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Responses of Six-Weeks Aquatic Exercise on the Autonomic Nervous System, Peak Nasal Inspiratory Flow and Lung Functions in Young Adults with Allergic Rhinitis

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ABSTRACT

Allergic rhinitis is a chronic respiratory disease. Sympathetic hypofunction is identified in all of the allergic rhinitis patients. Moreover, allergic rhinitis is associated with decreased peak nasal inspiratory flow (PNIF) and impaired lung functions. The aim of this study was to investigate effects of six-week of aquatic exercise on the autonomic nervous system function, PNIF and lung functions in allergic rhinitis patients.

Twenty-six allergic rhinitis patients, 12 males and 14 females were recruited in this study. Subjects were diagnosed by a physician based on history, physical examination, and positive reaction to a skin prick test. Subjects were randomly assigned to two groups. The control allergic rhinitis group received education and maintained normal life. The aquatic group performed aquatic exercise for 30 minutes a day, three days a week for six weeks. Heart rate variability, PNIF and lung functions were measured at the beginning, after three weeks and six weeks.

There were statistically significant increased low frequency normal units (LF n.u.), PNIF and showed decreased high frequency normal units (HF n.u.) at six weeks after aquatic exercise compared with the control group.

Six weeks of aquatic exercise could increase sympathetic activity and PNIF in allergic rhinitis patients.

Keywords: Allergic rhinitis; Aquatic exercise; Autonomic nervous system; Outcomes; Pulmonary functions

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INTRODUCTION

Allergic rhinitis (AR) is one of the most common respiratory disorders with a high prevalence and incidence.[1] It is characterized by symptoms such as sneezing, itching, rhinorrhea, pruritis and congestion. These symptoms attack the body when exposed to allergens such as, pollen, mites, dust and other stimuli. A previous study evaluated the relationship between AR and the autonomic nervous system (ANS).[2] The authors suggested that ANS dysfunction, especially sympathetic hypofunction was identified in all of the AR patients. As it is well known, the glands in the nose are supported by the autonomic nervous system. Increasing parasympathetic activity activates glandular mucous secretions that lead to nasal obstruction and decreased peak nasal inspiratory flow (PNIF). Moreover, AR impairs lung functions and increases risks to develop clinical asthma.[3-5]

Exercise is one of the alternative treatments for AR in mild cases of AR in pregnancy.[6] On the other hand, running or exercises may trigger rhinorrhea or rhinitis symptoms.[6] AR patients may therefore fear to exercise. Aquatic exercise has been known as pool therapy and hydrotherapy. It is a mild to moderate exercise. The benefits of aquatic exercise are mainly to relieve pain because of the warm water. Some studies showed the effects of aquatic exercise by demonstrating sympathetic dampening in elderly patients[7] but some studies suggested that low-intensity resistance exercise increased sympathetic activity.[8] The aim of this study was to investigate the effect of six-weeks of aquatic exercise on autonomic nervous system functions, PNIF and lung functions in AR.

MATERIALS AND METHODS

The present research was conducted at the Department of Physical Therapy, Faculty of Associated Medical Science, Khon Kaen University, Thailand.

Subjects

Twenty-six AR patients aged 18-30 years were recruited from Srinagarind Hospital and were diagnosed by a physician using histories and physical examinations. The diagnosis was made by presence of at least one or more of the AR symptoms for more than 3 months and positive skin prick test. The symptoms included nasal congestion, rhinorrhea, sneezing, and itching.[6] Patients were excluded if they had a history of asthma, other chronic respiratory diseases, cardiovascular disease, hypertension, diabetes mellitus, an orthopedic problem, a neuromuscular disorder, liver or kidney disease, an open wound, infections or fever. They were informed about the nature and risks of the experimental procedures, and all gave their consent to participate in the experiment. Subjects were randomly assigned to two groups. Control AR subjects received education and maintained normal life. Experimental AR subjects performed aquatic exercise. All subjects received antihistamine treatment as a standard treatment (Figure 1).

Study Protocol

The trial was performed on each subject in the following order. First, they were asked to provide their frequency of symptoms and drug usage. Anthropometric measurements of height, body weight, and BMI plus blood pressure, heart rate, PNIF, lung functions and heart rate variability (HRV) were performed. Data were collected at the beginning and after the third and the sixth weeks. These studies were approved by the Khon Kaen University Ethics Committee on Human Research (HE531449) and conformed to the standards set by the Declaration of Helsinki.

Aquatic Exercise Program

Each subject performed aquatic exercise at the laboratory. The temperature of the water was maintained around 28 - 30 degrees Celsius. Subjects rested for 15 minutes before beginning exercise. Subjects performed aquatic exercise for 30 minutes per day, 3 days per week for 6 weeks. Data were collected at the beginning, one day after the third week and one day after the sixth week. Participants usually used their normal prescribed medications.

The aquatic exercise program comprised of three steps; warm up, exercise, and cool down. The warm up and cool down steps were similar and included neck flexion, neck extension, side flexion and turn, roll shoulder forwards-backwards, shrug alternate shoulder, let arms float on top of the water and stretch them from side to side, holding on the float and turn around feet from side to side, circle hips in both directions in the water, face the wall and hold the bar (feet touch the wall and move down, keep hips close to the wall and let the body fall away from the wall),

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and take a large step forward while maintaining the anterior knee in the flexion, the posterior knee in extension, and feet in contact with the bottom of the pool.

There were 12 steps for exercise program as follows: 1) holding rail, floating, and turn body around from side to side; 2) holding rail, floating, and push the body into the water; 3) holding rail, floating, and push down; 4) walking as a circle in clockwise and anticlockwise direction for three times; 5) walking forwards-backwards along sideways; 6) walking forwards with moving hand to the opposite knee; 7) floating positing- push back into water and hold for 10 seconds; 8) floating position- move the body against the water from side to side; 9) sitting on a stool- perform shoulder flexion and extension; 10) sitting on a stool- shoulder adduction and go until 90° of horizontal adduction; 11) sitting on a stool and move legs as a circle in clockwise and anticlockwise direction; 12) sitting on a stool and pump both ankles.

HRV

Subjects arrived to the laboratory after an overnight of 8 hours sleep and gave up smoking, caffeine and alcohol on the day of the study. Subjects were rested on the bed for 5 min, and the respiratory rate (RR) was measured before electrocardiogram (ECG) monitoring (Biopac system, Inc; USA).[9] Lead 2 ECG monitorings were recorded for 15 min and the respiratory rate was measured post-ECG again.[2]

HRV was analyzed into the frequency domain (Biopac software acknowledge^{R} III version 3.9.1 for the MP 100). The frequency domain was calculated by transforming into fast fourier analysis obtained from the power spectrum of HRV. The power spectral components were divided into 3 frequencies: very low frequency, low frequency (LF: 0.04 – 0.15 Hz) modulated by the sympathetic system, and high frequency (HF: 0.15 – 0.40 Hz) mediated by the parasympathetic system.[10] All frequencies were transformed to a normalized unit (n.u.) to investigate the balance of the autonomic nervous system by a LF/HF ratio. These measurements assessed the status of the autonomic nervous system.

PNIF

Before measurement, subjects were informed about using the nasal inspiratory flow meter (GP Supplies Ltd., London). Subjects put on a spirometer mask covering the mouth and nose in a sitting position, and then performed a deep forced inspiration after normal expiration. Participants did 3 repetitions. Investigators recorded the best PNIF in L/min.[11] Data were recorded as percentages of predicted values. The predicted values are based on normal, age-, gender-, race-, weight-, and height-matched subjects.

Lung Function Tests

Before measurement, subjects were informed about using the spirometer (MINATO Autospiro AZ-505; Japan). The investigator recorded the forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC). Data were recorded as percentages of predicted values. The predicted values are based on normal, age-, gender-, race-, weight-, and height-match subjects.

Outcome Measurement

The primary outcome measurements measured the autonomic nervous system function from the HRV measurements. The secondary outcome measurements measured PNIF and lung functions.

Statistical Analysis

Statistical analysis was performed by SPSS version 16. The data were expressed as mean ± SD. The paired simple *t*-test was applied for differences from baseline. It could not be guaranteed that the baseline values would be the same between groups, so ANCOVA was employed in this study to adjust differences in baseline values for comparison between groups. Statistical significance was accepted at $p<0.05$.

Baseline Characteristics of Patients

There were 26 AR patients, 12 males and 14 females were included in this study. All subjects had positive skin prick test results. There were no intergroup differences in the baseline characteristics observed in this study (Table 1).

RESULTS

HRV

There were statistically significant differences in LF (n.u.), HF (n.u.) and LF/HF ratios from baseline after 6 weeks between the groups (Table 2), while no differences were found in these factors after 3 weeks in both groups from baseline. In a comparison of adjusted differences in baseline values between groups, there

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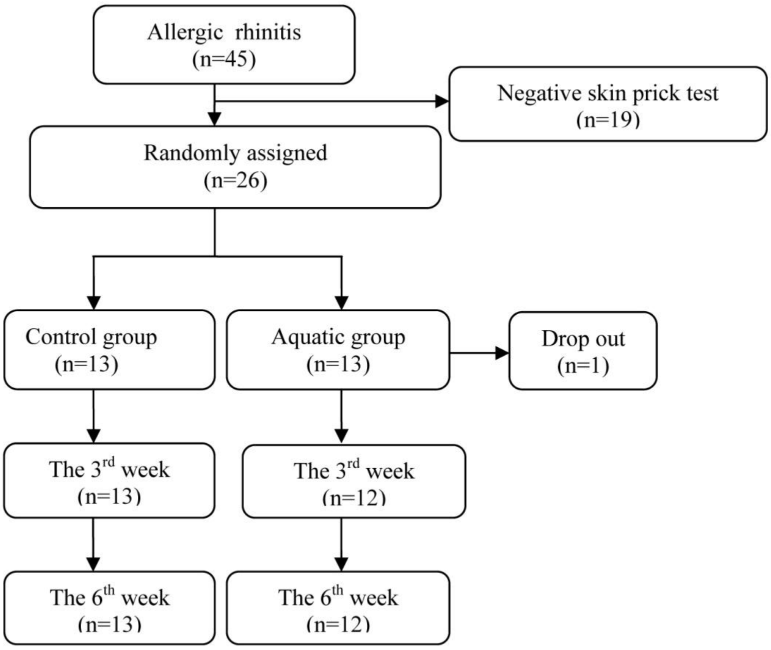

Figure 1. Recruitment and randomization of subjects

Table 1. Baseline characteristics of patients

Characteristics	Control (n=13)	Aquatic (n=13)
Age (years)	26.6±3.0	22±4.3
Weight (kg)	56.1±8.6	62.8±9.3
Height (cm)	165±6.2	165±10.3
BMI	20.3±2.0	22.8±11.3
Systolic blood pressure (mmHg)	110±12.6	115.4±6.3
Diastolic blood pressure (mmHg)	69.2±7.8	66.8±7.3
Heart rate (bpm)	77.7±11.98	72.7±8.3

Note BMI; Body mass index, kg; kilogram, cm; centimeter, mmHg; millimeter mercury, bpm; beat per minute. Values are mean ± SD.

was a statistically significant increase in LF (n.u.) and decrease in HF (n.u.) after 6 weeks of aquatic exercise compared with the control group. For the LF/HF ratio, there was an increase but not statistically significant difference after 3 weeks (Table 3).

PNIF

There was a statistically significant increase in PNIF after 3 weeks and 6 weeks of aquatic exercise compared with baseline while no changes occurred in the control group (Table 2). A comparison of adjusted differences in baseline values between groups showed that there was a statistically significant difference in PNIF after 6 weeks of aquatic exercise compared with the control group but not after 3 weeks (Table 3).

Lung Functions

There were no statistically significant differences in lung functions from baseline after 6 weeks in either group (Table 2). After adjustment for differences in baselines between groups, there were no statistically significant differences in lung functions in the aquatic group compared with the control group (Table 3).

Table 2. Comparison of outcome variables at baseline, the 3rd week and the 6th week in control and aquatic exercise groups (paired t-test).

Outcome	Group	Baseline	Week 3	Week 6
LF (n.u.)	control	39.9± 11.6	41.8± 15.6	48.1± 9.8*
	aquatic	39.5± 8.7	42.8± 12.4	55.3± 8.4*
HF (n.u.)	control	60.0± 11.5	58.1± 15.6	51.8± 9.8*
	aquatic	60.4± 8.7	56.6± 12.6	44.7± 8.4*
LF/HF	control	0.7± 0.3	0.8± 0.5	0.9± 0.3*
	aquatic	0.7± 0.2	0.8± 0.5	1.3± 0.4*
PNIF (%)	control	96.9± 19.5	105.7± 31.6	103.0± 31.3
	aquatic	102± 23.2	128.3± 37.7 *	130± 34.7*
FEV_1 (%)	control	80.3± 10.7	81.3± 9.8	80.1± 10.4
	aquatic	79.2± 13.1	79.5± 9.5	79.6± 10.6
FVC (%)	control	71.6± 8.9	73.0± 9.1	72.3± 10.0
	aquatic	70.2± 9.2	72.3± 6.8	72.0± 8.4
FEV_1/FVC	control	96.1± 2.9	96.0± 3.5	95.5± 4.8
	aquatic	96.5± 3.5	93.4± 6.4	93.6± 7.6

Note: This table shows the comparisons of the baseline with 3 weeks and baseline with 6 weeks. Values are mean ± SD. LF (n.u.); low frequency normalized unit, HF (n.u.); high frequency normalized unit, LF/HF; low frequency per high frequency ratio, PNIF; peak nasal inspiratory flow, FEV_1; forced expiratory volume in one second, FVC; forced vital capacity, FEV_1/FVC; forced expiratory volume in one second per forced vital capacity ratio; n.u.: normalized unit; PNIF, FEV_1, FVC are recorded as percentages of predicted values.

* significantly improved from baseline (p<0.05)

Table 3. Comparison of adjusted mean for difference in baseline values post-aquatic exercise between groups (ANCOVA).

Outcome	Week 3			Week6		
	Control	Aquatic	Difference (95%CI)	Control	Aquatic	Difference (95%CI)
LF (n.u.)	41.8	42.9	-1.1 (-12.7)-(10.4)	48.1	55.4	-7.3* (-14.4)-(-0.03)
HF (n.u.)	58.2	56.6	1.6 (-9.9)-(13.1)	51.9	44.6	7.3* (0.05)-(14.5)
LF/HF	0.84	0.85	-0.01 (-0.4)-(0.4)	0.9	1.3	-0.4 (-0.6)-(0.01)
PNIF (%)	108.5	125.4	-16.9 (-38.6)-(4.9)	105.4	127.9	-22.5* (-44.4)-(-0.4)
FEV_1 (%)	80.9	79.8	-1.1 (-3.6)-(5.7)	79.7	80.1	-0.4 (-4.8)-(4.0)
FVC (%)	72.5	72.8	-0.3 (-4.0)-(3.3)	71.8	72.5	-0.7 (-0.7)-(4.7)
FEV_1/FVC	96.1	93.3	-2.8 (-1.4)-(6.9)	95.5	93.6	-1.9 (-3.4)-(7.2)

Note: This table shows the comparisons of mean post-aquatic exercise between groups after adjustment for differences in baseline values at 3 weeks and 6 weeks. Values are adjusted means. LF (n.u.); low frequency normalized unit, HF (n.u.); high frequency normalized unit, LF/HF; low frequency per high frequency ratio, PNIF; peak nasal inspiratory flow, FEV_1; forced expiratory volume in one second, FVC; forced vital capacity, FEV_1/FVC; forced expiratory volume in one second per forced vital capacity ratio; n.u.: normalized unit; PNIF, FEV_1, FVC are recorded as percentages of predicted values.

*significant differences between group (p<0.05)

DISCUSSION

The aim of this study was to investigate the effects of six-week aquatic exercise on the autonomic nervous system function, PNIF and lung functions in AR patients. HRV was measured to assess the ANS function. The main finding of the present study is that the ANS adapted to aquatic exercise. At the beginning, it was found that there was ANS imbalance in both groups, especially sympathetic hypofunction in AR patients as demonstrated in previous studies.[2,3] The response of the ANS was increased in the LF n.u. and the LF/HF ratio and was decreased in the HF n.u. of HRV in the aquatic exercise group after 6 weeks. The increases of LF n.u. and LF/HF ratios after 3 weeks did not show a statistically significant difference and neither did the decrease in HF n.u. after 3 weeks. At 6 weeks, the LF n.u., LF/HF ratios were slightly increased and the HF n.u. was slightly decreased. The resultant increase in LF/HF of the exercise group did not show a statistically significant difference compared with the control group. These results suggested that aquatic exercise affected the ANS response, especially in that the sympathetic function component was improved. The change in hyperactivity of the sympathetic function resulted by six weeks of aquatic exercise. The intensity of the exercise was apparently enough to affect an increase in sympathetic activity. In the present study, the intensity of the exercise was mild to moderate. There continues, however, controversy about the intensity of exercise and the ability to activate ANS activity. Some studies showed that moderate to intense exercise could modulate parasympathetic activity,[12,13] but the other studies suggested that low intensity exercise activated sympathetic activity.[14] It does seem, however, that increasing sympathetic activity in AR is not harmful because it apparently increases the activity from hypofuction to normal function to appear like hyperactivity. This study did not compare these responses with healthy normal subjects.

The present study showed a decrease in parasympathetic activity caused by a decrease in HF n.u. after six weeks. Due to the apparent balancing of the ANS, an increase in LF/HF ratio or sympathetic hyperactivity and simultaneous parasympathetic hypofunction leads to a decrease in HF n.u. components, but the real mechanism is still unclear. AR is an inflammation of nasal mucosa. It shows nasal congestion and obstruction that may lead to limited air flow. All AR patients suffer from these symptoms, so a medication such as an antihistamine is necessary for these patients to stop congestion. PNIF is the method to evaluate the change in nasal airflow due to obstructive or inflammatory causes.[15] Interestingly, the present study showed a statistically significant increase in PNIF from baseline after 3 and 6 weeks of aquatic exercise although**,** there was no statistically significant difference between groups after adjustments of the differences in baselines. The data did show the benefits of aquatic exercise on PNIF in patients with AR. Taylor et al., suggested the clinical improvement of the PNIF that increased from a baseline of 13 l/min after low dose desensitization and 18.5 l/min after topical steroids.[16] Similar to Taylor et al., the present study showed improvement in PNIF from baseline.

The results of this study showed improvement in the ANS and PNIF, simultaneously. That improvement in the ANS probably induced the mucous gland in the nose to reduce secretion leading to an increased PNIF but the secretions were not measured. The real mechanism, however, is unclear.

Regarding lung function, the present study showed no statistically significant differences from the baselines and between groups. The data, however, still showed impairment of lung functions indicated by the low FVC, but the data showed no evidence of exercise induced bronchoconstriction

The limitations of this study are related to environmental control and some measurement limitations. One problem was that it was not possible to control the temperature of the water to the same degree every day. It was also difficult to measure the ANS in the nose directly. Finally, it was not known how long it would take the aquatic exercise to affect AR. In a further study, a better measurement of the ANS in the nose needs to be implemented and the volume the secretions of the mucous from the nose should be collected before and after aquatic exercise. A longer follow up period would also be informative.

In conclusion, six weeks of aquatic exercise can increase sympathetic activity and PNIF in AR. Aquatic exercise appears to be suitable for AR patients.

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