A LONGITUDINAL STUDY OF THE EFFECTS OF REGULAR SWIMMING EXERCISE ON HEALTH-RELATED PHYSICAL FITNESS IN CHILDREN

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Physical activity is very important for children. The purpose of this study is to evaluate the effect of long term regular swimming exercises on comprehensive health-related fitness in children. Twenty healthy children aged 6-7 years were recruited, 10 of which participated 18-month swimming program. Their cardiorespiratory fitness, body fat, flexibility, muscle strength, and endurance were measured at the beginning, and after 6, 12, and 18 months of the swimming program. The results showed that regular swimming exercise significantly improved peak oxygen uptake (VO_{2peak}), back strength, and kept lower body fat. However, flexibility, grip strength, and leg strength did not show significant changes.

KEY **WORDS:** swimming, health-related fitness, children

INTRODUCTION: At present, it is asserted that lifetime physical activity and health patterns are, or should be, established in childhood, such that active children would translate into active adults. Some of the health benefits of regular physical activity during childhood and adolescence may be realised before adulthood (Bar-Or, 1994). Cross-sectional studies have shown that physical activity obviously improves fitness in children, such as obtaining a more desired body composition, lower body fat, better aerobic capacity, and lower blood cholesterol (Peter et al., 1998; Harsha, 1995). Recently, several tracking studies (Jos, 2000; Karen, 1997) have been carried out on physical activity and health-related fitness in children.
However, there are some weaknesses in the published literature. First, most of the studies were cross-sectional, and evaluated the effects of exercise by measuring one or more components of an exercising group at one point in time and comparing the outcomes with a comparable non-exercising group. This kind of design is seriously invalidated by numerous confounding effects (Cook & Campbell, 1979). Children are in a phrase of continuous growth and development. Their morphological, physiological, and psychological characteristics are constantly changing, and these changes are similar to exercise effects. Second, the longitudinal studies that have been carried out generally determine the child's physical activity level by indirect estimation or by questionnaire, and seldom by regular programmed exercise. Third, no comprehensive assessment has been made on the effects of long-term regular exercise on health-related physical fitness in childhood. Therefore, the purpose of this study was to evaluate the comprehensive effects of regular swimming exercise on health-related fitness in an 18-month program.

METHODS: Subjects. Ten healthy children (8 boys and 2 girls) aged 6 to 7 years old were randomly recruited from an elementary school to participate in the swimming exercise program. Matching these exercise subjects in age, body height, and weight were another ten children recruited as controls. The control group did not participate in any regular sports or exercise, except the physical education courses within the elementary school curriculum.
Swimming Programs and Measurements. Subjects in the exercise group were taught the basic knowledge and skills of swimming. They practised swimming three times per week, 60-min each time, for a total of 18 months. All test components were measured for all subjects. The occasions of testing were selected at 6 months intervals, namely: at the beginning, and after 6, 12, and 18 months. VO_{2peak} was measured to indicate cardiorespiratory fitness using a cardiopulmonary function system (Jager Oxygon Champion, Germany). Subjects exercised to exhaustion using a progressive, continuous walking treadmill protocol. VO_{2peak} was determined when the subject's respiratory quotient was greater than 1.00, their heart rate was over 200 bpm, and they had reached volitional fatigue Body fatness was assessed as the sum of triceps and subscapular skinfolds. Skinfold thickness of the body right side was measured using

calibrated Evyoken-Type caliper by the same researcher. The measurements of each site were made in triplicate, and the mean of the three values was taken (mm). The maximum distance reached on a standardized sit-and-reach box (30cm) was used to assess flexibility. The farthest reach value (cm) was recorded. Endurance of muscle was measured as the number of sit-ups performed in 1min (times/min), and muscle strength included grip strength, back strength, and leg strength. Grip strength (kg) was recorded by the force exerted when the children squeezed the hand dynamometer. Isometric back extensor strength (kg) was measured with a back dynamometer (Hockey, 1993). The distance of a standing long-jump (m) was used to evaluate leg strength.

Table 1 Changes in Hand Grip Strength, Sit-Ups, and Standing Long Jumps in Both Groups Over Time

	Swimming Group				Control Group			
	time1	time2	time3	time4	**time1**	time2	time3	time4
Grip strength **(kg)**	5.83(1.73)	9.00(1.94)*	9.11(1.74)*	10.50(9.75)*•	5. 90(2.95)	8.35(1.37)*	8.45(1.83)*	9.75(1.31)*•
Sit-up (N/min)	17.22(6.36)	24.22(8.51)*	25.00(7.07)*	30.56(7.43)*	8.560(8.01)	15.22(9.76)*	16.67(7.78)*	17.11(9.18)*
Standing long jump (m)	1.25(0.17)	1.33(0.13)	1.43(0.15)*	1 470(0.16)*	1.090(0.11)	1.23(0.16)*	1.23(0.09)*	1.37(0.12)*

Values at time1, time2, time3, and time4 were recorded at the beginning of the study, and after 6, 12 and 18 months respectively * p < 0.05 versus timel • p <0 .05 versus time3

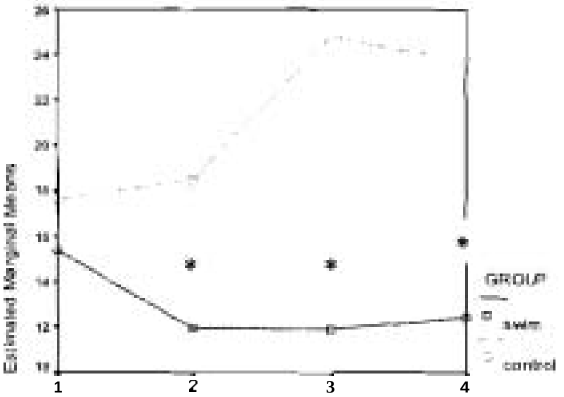

Figure **1** -The time-group interaction of **skinfold** thickness is significant (P < **0.05) * P < 0.05** versus the corresponding values in the control group.

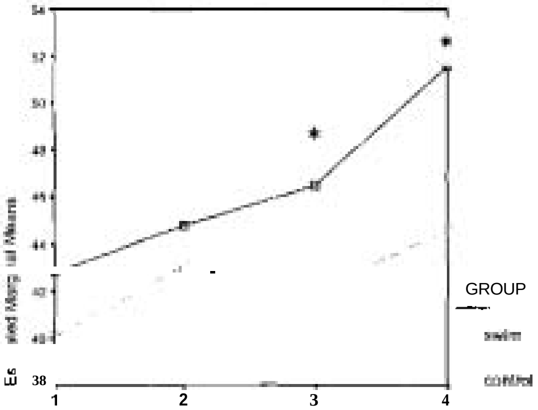

Figure **2** – The time-group interaction of VO_{2max} is significant (P **< 0.05) * P < 0.05** versus the corresponding values in the control group.

Data Analysis. In order to control the differences within and across groups, ANOVA with repeated measurements was used to determine the effects of different groups, different time spent participating in the exercise program, and the interaction of these two variables on the measurements. The significance level was set at 0.05.

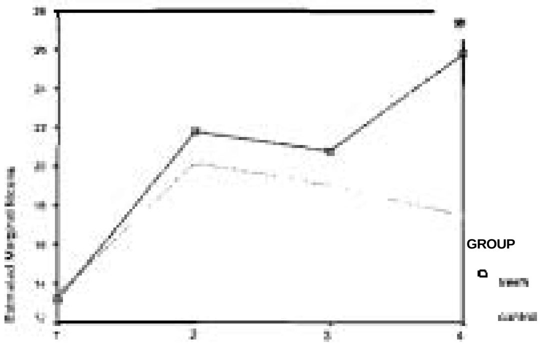

Figure 3 – The time-group interaction of back strength is significant ($p < 0.05$)
* $P < 0.05$ versus the corresponding values in the control group.

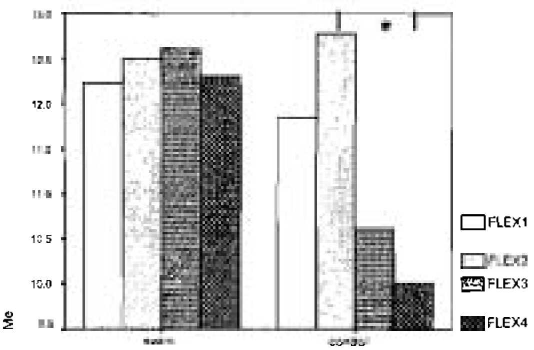

Figure 4 – Changes in flexibility in the two groups over time * ($p < 0.05$)

RESULTS: The results showed that the skinfold thickness of the control group increased with time. The values at 12 and 18 months were significantly greater than those at beginning of the study. In contrast, for the swimming group the values decreased slightly. Meanwhile, the interaction term between group and time was statistically significant ($p < 0.05$). Further simple effect testing showed that the swimming group had significantly lower skinfold thickness than those of the control group in the three time points after exercise (Figure 1).
Figure 2 illustrates the changes of VO_{2peak} in both groups. The VO_{2peak} values not only increased over time, but also had significant time-group interaction. The swimming group had significantly greater values of VO_{2peak} at the 12 and 18-month measurements than those of control group. The scores of the sit-up, standing long jump, and hand grip tests significantly increased with time in both groups, and did not show any significant difference between swimming and control groups (Table 1). For back strength, significant higher scores than those measured at starting point during the 6 month tests for both groups. Afterwards, the values from control group decreased slightly, but the test score from the swimming group significantly increased again. Statistical analysis found that there was significant time-group interaction and back strength of the swimming group at 18 months was significantly greater than that of the control group (Figure 3). The tendency of flexibility in the control group decreased significantly after 12 months, whereas that of the swimming group remained stable. However, there was no interaction between time and group (Figure **4).**

DISCUSSION: A primary goal of activity programs for youth is to promote physically active lifestyles that will be carried into adulthood, and thus reduce health problems related to inactivity (CSMF & CSH). Therefore, this study did not emphasise the intensity of exercise; rather, it focused on the need for children to live actively. After 18 months of regular swimming exercise, some of components of health-related fitness underwent interesting changes.
Skinfold thickness is a simple method of estimating body fatness in children. In this study, the sum of the skinfold thickness of the control group increased with growth, but that of swimming group decreased slightly. After the 6 months of exercise, the difference of the skinfold thickness of both groups was significant, which indicates that swimming can allow children to maintain lower body fatness. The tracking research undertaken by Simon (1998) indicated that preadolescents with high adiposity are more likely to remain so into adolescence. These stable characteristics may place them at greater risk for developing diseases later in life. Accordingly, increased levels of physical activity in children as early as possible is beneficial for maintaining an ideal body composition.
Some studies have indicated that exercise can improve VO2peak and submaximal exercise capacity in children (Jos et al., 2000; Thomas, 1995). The same result was found in this investigation, but the effects of exercise were still significant after 12 months. Compared with

other studies, the difference of changes may be related to the frequency, intensity, and duration of exercise.

Increased flexibility allows freer and more efficient movement with less resistance. In 7-12 year-old children, sit-and-reach values increase slowly, and occasionally even decrease (RSCHCS, 1988). The same tendency was observed in this study. However, the flexibility of the swimming group remained at a comparatively higher level than that of the control group. Since flexibility is not uniformly present in each joint, it is not a single characteristic. Because of this, physical activity should include specific exercises for each movement at each joint at which increased flexibility is needed (Hockey. 1993). The sit-and-reach test mainly determines the ability to stretch the lower back and hamstring muscles. The particular effect of swimming on the flexibility of the trunk may not be significant.

Among muscle strength and endurance in this study, only the back strength of the swimming group at 18 months was greater than that of the control group, which indicates that increased physical activity may produce stronger backs in children. However, the effect of exercise on muscles obviously occurred later than it did on body fat content and aerobic capacity. This result may be attributed to the development of back strength and the character of the specific exercise. Swimming is an excellent form of aerobic exercise, and provides a good training stimulus for the heart and lungs. Its effects on cardiorespiratory fitness and maintaining low body fat levels are prominent. Moreover, back strength requires the coordination of many muscles (Mayer 8 Gatchel, 1988), and swimming exercise uses almost all major muscle groups in the body, especially the upper body musculature. Therefore, this kind of exercise significantly improved back strength, but did not stimulate adequate gains in grip and leg strength. Different exercises give priority to improving the function of the muscle groups used in the exercise, so children should be encouraged to take part in different kinds of exercises. Meanwhile, because the benefits of swimming exercise for different health-related fitness components were gained after different periods of time, the long term value of physical activity should also be emphasised. This may help improve comprehensive health-related fitness in children.

CONCLUSION: This study demonstrated that 18 months of swimming exercise significantly improved VO2peak, back strength, and allowed children to maintain lower levels of body fat. However, flexibility, grip strength, and leg strength did not significantly change. These results may be attributable to the characteristics of growth in children, and the specific form of exercise studied.

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