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A Study on the Effects of Long Term Swimming on the Bodies of Young Children

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1. Introduction

Swimming is a sport which takes place in water, and as such the environmental conditions are very much different from those of land-based sports. The most different aspect of the swimming environment is the fact that humans can not breath underwater.

The time needed for breathing while swimming is usually about 1 second[12]. This is coordinated with the swimming stroke cycle, also about 1 second in duration. Thus, the breathing cycle in swimming is about 25% that of a comparable cycle[13] for resting condition on land. In addition, the inhalation cycle during swimming is to some degree inhibited, because of the pressure of the water against the abdomen and chest. Furthermore, expiration is labored because the swimmer is exhaling into the water. In this environment, over time, it is expected that the swimmer's respiratory muscle becomes stronger.

Meanwhile, in water, the body's specific gravity is ranged from 0.96-0.99 comparing with that of water. This being the case, a human immersed in water will be submerged at least as far as the forehead and thus breathing is rendered impossible. Therefore, in order to allow breathing, the efficient swimmer must assume face-down horizontal position with the head rotated to the side. For an athlete, the swimming stroke cycle takes 1 second. During this cycle the head is rotated to the side one time to facilitate breathing. If the distance of cycle is 1 meter and if the swimmer, in a typical workout course, covers 3,000 meters, then the head must be rotated in this manner a total of 3,000 times.

In the case of a well-experienced 11 or 12 year old swimmer, the respiratory function will be greatly affected by the swimming activity.

The pupose of this study will be to examine the effects of prolonged swimming on 11 and 12 year old children for getting some data of teaching method to young age peoples. So, these effects with respect to the children's height, weight, flexibility of the involved muscles, chest size, and respiratory function will be examined. Herewith are the results of the study.

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2. Procedures of the study

2.1 Characteristics of the respiratory function of the swimmer

2.1.1 Method of research

The research was conducted from August 1986 to May 1987 at a public primary school and three swimming clubs located in Tokyo.

The subjects consisted of forty 11–12 year old boys and girls. 20 of the participants (10 boys and 10 girls) had been swimming regularly for a period of at least 3 years, 5 days per week. This group will be called the swimmer. The second group of 20 children (also 10 boys and 10 girls) had no prior regular swimming experience. This is the students.

Those body parts measured for the experiment were the height, weight, chest size, back muscle strength, hand grip strength, abdominal flexibility, chest flexibility, vital lung capasity, the square of the total body surface area, expiration force, and inspiration force. Expiration and inspiration force was measured by means of causing the subjects to breath into a scaled hose (length 10 meters) which at the opposite end contained water (length 7 meters, 2,200cc). The amount of water displaced by the subject was measured (Refer to figure 1). The subjects were instructed to inhale and exhale to the maximum limit during an interval of two seconds in order to take the measurement.

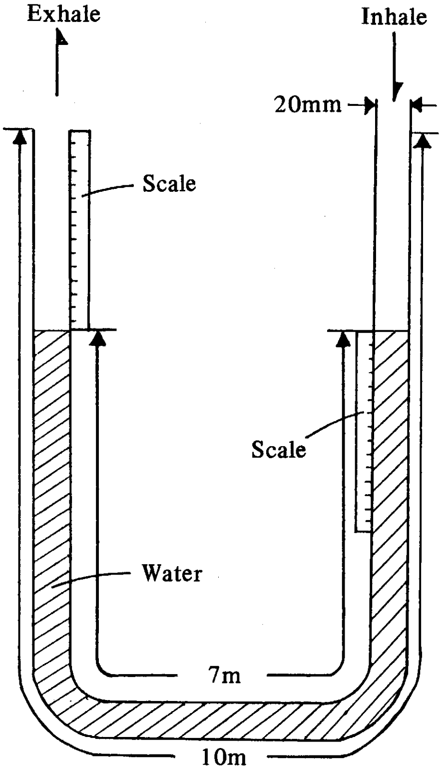

Fig. 1. Schematic illustration of apparatus for measuring respiratory force

2.1.2 Results of the investigation

Results of the investigation are presented in table 1. The difference between the results of the swimmer and the student were significant in chest size, vital lung capacity, expiration force and inspiration force. Moreover, abdominal flexibility was significantly different in the case of female subjects. There was no significant difference in the back muscle strength and hand grip strength across the two subject groups. However, in these areas, the swimmer tended to be stronger than the student.

2.2 Body symmetry of the subjects

2.2.1 Method of research

This research was conducted on September 26th and 27th, 1986 at a swimming club in Tokyo.

The measurements were conducted on forty 11 and 12 year old children (24 boys and 16 girls), all of whom had been swimming 5 days per a week, at least 2,000 meters per time,

Table 1. Average value and standard deviation of physical characteristics in two groups.

Items / Subject		Height (cm)	Weight (kg)	Chest Size (cm)	Back Strength (kg)	Grip Strength Right + Left (kg)	Abdominal Flexibility (cm)	Chest Flexibility (cm)	Vital Capacity (cc)	Total Square of Body Surface Skin (cm²)	Expiratory Force (cm)	Inspiratory Force (cm)
Swimmers	Male	145.7 6.5	39.2 5.9	74.5★ 6.5	88.3 22.9	42.5 8.6	4.4 1.6	4.2 0.9	2690.0★★ 543.8	123.4 10.5	98.6★ 20.7	86.4★★ 23.5
	Female	148.1 4.7	40.7 5.9	75.9 4.2	74.6 14.0	36.7 14.5	5.4 2.6	5.2 1.2	2573.3★ 282.0	131.0 9.3	76.0★ 13.3	70.8★★ 13.1
Students	Male	143.2 6.3	37.5 3.8	70.0 3.9	83.9 11.0	40.5 6.2	4.7 1.7	4.2 0.8	2166.0 357.2	123.5 8.4	81.2 24.8	76.7 16.0
	Female	148.8 5.7	41.0 4.5	73.2 3.5	67.9 19.5	37.7 6.9	3.4 1.2	5.3 1.2	2278.0 266.0	131.9 8.5	65.7 10.6	51.8 15.0

•Significant……★ P<0.5 Level ★★P< 0.01 Level

during a period of at least 3 years.

All of subjects were right-handed.

Those body parts measured for the experiment were height, skin fold (upper arm and back), right and left hand grip strength, forward body flexibility (right and left side, and together), behind back hand-to-hand touch[18] (right side and left side), and body rotation (right and left).

The behind back hand-to-hand touch mesurement was taken by instructing the subjects to place their hand back over the shoulder and flat to the back, extended as far as possible. The opposite hand was then placed, from the opposite direction, as near to or touching the first hand, extending as far as possible. The resulting measurement of flexibility was based on the degree to which the subjects could extend their hands in this manner. Measurement was made in centimeters.

The body rotation measurement was taken by instructing the subject to stand with the feet together and then to rotate the upper body as far as possible to one side. Four straight sticks were attached simultanously and respectively to the subject's head, shoulder, hip, and knee body sections. The rotation of the body was then measured from above using a video camera.

In addition to the above measurements, the subject's symmetry of shoulders, shoulder blades and hip bones was observed using a special apparatus. In addition to this, the subjects were instructed to bend foreward from the waist, with hands together and banbling free. In this way the curvature of flatness of the subject's back was observed.

2.2.2 Results of the research

The results are presented in table 2 and 3.

The technique of subjects in the crawl stroke was observed as follows: during swimming 14 subjects rotated their head to the right, 5 subjects rotated their head to the left, 21 subjects alternated between right and left.

Among all of the subjects there was no significant difference with respect to height, weight, or skin fold. All subjects were right-handed and there was a tendency for all subjects

Table 2. Average value and standard deviation of physical characteristics in three groups.

Items / Breathing Side	Height (cm)	Weight (kg)	Skin fold (mm)		Grip Strength (kg)		Foreward Body Flexibility (cm)			Back Behind Touch (cm)	
			Upper Arm	Back	Right	Left	Both	Right	Left	Right Up	Left Up
Right	141.1 7.8	34.8 5.9	12.1 4.6	8.9 3.6	17.5 3.4	16.5 3.3	11.1 5.1	12.3 4.5	11.8 4.5	4.9 6.7	0.9 9.5
Left	144.8 9.2	38.2 9.7	10.8 2.7	7.3 2.3	19.3 2.6	18.7 2.2	9.4 7.7	11.2 5.8	11.7 6.1	−0.7 11.2	1.2 9.0
Alternate	142.0 7.2	36.2 5.8	10.4 2.8	8.1 2.7	20.3 4.6	18.3 4.2	10.7 6.3	11.5 6.5	11.4 6.0	6.3 6.1	1.8 6.3

Table 3. Average value and standard deviation of body rotations in three groups.

Items / Breathing Side	Head Rotation (Right)	Shoulder Rotation (Right)	Hips Rotation (Right)	Knees Rotation (Right)	Total Rotation (Right)	Head Rotation (Left)	Shoulder Rotation (Left)	Hips Rotation (Left)	Knees Rotation (Left)	Total Rotation (Left)
Right	161.9 16.9	95.0 11.6	72.3 9.8	48.6 15.0	377.7 46.5	158.4 16.8	95.8 8.8	69.2 11.3	40.8 11.5	364.1 36.4
Left	165.4 11.2	94.0 5.5	65.6 7.8	36.0 9.4	361.0 31.0	159.2 20.2	94.2 7.8	70.1 10.8	46.8 13.5	370.4 44.1
Alternate	162.1 29.1	92.2 17.3	74.0 17.5	37.2 14.6	365.5 66.2	159.8 28.7	90.5 15.5	68.8 14.8	36.4 14.1	355.6 49.8

to be strongest in the right hand. In the measurement of body flexibility, right-breathing subjects were more flexible on the right body side and left-breathing subjects were more flexibile on the left body side. Across the right and left breathing groups, there was no significant difference in the degree to which the subjects were body flexible. Those subjects of the third group who alternated breathing between the right and left sides showed no significant difference in body flexibility between the right and left side. In behind back hand-to-hand flexibility, the right breathing subjects showed more flexibility in their right body side. Left breathing subjects showed more flexibility in their left body side. Those right and left alternating subjects showed considerably less difference between the right and left body sides than either of the two right-breathing or left-breathing groups.

In the measurement of head rotation, there was no significant difference across all subjects could rotate their heads to the right. Moreover the subjects from all three groups were about equally flexible in the shoulder rotation measurement. In the measurement of hip rotation, the subjects had greater flexibility in rotating to the habitual breathing side. Alternate side breathing subjects showed almost no difference in hip rotation flexbility to both the right and left sides. In the case of rotation at the knee, all subjects exhibited the same general tendency as for the above-descrived hip rotation. All subjects tended to be able to rotate to a greater degree at the knees as compared to the hips.

In the observation of body symmetry, among the three groups there was no significant difference in the condition of the three muscle regions (shoulders, shoulder blades, hips). However, there was a tendency among right-breathing subjects for the right shoulder region to be slightly rased. Also, there was an equal tendency among left-breathing subjects for the left shoulder region to be slightly rased.

In the observation of leaning back curvature, there was no tendency among subjects. The lean of all subjects was less than 3 degrees.

3. Discussion

People immersed in water will be affected by the pressure of the water against their bodies. While swimming, the swimmer's body extends into the water to a depth from 30 to 50 centimeters below the surface of the water. As a result of this, the in-water atomospheric pressure against the swimmer's body is from 1.03 to 1.05 atomosphers [1) 9)] . Therefore. the total square of gas changeable inside-surface area of the lungs is reduced during swimming [1) 4) 17)]. For breathing, this puts the swimmer at a disadvantage. Also, in water from 30 to 50 centimeters below the surface, vital capacity is reduced by 6 to 9 percent [7) 9) 13)]. As a result of this situation, any swimmer must train to improve their respiratory function involved vital capacity in order to offset this disadvantage. Accordingly, this discussion on respiratory function and capacity are concentrated first of all.

With respect to vital capacity, the results of this research showed that the swimmers have greater vital capacity than the students. It is thought that through swimming over a long period of time, vital capacity is increased. In previous research, the relationship between vital capacity and sex, height, weight, and squared body surface area has been established [2) 16)]. In this research, the body size of the swimmers and students was about the same. However, the vital capacity of the swimmers was significantly greater than that for the students. This observation was especially true in the case of the female subjects. It was observed that the chest size of the swimmers was significantly larger ($p<0.05$) than that of the students (Reffer to Fig. 2～4). This observation should be attribut-

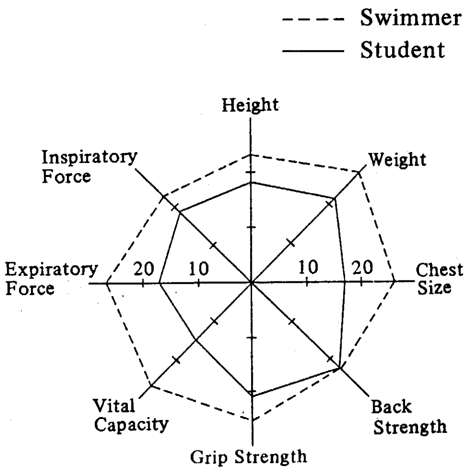

Fig. 2. Ranking graph of Parameters measured (Male)

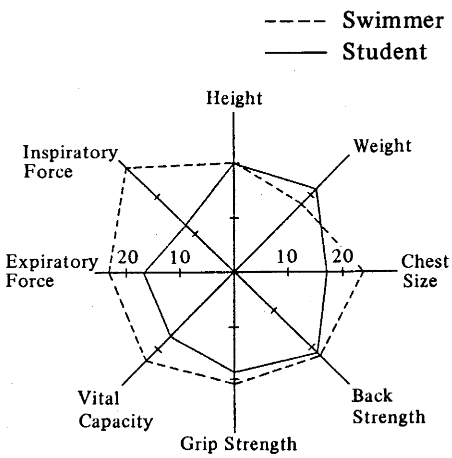

Fig. 3. Ranking graph of parameters measured (Female)

able to two reasons. First, the fact that in the pool the swimmer, because of the pressure of water against the body, must expand more effort to perform the same movement than they would out of the pool [9]. Secondly, the action of continually extending the arms over the head also influences chest size.

Usually, when the body is at rest, exhaling does not depend on muscle strength. However, after vigorous exercise, or during coughing, the breathing function depends on muscle strength. In this experiment, in the measrement of inspiratory and expiratory muscle capacity, maximum breathing force required the additional usage of many different muscles [6]. The strength of the respiratory muscles by themselves is difficult to measure. Taking this fact into account, the grip strength and back strength of all subjects. This being the case, any significant difference in measurement between the subjects in expiratory and inspiratory muscle strength was directly attributable to the respiratory muscles only, exclusive of other body muscle groups which might, at times, aid in breathing. Moreover, the subject's expiratory muscle strength was greater than the subject's inspiratory muscle strength because the former depends on the aid of body muscles in addition to the respiratory muscles. The swimmer's respiratory strength was greater than the students respiratory strength. The reason for this is that in the swimming environment the swimmers must consistently use more respiratory muscle strength than the students due the water pressure against the body of the swimmers. This view coincides with the findings of Ishico's thesis [5].

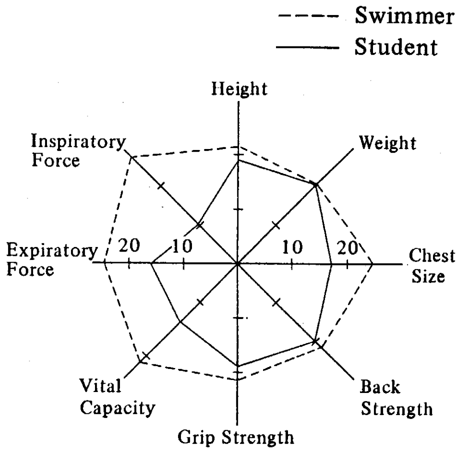

Fig. 4. Ranking graph of Paramenters measured (Total)

It is believed that swimming is a sport which requires body balance [14] and use of the whole body [9]. The number of people in the United States who participate in swimming activities during one year is greater than 100 million [19]. In the United States, a risk to children in the form of spinalcurvature damage as a result of the crawl stroke has been indicated [10] [11]. In response to these findings, the investigation of the relationship between head rotation in the crawl stroke and its effect on the body of children was undertaken in this experiment.

In the results of this experiment, no significant difference was found among swimmers with respect to the crawl stroke breathing direction and body flexibility. However, there was a slight tendency for swimmers to be more flexible on the body side from which they breathed. At the time of this experiment the swimmers were in the process of body development. These swimmers had been participating in swimming workout of more than 2,000 meter per time, 5 days per week, for period of at least 3 years. It was found that swimming did not contribute to imbalance or lack of body flexibility among young swimmers.

In the results of body rotation, the swimmers demonstrated greater 4 point body flexibility toward the direction from which they habitually breathed during swimming. Concerning the specific body rotation points, all swimmers showed greater head rotation flexibility in the right direction. In the case of shoulders, the same basic tendency was observed in all subjects. With respect to hips and knees, the swimmers showed greater flexibility to the direction from which they habitually breathed. This tendency was especially apparent in the knees rotation. Based on these results it can be concluded that knee and ankle rotation is influenced by the breathing direction in which the swimmer habitually breathes during swimming. On the other hand, it may be that the swimmer's breathing direction is influenced by the direction, to one side or another, in which the subject was originally more flexible at the knees and ankles. On this point, which influence is greater is not clear and further investigation is necessary.

In the measurement of body symmetry, there was no significant up and down variation observed in the involved body parts. However, the shoulder of the swimmer tended to be slightly raiŝed on that side from which the swimmer habitually breathed. The lean or back curvaure of swimmer was not significant. There does not appear to be any harmful effect on the bodies of young children resulting from the crawl stroke.

Swimming offers healthy benefits to the body [5) 14)]. In the swimming environment the swimmer's breathing is affected by the pressure of water against the body. Before undertaking this experiment it was felt that swimming somehow had both a positive and negative effect on the bodies of children. The results of this experiment showed that swimming has a positive effect on the respiratory function and chest size of the young swimmer. Concerning negative effects, it was shown that swimming affects the symmetrical balance of the child's body. However, this effect was very small and not thought to pose any serious risk to the child. It was observed that alternate-side breathing swimmers showed no imbalance in body symmetry. Therefore, we may conclude that alternate-side breathing is better than one-side breathing. For this reason, we should teach the alternate-side breathing technique to young practitioners of the crawl stroke. This belief is supported by Ben Davis. Moreover, Ben Davis has pointed out that alternated-side breathing gives an additional advantage to the competitive swimmer. In competitive swimming environment, alternated-side breathing allows the swimmer to check the progress opponents on both sides of their swimming lane.

Finally, since this experiment was concerned only with young swimmers who had a minimum of 3 years swimming experience, it will be important, in subsequent, research to expand this timeframe. A more thorough experiment should include the consistent, and regular observation of young subjects during the entire period from before the time they first begin swimming up to the years of early adulthood.

4. Conclusions

The purpose of this study was to investigate the effect of long term swimming on the bodies of young people and to discover an efficient swimming teaching method for young people. Therefore, 40 swimming and non-swimming children were measured for body structure, respiratory function, body flexibility, and body rotation. The results were as follows:

1) The swimmer's respiratory function was shown to be significantly superior to the function of non-swimmers with respect inspiratory(Male and Female $p < 0.01$), expiratory

(Male and Female $p<0.05$) force and vital capacity (Male $p<0.01$, Female $p<0.05$).

2) In the measurement of body structure, chest size (Male $p<0.05$) and abdominal flexibility of swimmers (Female $p < 0.01$) were shown to be significantly superior to those of non-swimmers.
3) Back strength and hand grip strength were not shown to be significantly different between swimmers. However, swimmers showed a slight tendency to be stronger in these area.
4) Body flexibility (Foreward flexibility and behind back hand-to-hand touch) was shown to be greatest on that side of the body at which the subject breathed during swimming. In the case of alternate side breathing swimmers, there was no significant difference in right or left body side flexibility as compared to the other two test groups.
5) In the measurement of body rotation, there was no significant difference in right or left side flexibility for the head and shoulder regions. However, with respect to the hip and knee regions, right-breathing swimmers were more flexible on the right side and left-breathing swimmers were more flexible on the left side. In the case of alternate side breathing swimmers, there was no significant difference in flexibility in those areas.
6) The right shoulder of right-breathing swimmers was slightly rased. The left shoulder of right-breathing swimmers was slightly rased. Alternate side breathing swimmers showed no particular tendency.
7) The degree of curvature of all subjects' back was less than 3 degrees. No relationship was found corresponding to the swimmers' habitual breathing sides.
8) Swimming has a positive effect on the body's respiratory function. one-side breathing, as compared to alternate-side breathing, tends to cause a slight imbalance in body symmetry.

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水泳運動が児童の身体に及ぼす影響について

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保健体育学

和　文　抄　録

本研究では，水泳運動が長年水泳を行ってきた児童の身体に及ぼす影響を調べ，学童期における水泳指導の基礎資料を得ることを目的とした。そのため，週当たり３日以上の水泳練習を３年以上にわたって行ってきた水泳児童40名とその対称群として日常特定の運動を行っていない一般児童20名を対象に，形態計測，呼吸機能検査，柔軟性および体捻転度の測定を行った。その結果，つぎのような結論を得た。

(1)　水泳児童の呼吸機能は，肺活量（男子は$P<0.01$，女子は$P<0.05$），呼息力（男女ともに$P<0.05$），吸息力（男女ともに$P<0.01$）の面において，一般児童に比較して有意に大きかった。

(2)　形態面では，胸囲（男女ともに$P<0.05$），腹部柔軟度（女子のみ$P<0.01$）において，一般児童に比較して水泳児童が有意に大きかった。

(3)　背筋力，握力は，両群間に統計学的有意性は認められなかったが，水泳児童の方がやや大きい傾向を示した。

(4)　体柔軟性（立位体前屈，後手たすき）は，呼吸方向への柔軟度が大きく，両側呼吸群では，片（右・左）側呼吸群に比較して後手たすき右上がやや大きいものの，左右差が小さい傾向を示した。

(5)　体捻転度は，頭部，肩部では呼吸側との関係は見られなかったが，腰部，膝部では呼吸側への捻転度が大きく，両側呼吸群では左右の差は見られなかった。また，下方部位にいく程，左右の捻転度の差が大きくなる傾向であった。

(6)　左右上下変動は，肩峰突起部において呼吸側に上昇が見られたが，肩甲骨上部および腸骨稜上部では見られなかった。

(7)　左右傾斜角は，全被検者ともに3°以下で，呼吸方向との関係は見られなかった。

(8)　以上のことから，水泳の呼吸機能にもたらす効果が認められたとともに，片側呼吸群では，両側呼吸群に比較して，身体の左右バランスに微小な不均衡性が認められた。