

The effects of aquatic exercise on body composition, physical fitness, and vascular compliance of obese elementary students

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The purpose of this study was to investigate the effects of aquatic exercise on body composition, physical fitness, and vascular compliance of obese elementary school students. For the purpose of this study, 20 obese elementary students were selected as subjects. The subjects were then divided into two groups: the swimming group (n = 10) and the control group (n = 10). The subjects were asked to exercise for 60 minutes a day, 3 times a week for 12 weeks with an exercise intensity of 50-70% HRmax. The following results were achieved: first, in terms of body composition, both body fat percentage and fat-free mass showed significant differences within the swimming group. There were also significant differences again in the posttest of difference between the two groups. Second, in terms of changes in physical fitness, there were,

again, no significant changes in muscular strength between the two groups. However, muscular endurance, flexibility, and cardiopulmonary endurance showed significant differences in the swimming group's test for difference within groups. Significant differences in both groups for the posttest of differences between groups were also seen. Third, in terms of vascular compliance, there was a significant increase in the right leg for the swimming groups' test of difference within groups, as well as in the posttest of difference between groups.

Keywords: Swimming, Body composition, Physical fitness, Vascular compliance

INTRODUCTION

As our lifestyle becomes more convenient because of the rapid development and changes in modern society, more and more instances of people getting obese occur. This is due to the increase of calorie intake and lack of exercise caused by Westernization, urbanization, and industrialization. With this, obesity is, in fact, a social issue.

Obesity means that the body fat percentage exceeds 30% of the body composition. It is the cause of many diseases, including dyslipidemia, insulin resistance, and decrease of HDL-C, as well as metabolic syndrome. The incidence of cardiovascular diseases, such as coronary artery disease, cerebral apoplexy, and high blood

pressure are also on the rise because of obesity (Fang et al., 2003; Rader, 2007; Riera-Fortuny et al., 2005). Children, adolescents in particular, who suffer from obesity will likely continue to suffer from it in adulthood (Eisenmann et al., 2002).

To date, the American College of Sports Medicine has investigated the effect of exercise in many obese adolescents through many studies. According to their current studies, it is recommended that to improve the physical strength of overweight and obese people, they should exercise more than three times a week at 55-90% HRmax (Chae et al., 2011; Jabbar et al., 2011; Wong et al., 2008). In other words, these studies have shown that physical activity and exercise can be the best ways to solve obesity (Warburton et al., 2006).

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It should be noted here that advanced research on exercise types related with obesity widely recommends aerobic exercise instead (Banz et al., 2003; Olson et al., 1991). However, this type of exercise is difficult for an obese person to participate in because excessive weight-bearing causes the joints to press together and thus aggravates pain.

Aquatic exercises, which use the water's buoyancy, can help decrease body fat while maintaining superior stability compared with ground exercises. Aquatic exercise is thus highly recommended for patients suffering from obesity.

Other than general endurance, one should not expect great improvement in physical strength factors with long-term aerobic exercises, for the latter has certain insufficient aspects (Parker, 1989). In contrast, aquatic exercises with resistance, such as swimming, can partly improve physical strength factors, along with endurance. These exercises do not only improve the functions of the respiratory system and the circulatory system, they also help develop muscular strength, endurance, and flexibility, effectively affecting changes in one's body composition. Advanced research concerning other variables related with obesity also shows that the vascular compliance of obese children, in particular, is related with increased blood pressure and circulatory disorders (Salvadori et al., 2008).

Some studies have also reported that obesity is a very serious health risk factor for all kinds of metabolic syndromes and cardiovascular diseases, in particular. Obesity is an independent risk factor of coronary artery disease and it also decreases the blood vessels' elasticity, thus giving rise to related disorders (Kraemer et al., 1997). A healthy blood vessel means compliance and flexibility of vascular compliance, and is an important indicator in evaluating circulatory diseases. Vascular compliance starts decreasing as we age, thus stressing the importance of its early diagnosis and management (Jani and Rajkumar, 2006).

Despite some minor differences concerning subjects of study and exercise methods, all of the advanced studies on physical activities and vascular compliance that were examined report that vascular compliance was improved through exercise. This proves that having good vascular compliance has a positive effect on physical activities (Alan et al., 2001; Barinas et al., 2006). Although a study did show that aerobic exercise had a positive effect on circulatory diseases caused by obesity in children, the studies that did investigate the effects of aquatic exercise on the circulation of blood vessels are very insufficient.

Therefore, the purpose of this study is first, to investigate the effects of aquatic exercise on the body composition, physical fit-

Table 1. Physical characteristics of subjects

Variables Group	Age	Height (cm)	Weight (kg)	Body fat percentage (%)
Swimming group (n=10)	11.45±2.87	127.46±5.37	44.53±8.83	34.45±3.24
Control group (n=10)	11.11±1.69	126.74±3.25	46.73±8.86	33.92±2.70

ness, and vascular compliance of obese elementary school students; and, second, to provide and prescribe obese patients with basic materials of effective exercises.

MATERIALS AND METHODS

Subjects of study

The subjects of this study were 24 male elementary school students of Y elementary school located in B city, who have understood the purpose of this study and consented to participate. They were divided into two groups. The first is the swimming group (n=12) who participated in a swimming program 3 times a week for 12 weeks. The second is the control group (n=12) who did not participate in the swimming program. During the study period, a total of four students, two students from the swimming group and two students from the control group, were excluded from the study because of personal reasons and physical limitations. The physical characteristics of the subjects are described in Table 1.

Measurement methods

1) Body composition

As the students wore simple clothes, their individual weights were measured automatically using InBody 430 (Biospace, Korea). InBody 430 can automatically measure weight after entering the subject's height. The students were asked to relax and spread their arms while standing as their weight (kg), body fat percentage (%), and fat-free mass (kg) were measured.

2) Muscular strength (Grip strength)

Each student's grip strength was also measured. The subjects were asked to flatten their feet on the ground in a comfortable position, with both legs apart by a shoulder's width to make an erect posture. The width of the digital dynamometer (TKK-5401, Japan) was adjusted to fit the subjects' hands, allowing the second joint of their fingers to form a right angle. While the students were holding this pose, their grip strength was measured twice for left and right, respectively. The highest scores were then recorded.

3) Muscular endurance (Sit-ups)

Muscular endurance was measured through sit-ups. The students were asked to put their legs apart by 30 cm with their legs bent at a right angle, as they lied on their backs on the mat with the fingers of both their hands laced behind their heads. With the command “start”, they raised themselves, making both of their elbows touch their knees. The number of times when they made correct action was recorded.

4) Flexibility (Sitting trunk forward flexion)

By using a sitting trunk forward flexion measurement instrument (DW-704, Japan), the students' flexibility was measured. The subjects were asked to remove their shoes and sit on the ground with their feet together. With the command “start”, they stretched both of their hands and bent their upper bodies to allow the middle fingers of both their hands to reach and slowly push the instrument. The students were asked not to bend their knees as they performed the test. The test was repeated twice for each student and the better scores were then recorded.

5) Cardiopulmonary Endurance (20-meters Shuttle run)

Cardiopulmonary endurance was measured by asking the students to do a shuttle run on a flat, 20-m long surface. The test was done with the help of a playback equipment. A signal was given at the starting point and the students were asked to run to a pre-determined arrival point. After that, they did not immediately start again but were instead asked to move to a starting point at the opposite side when they hear the next signal. The exercise was repeat-

ed until the students' limits were reached. When the students were unable to finish one lap before the second signal, the test was deemed over and only the previous number of times the student successfully performed the exercise was recorded.

6) Vascular compliance

The measurement of vascular compliance was done using PWV 3.0 (KM-Tec, Korea). The subjects were asked to comfortably lie down as the researcher placed two electrodes on their arms—one on the left and one on the right. The sensor was then inserted in one of their thumbs. After the procedure, the vascular compliance of their upper limbs was measured. After the upper limb measurement was finished, the sensor was placed on a toe to measure the vascular compliance of lower limbs. The test thus recorded vascular compliance measurements for both hands and feet.

Exercise program

The swimming exercise program is described in Table 2.

Data processing

For the data processing of this study, the averages and the standard deviation of each measuring item were calculated using SPSS Version 18.0. Paired t-test was taken for the changes within groups and an independent t-test was conducted for the changes between groups. The level of significance for all statistical data was $\alpha = 0.05$.

Table 2. Swimming program

Exercise content		Exercise intensity	Frequency
Warm up (10 min)	Stretching for relaxing muscle and joint intensity (Warm up)	RPE 7-9	
The main exercise (40 min)	1 Pull side kick	1-6 weeks	3 times/ week
	2 Freestyle kick	50-60% HRmax	
	3 Free pull	RPE 11-13	
	4 Pull and Kick (respiratory combination)	7-12 weeks	
	5 Freestyle swim	60-70% HRmax	
	6 Backstroke kick	RPE 13-15	
	7 Backstroke pull		
	8 Pull and Kick (respiratory combination)		
	9 Freestyle and backstroke drill		
	10 Interval swimming		
Cooling down (10 min)	Walking and stretching in the water (Down)	RPE 7-9	

Table 3. Change of body composition

Variable	Group	Pretest	Posttest	t
Weight (kg)	Swimming group (n=10)	44.53±4.56	40.80±2.11	2.60*
	Control group (n=10)	46.73±3.20	44.38±4.75	1.08
t		-1.24	-2.1 [#]	
Body Fat percentage (%)	Swimming group (n=10)	34.45±2.28	29.90±1.75	4.87***
	Control group (n=10)	33.92±2.58	35.1±1.65	-1.35
t		0.48	-6.78 ^{##}	
Fat-Free Mass (kg)	Swimming group (n=10)	30.64±1.41	35.34±1.91	4.87***
	Control group (n=10)	30.17±1.31	30.94±1.66	-1.26
t		0.94	5.35 ^{##}	

*: Test for difference on the change within groups, * $P < 0.05$, *** $P < 0.001$.

[#]: Test for difference on the change between groups, [#] $P < 0.05$, ^{##} $P < 0.001$.

RESULTS

Change of body composition

As a result of the test of difference on weight within groups, a significant difference (2.60*) was observed in the swimming group and no significant difference was found in the control group. Also, a significant difference was shown in the posttest of difference between groups (-2.1[#]).

As a result of the test of difference on body fat percentage within groups, a significant difference was found in the swimming group ($t=4.87^{***}$) and there was no significant difference in the control group ($t=-1.335$). There was a significant difference in the posttest of difference between groups ($t=-6.78^{##}$).

As a result of the test of difference on fat-free mass amount within groups, the swimming group ($t=4.87^{***}$) showed a significant difference and the control group ($t=-1.26$) did not show a significant difference. With this, a significant difference was also observed in the posttest of difference between groups ($t=5.35^{##}$) (Table 3).

Change of physical fitness

The result of the test of difference on muscular strength within groups showed no significant differences in the swimming group

($t=-0.85$) and the control group ($t=-1.17$). No significant difference was also observed in the result of the test of difference between groups.

The result of the test of difference on muscular endurance within groups showed a significant difference in the swimming group ($t=-2.48^*$), but no significant difference in the control group ($t=2.15$). There was also a significant difference in the result of the test of difference between groups ($t=2.53^{\#}$).

The result of the test of difference on flexibility within groups showed a significant difference in the swimming group ($t=-7.13^{***}$). However, the control group ($t=-1.22$) did not show a significant difference. There was a significant difference in the result of the test of difference between groups ($t=2.13^{\#}$).

The result of the test of difference on cardiopulmonary endurance within groups showed a significant difference in the swimming group ($t=5.28^{***}$), but the control group ($t=0.88$) did not show any difference. Also, a significant difference occurred in the result of the posttest of difference between groups ($t=-3.86^{##}$) (Table 4).

Change of vascular compliance

The test on the left leg within groups showed results that had a significant difference in the swimming group ($t=-2.64^*$). How-

Table 4. Change of physical fitness

Variable	Group	Pretest	Posttest	t
Muscular strength	Swimming group (n=10)	12.51±6.22	13.21±6.16	-0.85
	Control group (n=10)	11.23±6.49	13.12±5.86	-1.17
t		0.45	-0.07	
Muscular endurance	Swimming group (n=10)	49.49±15.73	60.1±11.54	-2.48*
	Control group (n=10)	51.10±13.1	47.6±10.29	2.15
t		-0.24	2.53 [#]	
Flexibility	Swimming group (n=10)	6.11±6.34	18.71±9.58	-7.13***
	Control group (n=10)	6.42±5.02	11.1±5.89	-1.22
t		-0.11	2.13 [#]	
Cardiopulmonary endurance	Swimming group (n=10)	13.72±2.45	17.45±2.22	5.28***
	Control group (n=10)	14.08±2.66	13.67±2.17	0.88
t		-0.26	3.86 ^{##}	

*: Test for difference on the change within groups, * $P<0.05$, *** $P<0.001$.

[#]: Test for difference on the change between groups, [#] $P<0.05$, ^{##} $P<0.001$.

Table 5. Change of vascular compliance

Variable	Group	Pretest	Posttest	t
Right arm	Swimming group (n=10)	321.46±20.54	332.38±21.74	-1.37
	Control group (n=10)	312.86±18.74	318.55±21.06	-0.69
t		0.97	1.44	
Left arm	Swimming group (n=10)	311.41±17.67	330.70±26.33	-1.76
	Control group (n=10)	321.94±19.15	317.05±17.87	0.57
t		-1.27	1.36	
Right leg	Swimming group (n=10)	361.34±25.66	381.93±16.87	-2.64*
	Control group (n=10)	351.27±29.16	349.16±28.24	0.13
t		0.82	3.15 [#]	
Left leg	Swimming group (n=10)	323.10±36.84	345.26±25.49	-1.57
	Control group (n=10)	332.83±25.56	342.00±33.23	-0.61
t		-0.68	0.24	

*: Test for difference on the change within groups, * $P<0.05$.

[#]: Test for difference on the change between groups, [#] $P<0.01$.

ever, the control group did not show a significant difference. There was also a significant difference ($t = 3.15^{**}$) in the result of the posttest of difference between groups (Table 5).

DISCUSSION

The main purpose of this study is to investigate the effects of aquatic exercise on body composition, physical fitness, and vascular compliance of obese elementary school students. The meaning reflected in the relationships between the variables and the results is discussed as follows:

(1) The swimming group showed significant changes in body composition, body fat percentage ($P < 0.001$) and fat-free mass ($P < 0.001$). The result of the posttest of difference between groups ($P < 0.001$) also revealed a significant difference. Body composition is an important element in the health and fitness model for individuals. More importantly, it acts as a basis that can help distinguish obesity from a normal body weight, according to an individual's body composition measurement. Body composition can be largely divided into two components: body fat and fat-free mass (Tudor-Locke et al., 2004).

Advanced research related with body composition revealed that for each frequency of a long-term aquatic exercise, it can help control the negative energy balance, thus resulting in a continuous body fat decrease of body fat obese students. This is due to the fact that long-term aquatic exercise, as an aerobic exercise, effectively consumes body fat (Owens et al., 1999). Wilder (1993) also conducted a study in which women had swimming exercises at 50-60% of the maximum heart rate, 3 times a week for 12 weeks. The results of this study reported that their body fat percentage remarkably decreased. These studies support the result of the current research.

(2) In the change of physical fitness, there was neither a significant difference in muscular strength showed within groups nor between groups for both groups. However, within groups for the swimming group, significant differences in muscular endurance ($P < 0.05$), flexibility ($P < 0.001$), and cardiopulmonary endurance ($P < 0.001$) were observed.

In the posttest of difference between groups, significant differences were observed from all levels of muscular endurance, flexibility, and cardiopulmonary endurance ($P < 0.05$).

Miller et al. (1990) suggested that regular exercises or physical activities can be positive for those afflicted with obesity. It helps improve one's condition and enhance basic physical strength, including that of elementary school students. It was also suggested

that the amount of physical activities during adolescence has a close relationship with aerobic function and exercise capacity (Hands et al., 2008).

In addition, the result of a study on women's exercise revealed that aquatic exercise helped improved flexibility and grip strength. In the aforementioned study, the women were divided into a dance exercise group and an aquatic resistance exercise group. Both groups were asked to exercise for 24 weeks. After 24 weeks, only the aquatic exercise group showed significant changes (Tsourlou et al., 2006). Thus, this also supports the results of the current study.

(3) With regard to vascular compliance, the right leg showed a significant difference within groups for the swimming group ($P < 0.001$). A significant difference was also observed in the result of the posttest of difference between groups ($P < 0.01$).

According to Safar et al. (2002), vascular compliance is determined by its elastin properties, in particular, one's arterial elasticity. Because vascular compliance is the cause of the degenerative change in the vascular endothelial cell, the accumulation of fiber and calcium other than endotheliocyte (Meaume et al., 2001) or the increase of systolic blood pressure, it was reported that constant low-intensity aerobic exercise helps increase vascular compliance. Compared with high-intensity aerobic exercise—the former thus has a more positive effect (Hajjar and Kotchen, 2003).

In addition, it was reported that degeneration in vascular compliance, caused by obesity in adolescence, is closely related with higher risks of having blood pressure and circulatory disorders (Salvadori et al., 2008). In one study, wherein 400 subjects were involved in regular aerobic exercises, a significant increase in their vascular compliance was observed (DeSouza et al., 2000). In another study, a onetime aerobic exercise was conducted with many groups (Alan et al., 2001). In this study, it was also revealed that the exercise had a positive effect on the subjects' vascular compliance as well.

These studies have revealed that changes in the vascular compliance happen after the aerobic exercises. During exercise, the increased blood flow rate inflates the blood vessel, thus affecting the vascular compliance. Ultimately, this decreases peripheral resistance, which positively affects the blood vessel (Silva et al., 2004). Again, these serve to support the current study.

Although the current study on the effects of swimming brought somewhat contrasting results compared with some of the previous studies, as most of them focused on the effects to the upper body, it still supported most of the conclusions derived from them. The slight differences may be attributed to the fact that the current

study had used slightly different exercises.

It should be noted here that a significant effect on the vascular compliance of the upper limbs was observed. This is due to the fact the subjects were beginners who are not skilled swimmers. Taking into consideration that the exercise largely centered on basic kicking, constant participation in swimming will definitely increase vascular compliance. Another important consideration here is the fact that because swimming is not actually a muscular exercise, significant changes in the subjects' muscular strength was not expected. However, it is hypothesized that muscular strength will be improved if a more complex exercise program is used. In a follow-up study, it is suggested that a more complex exercise and long-term exercise program be used in order to have more desirable results.

To investigate the effects of aquatic exercise on body composition, physical fitness, and vascular compliance of obese elementary school students, the study divided 20 obese elementary students into 2 groups the swimming group and the control group. Each group was composed of ten students. The students were asked to exercise 60 min a day, 3 times a week for 12 weeks with an exercise intensity of 50-60% HRmax for 1-6 weeks. For the following 7-12 weeks, the students were asked to exercise with an intensity of 60-70% HRmax. The following are the study's findings:

(1) Changes in the body composition of the subjects were observed. With regular aquatic exercise, the body fat percentage and fat-free mass showed significant differences in the swimming group.

(2) The swimming group showed significant differences in physical fitness, muscular endurance, flexibility, and cardiopulmonary endurance.

(3) The swimming group has a significant increase in the vascular compliance of the right leg.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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