は、原稿の最後には出現順にまとめたリストを掲載すること。なお引用してない文献を記載してはならない。表記は以下の例を参照し、スペースはすべて半角、「,」「.」「:」ともにすべて半角を用い、そのあとには半角スペースをあけること。欧文の雑誌名は、短縮表記とすること。

例１．雑誌の場合

1) 佐野裕司, 菊地俊紀, 阿保純一: 加速度脈波を用いた簡便な潜水反射試験法の開発. スポーツ整復療法学研究, 8(3):103-110, 2007.

2) Ferrigno M, Ferretti G, Ellis A, Warkander D, Costa M, Cerretelli P, Lundgren CE: Cardiovascular changes during deep breath-hold dives in a pressure chamber. J Appl Physiol, 83(4):1282-1290, 1997.

例２．書籍およびプロシーディング等の場合

3) 篠宮龍三: ブルーゾーン. 牧野出版, 東京, pp134-137, 2010.

4) Agostoni E: Limitation to depth of diving. In: Rahn H. et al. (Eds.), Physiology of breath-hold diving and the ama of Japan, National Academy of Sciences - National Research Council, 139-145, 1965.

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附則
1.　この規定は、2021年12月6日から施行する。

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