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Effects of One-Year Swimming Training on Blood Pressure and Insulin Sensitivity in Mild Hypertensive Young Patients

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Abstract

Swimming is a lifestyle intervention recommended by many clinicians in the prevention and treatment of hypertension. Yet, not all studies have agreed that swimming training can reduce blood pressure (BP). Inclusion of normotensive subjects could be a confounder for discrepancies among studies. In this one-year longitudinal study, long-term effects of swimming training on BP were investigated in 7 mild hypertensive patients (systolic BP (SBP) > 140 mmHg) and 16 normotensive controls. At baseline, these subjects (aged 21.5 ± 0.1 years) did not participate in any form of sport training activity for the previous 3 months before enrollment into the training program. The training distance progressed from 0 (baseline) to 7 kilometers per week. BP and the homeostasis model assessment for insulin resistance (HOMA-IR) were determined under fasted condition at baseline and 48 h after the last swimming bout. The hypertensive patients displayed significantly greater HOMA-IR than age-matched normotensive controls. When data of all subjects were pooled, plasma glucose concentration was only slightly lowered after training, but weight, height, body mass index, SBP, diastolic BP (DBP) and HOMA-IR values were not significantly altered. However, when observation was restricted to the hypertensive patients, swimming training significantly lowered SBP by ~17 mmHg, concurrent with 41% reduction in HOMA-IR. Intriguingly, SBP in the normotensive subjects was elevated by ~ 6 mmHg after training. Conclusions: The present study found normalization rather than universal reduction effect of swimming training on BP. Furthermore, the BP-lowering effect of training in hypertensive patients appears to be associated with improvement in insulin sensitivity.

Key Words: **glucose tolerance, hypertension, insulin resistance, insulin sensitivity, HOMA-IR, systolic BP, diastolic BP, exercise training**

Introduction

Individuals with high blood pressure in early lifetime have greater chances to develop hypertension in later adulthood (7). Swimming is a recommended training mode in the prevention of development of hypertension, which is largely based on evidence from studies using other forms of aerobic exercise (10). Few studies have determined specifically intervention effects of long-term swimming training on resting BP. One early study performed in middle-aged hypertensive subjects with 10-week swimming

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training has reported only 2% drop in BP which cannot be considered an impressive outcome by clinicians and patients (29). Another study reported significantly elevations in BP for normotensive women after swimming training (8). However, intervention studies using other modes of exercise training to reduce BP have also generated inconsistent results (8, 9, 14, 17). In contrary, most epidemiological evidences have consistently shown the benefit of exercise training on BP (2). One possibility that may account for this discrepancy can be the inclusion of normotensive subjects.

Insulin resistance has been proposed as a pathogenic origin in the development of hypertension (1, 21, 27, 28). Interventions that increase insulin sensitivity can lower BP supports this causal relationship (30). Increasing physical activity is generally known as an effective intervention for enhancing insulin sensitivity (13). Previous reports have suggested that the homeostasis model assessment of insulin resistance (HOMA-IR) serves as an important factor in the etiology of hypertension for both adults and children (16, 21). In this study, we evaluated one-year swimming training effect on BP with inclusion of 7 mild hypertensive patients and 16 normotensive age-matched subjects. Their HOMA-IR and weight status were also recorded before and 48 h after the last swimming bout.

Table 1. Characteristics of subjects

N = 23	*Pre*	*Post*	*P*
Age	21.5 ± 0.1	–	–
Height (cm)	172.5 ± 1.2	173.5 ± 1.2	.562
Weight (kg)	65.7 ± 1.5	67.2 ± 1.4	.460
BMI	22.1 ± 0.5	22.4 ± 0.5	.690
HOMA-IR	1.91 ± 0.35	1.45 ± 0.13	.224
SBP (mmHg)	130.2 ± 2.5	131.4 ± 2.2	.732
DBP (mmHg)	73.3 ± 1.4	73.6 ± 1.6	.839
Glucose (mg/dL)	90.5 ± 1.7	83.0 ± 1.2	.001
Insulin (μU/ml)	8.2 ± 1.3	7.0 ± 0.6	.442
Cholesterol (mg/dL)	174.4 ± 4.3	176.2 ± 4.9	.784

P, probability of type I error for the difference between initial value and post-training value. Abbreviations: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure, HOMA-IR, homeostasis model assessment for insulin resistance.

Materials and Methods

Human Subjects

A total of 23 young participants with an average age of 21.5 ± 0.1 years, including 7 mild hypertensive patients and 16 normotensive age-matched subjects, voluntarily enrolled in this one-year swimming training. Subjects were initially screened according to their basic swimming capability. All subjects were capable of swimming for more than 800 meters. This study was approved by the institutional ethical committee and the subjects gave informed consents.

Intervention

These subjects remained sedentary for at least 3 months before beginning of the intervention. Swimming training started from the first year of college and the swimming distance progressively increased from 0 to 7 kilometers.

Measurements

All measurements were performed before and 1 year after the swimming training, 48 h following the last swimming bout and under fasted condition in the morning. Measurements consisted of anthropometric assessments (height, weight), glucose, insulin and BP determination. Systolic (first phase) and diastolic (fifth phase) BP were measured by auscultation with a mercury column sphygmomanometer in the seated position after a 5-min rest period. The mean of 2 determinations was used for BP measurement before blood sample collection.

Plasma glucose and insulin were measured within 3 h following sample collection (15). Glucose concentration was determined using the method of glucose oxidase. Insulin was determined using the method of ELISA with a commercial kit (Diagnostic Systems Laboratories, Inc. Webster, TX, USA). Insulin resistance was determined according to the HOMA-IR as the product of fasting plasma glucose (mM) and insulin (μU/ml) divided by the constant 22.5 (3).

Statistical Analysis

Paired *t* test was used to determine the mean differences between baseline and post-training values on all metabolic and anthropometric variables. Two-way ANOVA with repeated measurements was used to determine the interactive effects of initial BP and time on all variables. Fisher post-hoc test was used to compare mean differences between groups. Pearson correlation was used to determine the association between baseline and the magnitude of change on metabolic variables. A level of $P < 0.05$ was considered significant on all tests, and all values are expressed as means ± standard errors (SE).

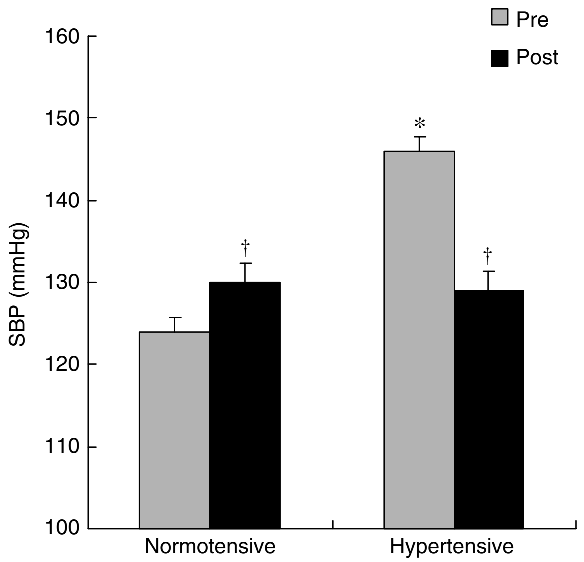

Fig. 1. Systolic BP after one-year swimming training. *Significance against normotensive control; †Significance against Pre.

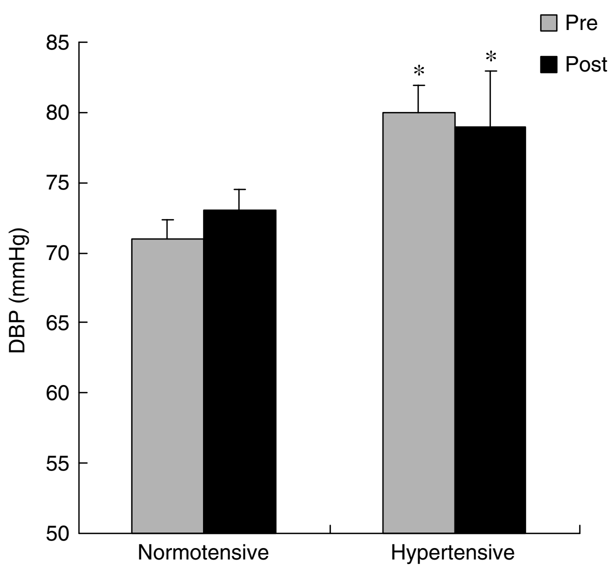

Fig. 2. Diastolic BP after one-year swimming training. *Significance against normotensive control.

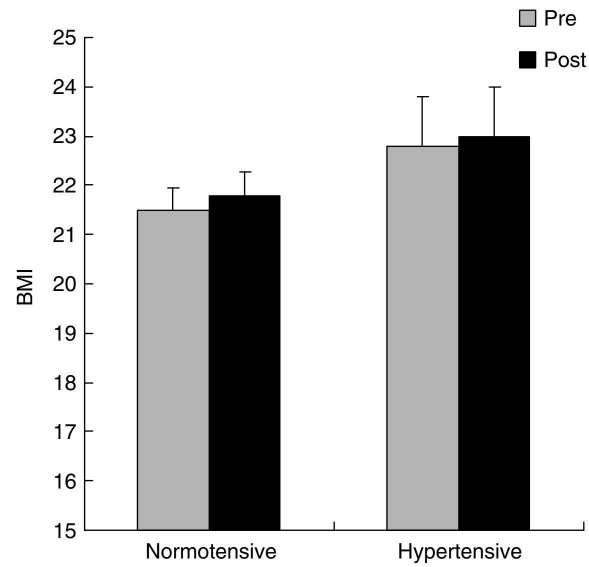

Fig. 3. BMI after one-year swimming training.

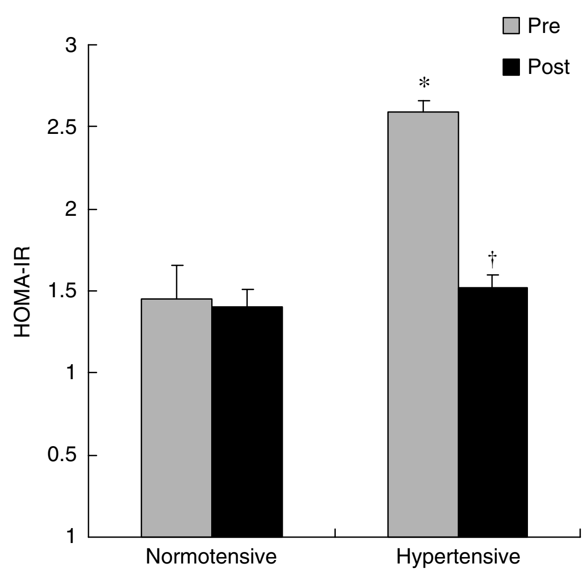

Fig. 4. HOMA-IR after one-year swimming training. *Significance against normotensive control; †Significance against Pre.

Results

Table 1 shows anthropometric and metabolic variables at baseline and following one year of swimming training with inclusion of all subjects. Weight, height, BMI, DBP and HOMA-IR values were not significantly altered with the one-year swimming training. Fasting plasma glucose level was slightly reduced after training ($P < 0.05$). Blood pressure data are shown in Fig. 1 (SBP) and Fig. 2 (DBP). Body mass index (BMI) was not affected by swimming training for both normotensive subjects and hypertensive patients (Fig. 3). HOMA-IR data are shown in Fig. 4. SBP, DBP and HOMA-IR in the hypertensive group were significantly greater than those in the normotensive group ($P < 0.05$). Swimming training significantly lowered SBP and HOMA-IR in the hypertensive group ($P < 0.05$). However, for the normotensive subjects, SBP was significantly elevated from 124 to 130 mmHg ($P < 0.05$).

Discussion

Swimming is a recommended intervention in the prevention and treatment of hypertension. However, previous studies reported inconsistent results on positive training effects of swimming on resting BP (8, 29). In the study, we found a significant BP lowering effect of swimming training for mild hypertensive young patients. However, swimming training slightly elevated SBP in the normotensive subjects. Such opposing trend towards normal values of BP brought no significant change in BP by training when data from all subjects were pooled. Thus, the present study demonstrates a normalization effect, rather than a reduction effect, of swimming training on resting BP. Such a finding might explain the inconsistent results of swimming training on resting BP from previous studies (8, 9, 14, 17), and reconfirms the benefit of exercise training on suppressing eccentric BP towards normal.

One factor that is causally linked with hypertension is the weight status (9, 24). In this study, the mean BMI of the subjects was not altered by swimming training in the hypertensive subjects. This indicates that the training effect on BP reduction was not associated with changes in weight status for this cohort. This is not surprising sine it has been previously found in young adults that the percentages of the variance of BP that could be explained by BMI were less than 15% (33). Other factors, such as increases in muscle mass (5), could be involved with the change of BP by swimming training in the study. This might be due to changes in body composition rather than weight fluctuation (22, 23).

Hypertension is a part of insulin resistance syndromes in humans (27). In the study, we also found that the training effect on HOMA-IR was highly correlated with their initial values. HOMA-IR is a surrogate measure of insulin resistance (4) based on glucose-insulin feedback system in the homeostatic state (overnight fasting) (31). Intervention that enhances insulin sensitivity can alleviate hypertension, whereas hypertensive medicine could not reverse insulin resistance (27). This highlights a causal relationship between BP and insulin resistance. The fact that the training effect on insulin sensitivity occurred without altering weight status is consistent with a previous study reported for younger ages (25).

The similar trend in the relationships between training effect on BP and HOMA-IR and their initial values suggests a possibility that the beneficial effect of swimming training could be mediated by increased responsiveness in endothelium-dependent vasodilation, which is highly associated with insulin sensitivity (34). Type 2 diabetes patients are characterized by a significantly blunted vasodilator response to insulin as well as an attenuated effect of insulin in decreasing vascular resistance (18, 28). Furthermore, increased protein glycation (formation of advanced glycation end products) due to hyperglycemia is increasingly recognized to be linked with insulin resistance. Modification of endogenous proteins could lead to non-specific inflammatory responses, which in turn increase oxidative stress and cause vasculature damage (32). As a result, endothelial dysfunction and reduced capillary density in periphery develop (11), and thus contributes to increased blood pressure. Although the training effect on reducing HOMA-IR has been confirmed in numerous studies (20, 25, 26), the additional knowledge provided by this study is that the swimming training effect is more pronounced for individuals with initially lower insulin sensitivity in this young cohort.

The present study found that swimming training significantly increased SBP in normotensive subjects. One possibility accounting for increased BP in normotensive subjects is the normal training effect on increasing plasma volume. An acute bout of exercise can increase plasma volume within a day (12) which might improve hypotension for those initially low BP subjects but not for normotensive individuals. Low plasma volume is generally known as a major cause of hypotension (19). The plasma volume expansion phenomenon of training is related to increase in albumin synthesis (6) which leads to greater water retention in circulation. Furthermore, the exercise mode appears to be important for the BP lowering effect of exercise training. Cox *et al.* (8) have found that, relative to walking, regular swimming significantly elevates BP in previously sedentary, normotensive subjects.

In conclusion, previous studies have reported inconsistent findings with regard to swimming training effect on resting BP. This discrepancy could be due to inclusion of normotensive subjects based on the current finding that an elevated BP with training restricted only to the normotensive young subjects, whereas hypertensive subjects exhibited an opposing change. The results of the study demonstrate that long-term swimming training can normalize BP and HOMA-IR towards norm for young adults. The benefit of swimming training on resting BP is, thus, reconfirmed in the study.

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