A STUDY OF POTENTIAL OLYMPIC SWIMMERS: I, THE STARTING POINT

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ABSTRACT

Physiological and anthropometric profiles of a group of successful young swimmers are presented. Anthropometrically the swimmers appear to fall within fairly narrow limits but are physically more mature than their peers. Physiologically there is greater diversity within the group representing perhaps the varying demands of the swimming events practised. All values for the physiological parameters measured are high compared with children of similar ages. For the future it is hoped to relate performance in swimming to the variables measured and to assess any changes which occur thus perhaps colouring the profiles presented here.

INTRODUCTION

The prestige associated with the winning of Olympic medals coupled with the national importance of being able to compete and succeed in sport at international level has led to a great deal of thought being applied to the methods employed in training athletes. Success in sport at the highest level is obviously dependent upon the training methods that have been employed throughout an athlete's career and therefore great emphasis is being laid upon the commencement of training very early on in a child's life, often in the pre-pubertal years. The training methods currently in vogue, particularly in swimming, involve young children in long, very strenuous training sessions over periods of several years and which effectively dominate their lives over the most important part of their development into adults. This rapid increase in the amount of training expected of these youngsters appears to have outstripped the literature that is available concerning the effects of this rigorous training and because of the change in emphasis of commencing training in the early pre-pubertal years there is a great need for longitudinal data to be collected (Cunningham and Eynon, 1975) to assess accurately the effects of the training. Therefore this paper is the first of what we hope will be a series of papers concerning the development and progress of a group of young potential Olympic swimmers. The study has two basic aims; first, to assess the performance capacity of each swimmer in order that a training regimen may be devised on a personal basis; second, to monitor the longitudinal effects of a very strenuous and vigorous training programme which is continuous over the very important pubertal years of a select group of young children. This first paper is concerned with the initial testing procedures and describes the swimmers in terms of both physiological and anthropometric parameters.

SUBJECTS AND METHODS

The subjects studied consisted of 9 male swimmers ranging in age from 13.4 yrs. to 19.7 yrs (mean age = 15.7) and 12 female swimmers ranging in age from 12.8 yrs. to 16.9 yrs. (mean age = 15.3). Each of the subjects was an active member of the newly formed City of Manchester Swimming Club, an exclusive club geared for high-level competitive swimming, and the training undertaken each day amounted to an average of 10,000 metres consisting of a variety of exercises. Furthermore, of the 120 swimmers who belong to this club, this group of 21 represented the best in the club by virtue of their times for various events compared with national times for the same events. As an indication of the standard of the group, one of the male swimmers had been a member of the British Olympic team in Montreal and 8 of the swimmers are already full or junior internationals. Furthermore if the best time for the best event of each of the individuals is compared to the World Record for the same event and age group ($\text{World Record} \div \text{Best Time} \times 1000$) the boys have a mean value of 889 and the girls have a mean value of 907, highlighting further the high level of competence present within the group.

Anthropometric measurements: A somatotype rating was developed for each of the swimmers using the Heath-Carter method outlined by Hebbelinck, Duquet and Ross (1972) and body density was predicted from the log of the sum of 4 caliper skinfold thicknesses (Durnin and Rahaman, 1967) the measurements being made on the left side of the body over the biceps, triceps, subscapular, and suprailiac regions. The percentage of fat in the body was calculated from the formula of Siri (1961) and subsequently the Absolute Body Fat and Lean Body Mass were also estimated. In addition several basic body measurements e.g. height,

weight and sitting height, were made using the methods outlined by Tanner (1964) and in order to eliminate inter-observer error all of the anthropometric measurements were taken by the same observer (K.M.B.).

Physiological Measurements: The vital capacity for each subject was measured using a Krausz Harari spirometer and the value recorded was the best of three attempts taken over 15 mins.

A work capacity test was performed on a variable load friction-type cycle ergometer (Monark-Sweden), each subject having been seated on the ergometer with the seat adjusted so that the leg was in a position of nearly full extension when the pedal was at the lowest part of its excursion. Each subject pedalled continuously at a standardised rate of 60 revolutions per minute for 10 minutes at three workloads. The first two work loadings varied with the sex of the subject (boys; 123 watts and 196 watts, girls; 74 watts and 147 watts) following a pilot study which showed the necessity for different work loads. These work loadings were used for 3 and 4 mins. respectively. During the 7th minute of work a work-load/heart rate graph was drawn and the final work load was set at a predicted heart rate of 170. All subjects then cycled for 3 min. at their predicted Physical Work Capacity 170 (P.W.C.170) work load.

Heart-rates were determined for two minutes prior to the exercise, for each minute during the exercise, and for 3 min. after completion of the exercise by auscultation at the common carotid artery for a 10 beat count using a "Heuer Pulse-rate" stop watch.

A Cambridge Scientific Instruments circuit, incorporating a Parkinson Cowan gas meter and Taylor Servomex oxygen analyser, enabled the continuous measurement of minute ventilation (VE) and oxygen uptake ($\dot{V}O_2$), which were corrected for S.T.P.D.

RESULTS AND DISCUSSION

Anthropometric Variables: the somatotype ratings were plotted on a modified Heath-Carter somatotype rating chart (See Fig. 1) and the average ratings for male and female swimmers were also calculated (Table I).

TABLE I
Average Somatotype Ratings

	Endomorphy		Mesomorphy		Ectomorphy	
Girls	2.1	S.D. 0.5	3.8	S.D. 0.9	3.5	S.D. 0.8
Boys	1.6	S.D. 0.6	4.6	S.D. 1.0	3.4	S.D. 1.0

As a group the swimmers were restricted to an area on the somatotype chart which accords closely to that described by Tanner (1964) as being representative of

Figure 1: The somatotype ratings of the swimmers.

● = girls

mean = ●

▼ = boys

mean = ▼

Olympic track and field athletes. The endomorphic component is low, the mesomorphic component is high and the swimmers appear average in terms of ectomorphy. On further analysis the girls have a higher endomorphic component than the boys who are considerably more mesomorphic. In terms of ectomorphy, the two sexes are similar. For the future it is hoped to correlate these somatotype ratings with the rankings of their abilities in terms of World Swimming Times and the various strokes and also to monitor any changes in these ratings as the younger swimmers pass through the pubertal years.

The results of the skinfold thickness measurements are shown in Table II.

TABLE II
Mean calculations from
the skinfold thickness measurements

	Body Density ±2.S.D.	Body Fat % ±2.S.D.	Absolute Body Fat kg ±2.S.D.	Lean Body Mass kg ±2.S.D.
Boys	1.070 ± 0.012	12.8 ± 5.4	8.1 ± 4.0	54.7 ± 13.3
Girls	1.051 ± 0.010	20.9 ± 4.0	11.3 ± 3.4	43.0 ± 4.1

The higher body density value for the male swimmers is a reflection of the higher mesomorphic component

and lower endomorphic component of the somatotype ratings shown earlier.

The percentage body fat calculations shown in Table II illustrate further this difference in endomorphic component between male and female swimmers and is highlighted by the difference in proportions between absolute body fat and lean body mass. Assuming that the power that is necessary for swimming is generated by the lean body mass and regarding the absolute body fat merely as extra weight to be carried, the average male swimmer has more power producing elements per unit of body fat than the average female swimmer. This might help to explain why a male swimmer can produce a faster time for a given distance for any stroke than his equivalent female counterpart.

TABLE III

Comparison of Anthropometric Measurements with Normal Standards

CENTILES

GIRLS N = 12

	3	10	25	50	75	90	97
Height — Age		7		7	3	1	1
Weight — Age	1		6	3	2		
Triceps Skinfold — Age	3	6	2	1			
Subscapular Skinfold — Age	2	6	3	1			
Sitting Height — Stature		2	3	3	3	1	

BOYS N = 9

	3	10	25	50	75	90	97
Height — Age			2	2	4		1
Weight — Age			1	1	6	1	
Triceps Skinfold — Age	1	2	5	1			
Subscapular Skinfold — Age	1		4	3		1	
Sitting Height — Stature		2	1	2	3		1

Where normal standards were available (from the Institute of Child Health, London 1977) an assessment was made concerning the normality of the basic anthropometric measurements of the swimmers. (See Table III).

As a group the swimmers were tall for their age with none of the girls being below the 50th centile and over half of the boys being above the 75th centile. In terms of weight the girls centre around the 50th centile whilst 7 of the 9 boys were above the 75th centile. This combination therefore reflects once more the average ectomorphic somatotype component discussed earlier but indicates that these swimmers are physically much larger for their age than their normal peers.

The low somatotype rating of endomorphy for the group is highlighted further by the comparison with normal standards for both triceps and subscapular skinfold measurements and although the girls had a higher average body fat percentage than the boys this did not manifest itself in the comparison with the normal skinfold thickness measurements, a larger proportion of the girls being below the 10th centile for their age.

A comparison of sitting height with stature reveals that neither of these parameters is dominant. Some of the swimmers do certainly have long legs compared with their body length but equally so do some of the swimmers have short legs compared with their body length. It might be argued that from the figures in Table III there might be a tendency for a swimmer to have long legs compared to his body length but the lack of numbers of subjects in this respect limits the production of any firm conclusions.

It is hoped that these anthropometric measurements may be used in later stages of the study when more normal standards become available and when further measurements have been made. In addition it is hoped to correlate these measurements with swimming performances and to supplement them with an assessment of physical maturity e.g. menarche.

Physiological Variables: Maximal work tests demand full effort from the subject and the end point is partly dependent upon both motivation and determination which vary to a large degree from subject to subject. For this reason the work test used in this study was based on standard submaximal work loads from which the P.W.C. 170 could be predicted for each subject and used as a final work load. P.W.C. 170 represents the expected work load that would be performed at a pulse rate of 170 to indicate "maximum" working capacity, the term "maximum" being used to refer to the greatest work load that can be maintained in a steady state. P.W.C. 170 values, predicted using steady state heart rates obtained during the first two work loads showed a group mean of 218 Watts with a range from 159 Watts to 380 Watts. Although the boys have a higher working capacity than the girls in terms of gross P.W.C. 170 values (boys 223 Watts, girls 214 Watts, Table IV) the trend is reversed when values are corrected for lean body mass, the girls having higher P.W.C. 170 of 5.0 Watts/kgLBM compared

with the 4.1 Watts/kg LBM for the boys. The group mean of 3.8 Watts/kg with a range from 2.9 – 7.0 Watts/kg for P.W.C. 170 related to total body weight is considerably greater than the findings of Cunningham and Eynon (1975) in a study examining the working capacity of Canadian swimmers between 10-16 years of age although our value for male swimmers (3.5) accords very closely with their values and it is our female swimmers who have the significantly higher value (3.9). Perhaps this merely reflects the difference in ability between the two groups of swimmers studied, Cunningham and Eynon (1975) having selected their swimmers on a more general basis with a much wider range of ability. Furthermore our results are considerably larger than the values reported in other research using children not engaged in intensive athletic training (Adams et al., 1961, Cumming and Cumming 1963, Cumming and Friesen 1967, Howell and MacNab 1968, Seliger et al., 1971, Shephard 1971).

Fitness scores (Table IV) were calculated using a slight modification of the formula proposed by Johnson, Brouha and Darling (1942). The validity of using only three heart-rate determinations has been adequately shown and is based on the principle that the rate at which an individual's heart rate slows down after it has been accelerated by strenuous exercise can yield an index of his fitness (Gallagher 1944). Results for Fitness Index (F.I.) show little difference between the boys (F.I.

167) and the girls (F.I. 176) the lowest F.I. values being attributable to poor recovery rates for the first minute of recovery. The group as a whole however showed dramatic 27% recovery during the first minute which slows to 9.5% between recovery minutes 1 and 2 and to 4.5% between recovery minutes 2 and 3.

The respiratory demands made upon the body in competitive swimming are large and therefore the respiratory values for this group of outstanding swimmers are of particular interest. The group has a mean vital capacity (V.C.) of 4.6 litres with the boys (4.9) having a 17% larger V.C. than the girls (4.3). (Table V). These values are well above the values for V.C. quoted by Seely, Guzman and Becklake (1974) from their study using Canadian children who are not in training.

Maximum minute ventilation (VE) during exercise reached 64.3 l/min for the group with a large range of values from 46.4 l/min to 90.1 l/min. The larger lung volumes of the boys may account for their higher VE of 72.1 l/min compared to the 56.5 l/min for the girls.

One of the most reliable measurements of cardiorespiratory function during a work test is the measurement of oxygen consumption (VO_2) (Cumming and Cumming, 1963). The oxygen extraction and transporting systems play a vital role to any athletic performance.

TABLE IV
P.W.C. 170, heart rate % recovery, and fitness index based on exercise and recovery heart rate values

	P.W.C.170 watts	P.W.C.170 watts/kg	P.W.C.170 watts/kg.LBM	HEART RATE % RECOVERY			FITNESS INDEX Time in secs. x 100 H.R. Recovery 1 + 2 + 3
				Max. H.R. — Max. H.R. 1 min.	Recov. H.R. x 100 2 min.	3 min.	
WHOLE GROUP							
Mean	217.9	3.8	4.5	27	37	41	173
Range	159.4-380.1	2.9-7.0	3.6-8.7	17-38	26-57	36-53	145-225
N = 17							
BOYS							
Mean	222.5	3.5	4.1	29	37	41	167
Range	174.1-272.2	2.9-20.4	3.6-4.6	20-34	28-41	37-44	145-182
S.D.	32.5	0.4	0.5	5	5	2	13
N = 8							
GIRLS							
Mean	213.5	3.9	4.9	25	36	41	176
Range	159.4-380.1	2.9-7.0	4.1-8.7	17-38	26-57	36-53	158-225
S.D.	74.6	1.4	1.6	6	9	6	23
N = 9							

TABLE V
Respiratory results for the group

GROUP	Vital Capacity litres	Maximum Ventilation during exercise l/min	Max. $\dot{V}O_2$ during exercise ml/kg LBM	Predicted Max. $\dot{V}O_2$ ml/kg LBM	O ₂ Pulse ml/beat
Me					
Mean	4.6	64.3	61.7	72.5	16.2
Range	3.5–5.9	46.4–90.1	48.2–83.4	44.5–105.3	10.5–23.2
N = 17					
BOYS					
Mean	4.9	72.1	64.6	65.9	17.9
Range	4.0–5.9	56.6–90.1	53.3–83.4	44.5–84.9	15.1–23.2
S.D.	0.8	11.9	11.8	12.0	3.0
N = 8					
GIRLS					
Mean	4.3	56.5	58.8	79.0	14.4
Range	3.5–5.1	46.4–66.9	48.2–69.3	59.7–105.3	10.5–17.7
S.D.	0.5	8.5	8.7	14.2	2.8
N = 9					

and no less in swimming. When related to the dynamic tissue content of the body (Lean Body Mass) the boys showed a higher oxygen uptake of 64.6 ml/kg L.B.M. with a range from 53.3 to 83.4 ml/kg L.B.M. with the girls' values ranging from 48.2 to 69.3 ml/kg L.B.M. with a mean value of 58.8 ml/kg L.B.M. The overall group mean was 61.7 ml/kg L.B.M. and it would appear that even in young swimmers aerobic capacity is well developed. Maximum $\dot{V}O_2$ values predicted for each swimmer from submaximal $\dot{V}O_2$ values according to the technique described by Åstrand and Rodahl (1970) were not appreciably higher than those measured during the final 3 min. of exercise showing that many subjects were working above 90% of their maximum. Predicted max. $\dot{V}O_2$ mean values were higher for the girls (79.0 ml/kg L.B.M.) than the boys (65.9 ml/kg L.B.M.) with a group mean of 72.5 ml/kg L.B.M. The upper value for the girls is particularly significant with a value of 105.3 ml/kg L.B.M. representing a gross predicted $\dot{V}O_2$ max. of 4.6 l/min. for one of the younger subjects. The highest gross predicted $\dot{V}O_2$ max. for the boys is 4.5 l/min. Oxygen pulse (ml/beat) calculated from values taken during the first minute of work summarises the efficiency of the cardiorespiratory system. The amount of oxygen transported for each contraction of the heart is significantly higher for the boys at 17.9 ml/beat (range 15.1–23.2 ml/beat) than for the girls at 14.4 ml/beat (range 10.5–17.7 ml/beat). The overall group mean is 16.2 ml/beat with a range from 10.5–23.2 ml/beat.

The individual profiles for the subjects in this group of swimmers reveal some outstanding physiological

potential in terms of cardiovascular and cardiorespiratory adjustments to severe exercise. A longitudinal study of this kind should be of great interest in monitoring the development of this potential with age, experience and training. At this stage it is also of interest to note that some subjects can be roughly categorised into "work efficient" and "recovery efficient" but it remains to be seen whether or not this is significant. Besides achieving good recovery heart rates and high F.I. some subjects display poor continuous adjustments during work in terms of low PWC 170 values, low predicted max. $\dot{V}O_2$ values and poor O₂ pulse readings. Only time will tell whether general cardiorespiratory efficiency improves with training or whether it is event specific in terms of sprint or distance performance.

As the first in a series of papers involving a longitudinal study of a group of successful young swimmers this paper has attempted to describe the group using both anthropometric and physiological parameters. It is hoped to develop these profiles further using other parameters, bearing in mind their deviation from the normal. In addition, it is hoped to relate this development directly to swimming performance.

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