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Short Report

Water Immersion in the Supine Position Increases Pulse Wave Velocity

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Abstract

The present study aimed to clarify the effects of the supine position in water on arterial stiffness. Twelve healthy Japanese males volunteered to participate in this study. Two conditions were compared, land and water condition. The brachial-ankle pulse wave velocity (baPWV), heart rate, blood pressure, and thermal sensation were measured after 5 minutes in the supine position in both conditions. The baPWV, and diastolic blood pressure were significantly higher in the water condition than in the land condition ($P<0.05$). This finding probably reflects the effects of blood vessel constriction and/or activity of the autonomic nervous system.

1. Introduction

Immersion in water leads to changes in heart rate (HR), oxygen uptake, and body temperature, and the response to immersion varies with the physical characteristics of the water (e.g., water temperature [1, 2], buoyancy [3], and viscosity [4]). Previous studies of subjects floating in the supine position in water at 30℃ have demonstrated that an increase in venous return caused by water pressure results in a decrease in HR and a significant increase in cardiac vagal activity [5]. The HR of subjects standing in water up to the level of the xiphoid process is usually lower in a standing position in water compared to standing on land. The measurement of pulse wave velocity (PWV) is useful for evaluating arterial stiffness, and HR and blood pressure (BP) influence PWV [6-8]. We hypothesized that the PWV would be greater on land than during immersion in water at a temperature of 30℃ because of the circulatory response to immersion. Therefore, the present study aimed to investigate the effects of water immersion in the supine position on PWV.

2. Methods

2.1. Subjects

Twelve healthy Japanese males volunteered to participate in the present study. Their mean (±SD) age,

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height, and body weight were 22.6 ± 2.4 years, 173.5 ± 7.9 cm, and 69.5 ± 7.7 kg, respectively. All subjects were non-smokers, and were not actively involved in regular physical exercise above normal living conditions. None had a history of any disease known to affect the cardiovascular system. No subject was taking regular water exercise. All subjects gave their informed consent and the experiment was approved by the Ethics Committee on Human Experiments at the Kawasaki University of Medical Welfare.

2.2. Experimental setup

The experimental conditions are illustrated in Fig. 1. The subjects lay in a supine position on land (room temperature: 28.6 ± 0.4℃) or in water (water temperature: 30℃). The study was a cross-over study, and subjects were randomly assigned to either the land condition or the water condition on the first trial day. After 2-3 days, they returned for the second trial. All participants abstained from bathing, vigorous activity, and alcohol or caffeine intake on the day before measurements were obtained. On arrival at the study site, the subjects lay quietly for at least 15 minutes before assuming the study position. Measurements were obtained after the subjects had remained in the supine position for 5 minutes on land or water.

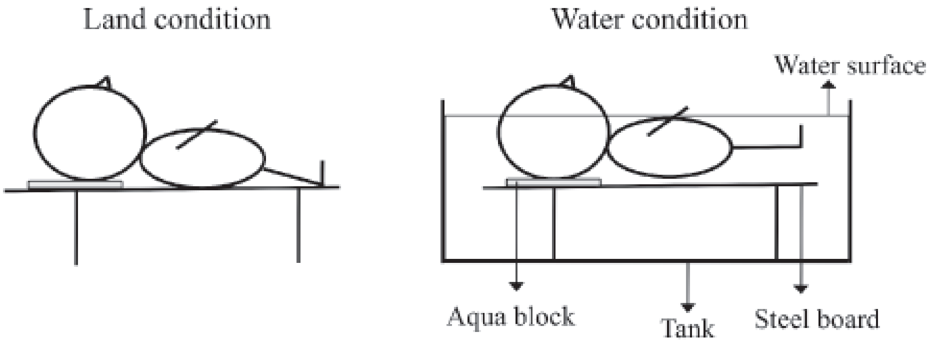

Fig. 1 Schematic representation of the experimental setup
In the water condition, the subjects lay in the supine position on a steel board under the water. The entire body, except for the face, was submerged.

2.3. Measurement of brachial - ankle PWV (baPWV), HR, BP, and thermal sensation

Arterial stiffness was evaluated on the basis of baPWV. The baPWV, HR, and BP were measured using a noninvasive volume plethysmographic apparatus (form PWV/ABI, Omron Colin Co., Kyoto, Japan) [9]. The averages of baPWV for the right and left sides and averages of BP measured at the right and left arm were calculated and used for analysis. The thermal sensation was used scale of a subjective thermal sensation (-2: warm, 0: neutral, +2: cool, +5: cold, +9: severe cold, +13: intolerable cold) [10].

2.4. Statistical analysis

All data are expressed as means ± standard deviations (SD). Differences in values between the land and water conditions were measured. Statistical significance was evaluated using a paired *t*-test, and the significance level was set at $P<0.05$.

3. Results

The baPWV, diastolic BP, and thermal sensation were significantly higher in the water condition than in the land condition ($P<0.05$). There was no significant difference in HR and systolic BP between the land and water conditions.

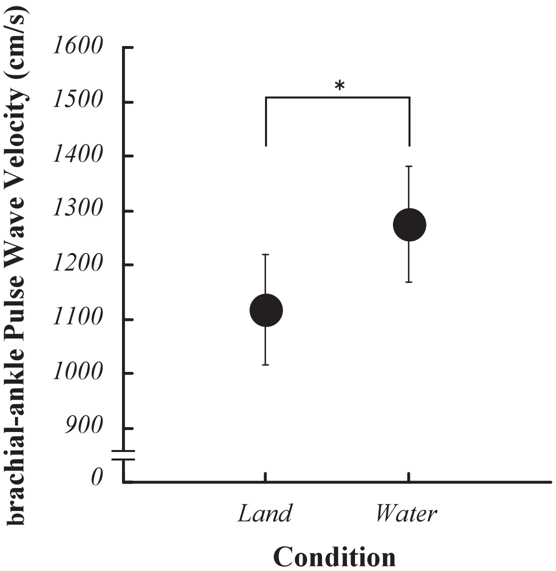

Fig. 2 Comparison of baPWV between the land and water conditions
＊ P<0.05

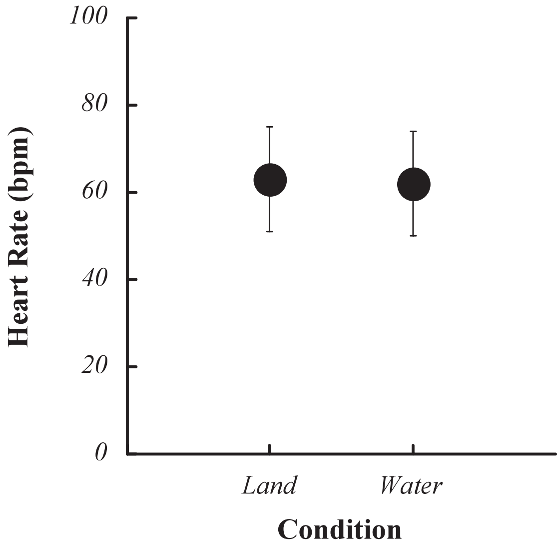

Fig. 3 Comparison of heart rate between the land and water conditions

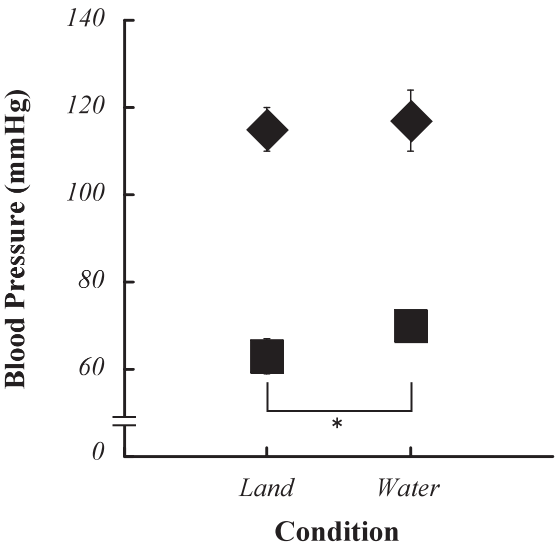

Fig. 4 Comparison of blood pressure between the land and water conditions
◆ : systolic blood pressure
■ : diastolic blood pressure
＊ P<0.05

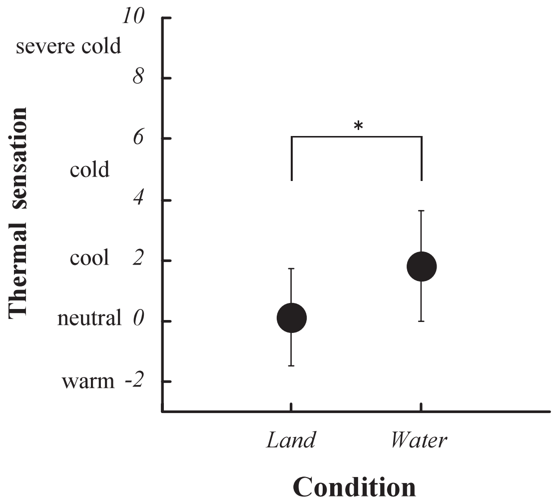

Fig. 5 Comparison of thermal sensation between the land and water conditions
＊ P<0.05

4. Discussion

Multiple linear regression analysis has shown that age, systolic BP, and HR are independently and positively correlated with baPWV [7]. The increase in baPWV with increasing age is more marked in hypertensive subjects than in normotensive subjects [11]. HR and BP can influence baPWV, but the results of the present study suggest that baPWV is also strongly influenced by other factors. Subjects felt cold after the water condition, suggesting that the water temperature used in this study (30℃) was not warm enough to maintain body temperature during immersion. However, there was no change in the measured rectal temperature, probably because the duration of immersion was only 5 minutes. It is possible that baPWV was influenced by skin vasoconstriction during water immersion in the supine position. Floating in the supine position in water at 30℃ has been shown to be associated with a significant decrease in HR and a significant increase in cardiac vagal activity compared with lying in the supine position on land [5]. However, in the present study, there was no significant difference in HR between the two conditions. This contradiction could be a result of differences in the experimental design of the water immersion condition and the fact that the supine position in water used in the present study did not enhance cardiac vagal activity. The effects of autonomic nervous system activity on the regulation of the circulatory system during water immersion and the effects of buoyancy related to gravity reduction are important factors influencing cardiac vagal activity.

5. Conclusion

The present study found that baPWV was significantly increased in subjects lying in the supine position in water at a temperature of 30℃ compared with that in subjects lying in the supine position on land. This finding probably reflects the effects of blood vessel constriction and/or activity of the autonomic nervous system.

References

1. Craig AB, Dvoral M: Comparison of exercise in air and in water of different temperatures. *Med Sci Sports* 1 (3): 124-130, 1969.
2. Choi JS, Ahn DW, Choi JK, Kim KR, Park YS: Thermal balance of man in water: prediction of deep body temperature change. *Appl Human Sci* 15 (4): 161-167, 1996.
3. Onodera S, Miyachi M, Yano H, Nakamura Y, Kimura K: Effect of differences in buoyancy of water on oxygen uptake and heart rate during swimming. *Med Sport Sci Basel Karger* 39: 126-130, 1994.
4. Onodera S, Miyachi M, Yano H, Kimura K, Nakamura Y, Ikeda A: Influence of viscous resistance and water temperature on oxygen uptake and rectal temperature during treadmill walking in water. *Kawasaki Med Welfare J* 3 (1): 167-174, 1993 (in Japanese).
5. Nishimura M, Onodera S: Effects of supine floating on heart rate, blood pressure and cardiac autonomic nervous system activity. *J Gravit Physiol* 7 (2): 171-172, 2000.
6. Hashimoto J, Chonan K, Aoki Y, Nishimura T, Ohkubo T, Hozawa A, Suzuki M, Matsubara M, Michimata M, Araki T, Imai Y: Pulse wave velocity and the second derivative of the finger photoplethysmogram in treated hypertensive patients: their relationship and associating factors. *J Hypertens* 20 (12): 2415-2422, 2002.
7. Hashimoto J, Watabe D, Kimura A, Takahashi H, Ohkubo T, Totsune K, Imai Y: Determinants of the second derivative of the finger photoplethysmogram and brachial-ankle pulse-wave velocity: the Ohasama study. *Am J Hypertens* 18: 477-485, 2005.
8. Yamashina A, Tomiyama H, Arai T, Koji Y, Yambe M, Motobe H, Glunizia Z, Yamamoto Y, Hori S: Nomogram of the relation of brachial-ankle pulse wave velocity with blood pressure. *Hypertens Res* 26 (10): 801-806, 2003.
9. Tomiyama H, Yamashina A, Arai T, Hirose K, Koji Y, Chikamori T, Hori S, Yamamoto Y, Doba N, Hinohara S: Influences of age and gender on results of noninvasive brachial-ankle pulse wave velocity measurement--a survey of 12517 subjects. *Atherosclerosis* 166 (2): 303-309, 2003.
10. Tanaka M, Yamazaki S, Ohnaka T, Harimura Y, Tochihara Y, Matsui J, Yoshida K: Effects of feet cooling on pain, thermal sensation and cardiovascular responses. *J Sports Med Phys Fitness* 25 (1-2): 32-39, 1985.
11. Asmar R, Benetos A, Topouchian J, Laurent P, Pannier B, Brisac AM, Target R, Levy BI: Assessment of arterial distensibility by automatic pulse wave velocity measurement: validation and clinical application studies. *Hypertension* 26 (3): 485-490, 1995.