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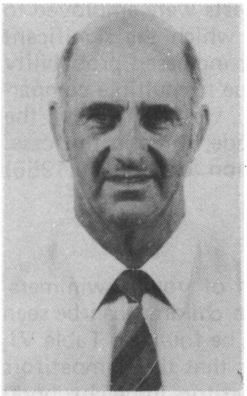

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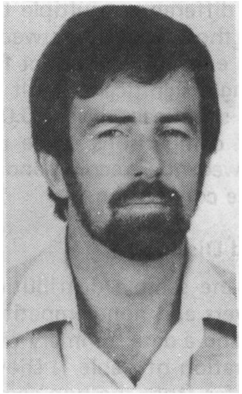

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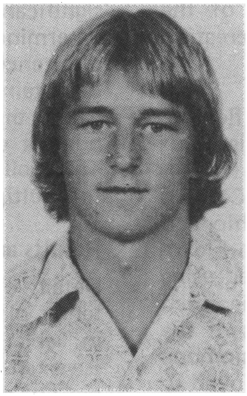

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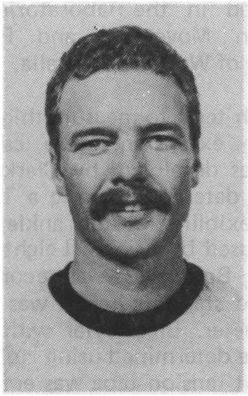

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BIOLOGICAL CHARACTERISTICS OF YOUNG SWIMMERS, TENNIS PLAYERS AND NON-COMPETITORS

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ABSTRACT

One hundred and twelve finalists in the State Swimming Championships aged between seven and twelve years and 65 ranked tennis players of similar age were selected on the basis of their sporting performances. A third group comprised children of similar socio-economic status who only took part in casual sport. The tests which were used in the study were those considered to be important for successful athletic performance. A multifactorial analysis of variance and post-hoc t-tests were applied to the data to determine if any statistical differences were apparent between the three groups. The results demonstrated that no size, body shape, flexibility, strength or lung function differences were evident between the competitors and non-competitors, but that the swimmers and tennis players were superior to the non-competitors in cardiovascular endurance.

INTRODUCTION

The question of whether champion athletes are born or made has long puzzled coaches and scientists alike. This question could possibly be clarified by using a longitudinal growth study following a random selection of subjects from infancy to adulthood. Such studies however are difficult and costly to complete, therefore scientists have tended to use cross-sectional designs in an effort to provide further insights into the development of champion athletes.

The purpose of this study was to attempt to identify the anatomical and physiological characteristics which differentiate young swimmers, young tennis players and non-competitive schoolchildren from one another.

Procedures

Subjects: A total of four hundred and six subjects in three separate groups aged between seven and twelve years inclusive were used in the study. These children were classified into one of three groups according to their involvement in sporting competition. The 112 subjects in the first experimental group were either finalists or reserve finalists in the 1981 Western Australian State Swimming Championships. The other experimental group comprised 65 children who regularly attended tennis training with senior coaches of the Western Australian Lawn Tennis Association and they were selected according to similar criteria to that of the swimmers. These subjects will be called competitive groups. The 229 subjects in the third sub-population, known as the non-competitive group, were randomly selected from State Primary Schools, based on the criteria that they were only involved in casual sport. The sample for this group was chosen on a socio-economic basis to match the status of the competitive groups.

Administration of the Tests: The tests employed in this study were administered in the laboratories of the Department of Human Movement and Recreation Studies at the University of Western Australia.

Cable tension strength tests to measure thigh flexion, leg extension and arm extension, were carried out following the procedures developed by Clarke (1976), while grip strength was determined using a TEC Hand Grip Dynamometer. Flexibility at the ankle, hip and shoulder joints was assessed by using a Leighton Flexometer (Leighton, 1942). Body mass was recorded using a Seca balance scale and standing height was measured with a Holtain stadiometer. Bicondylar widths of the humerus and femur were determined using Holtain bone calipers, while a constant tension tape was employed to measure the calf and arm girths of each subject. Harpenden skinfold calipers were utilised to assess triceps, subscapular, suprailiac and calf skinfolds. The sum of the triceps, subscapular and suprailiac measures was subsequently used to provide an indication of body fat. In addition, relevant measurements from the above tests were used to calculate the somatotype of each subject according to the Heath-Carter Somatotype Method (Carter, 1980).

A Vitalograph Single Breath Wedge Spirometer was used to assess Forced Vital Capacity (FVC), and Forced Expiratory Volume in the first second (FEV_1), while a PWC_{170} test was employed to determine the physical exercise capacity of each subject on a Monark bicycle ergometer.

Data Analysis

An analysis of variance was applied to the data to determine whether there were significant differences between the three groups over each age and sex classification. In this analysis, a hierarchical approach was necessary so that any significant age or sex effect may be accounted for prior to assessing the effect of different treatment groups. This procedure was employed due to the unbalanced nature of the research design (Aitken, 1978).

Interactions between age, sex and treatment were not significant which indicated that treatment effects did not depend on sex and age. These interaction terms were therefore dropped from the model (Aitken, 1978). Similarly, when testing the significance of the main effects, if age and sex effects were significant for the variable in question, they were retained in the model. This procedure accounted for differences due to age and sex which, because of the unbalanced design, had to be eliminated prior to the assessment of the treatment effects. A significance level of 0.025 was adopted to compensate for the overall possibility of a Type I error due to the multiple F tests used in the analysis (Aitken, 1978).

For those variables where the F ratio indicated a significant difference, multiple t tests were employed to determine those groups between which the significant differences existed. To correct for increased probability of obtaining a significant result due to multiple comparisons, the significant level (0.05) was divided by the number of comparisons to be made, three in this case. This followed the recommendation of Miller (1956) for multiple comparison.

Results and Discussion

Details of the sample distribution of young swimmers, tennis players and non-competitive children can be seen in Table I and a data summary can be found in Table VI. An examination of Table II shows that the competitors did not differ from the non-competitors in height, body mass or somatotype. This observation supports the findings of a number of previous studies (Magel and Andersen, 1969; Sobolova et al, 1971; Andrew et al, 1972; Cunningham and Enyon, 1973). Body fat, as determined by the sum of three skinfold measures (triceps, subscapular, supra-iliac), was found to be significantly lower among the swimmers when they were compared to the non-competitive group. This result was similar to that of earlier studies (Sobolova et al, 1971; Vaccaro et al, 1980) and it is probable that the high energy output required in swimming training is responsible for this difference.

TABLE I

Number of subjects included for each treatment, age and sex classification

	Age					
	7-8		9-10		11-12	
	Male	Female	Male	Female	Male	Female
Swimmers	5	5	17	19	31	38
Tennis Players	5	5	19	13	13	10
Non-competitors	15	28	66	62	25	33

With respect to joint mobility, this study revealed that the young swimmers had less arm flexion-extension mobility at the shoulder joint than the non-competitors (see Table III), which was in contrast to studies of adult swimmers (Cureton, 1940; Bloomfield, 1967). Further study of flexibility impeding factors such as increased muscle mass, connective tissue and bone shape around the shoulder joint in swimmers is necessary to explain this result. The swimmers displayed significantly more thigh latero-medial rotation at the hip joint than their non-competitive counterparts. Greater thigh rotation would allow the swimmer to turn the leg outwards during the breaststroke, and inward during the other racing strokes to apply more force against the water, and this would presumably be an advantage. The tennis players demonstrated less hip mobility than the non-competitors, but in sports such as tennis, rotation of the thigh at the hip may be of little benefit. The results of

TABLE II

Group comparisons of height, body mass, body fat and somatotype components

Variable	Treatment Effect	Swimmers (S) vs Tennis Players (T)	Swimmers (S) vs Non-competitors (N)	Tennis Players (T) vs Non-competitors (N)
Height	F=4.54**	t=3.02* S > T	t=1.373	t=2.207
Body Mass	F=1.04			
Body Fat	F=3.78**	t=0.67	t=2.64* S < N	t=1.524
Endomorphy	F=3.24			
Mesomorphy	F=0.16			
Ectomorphy	F=2.63			

** Significant at the 0.025 level of confidence.

* Significant difference between the treatment groups at the 0.05 level of confidence (adjusted for multiple comparisons).

TABLE III

Group comparisons of flexibility measures

Variable	Treatment Effect	Swimmers (S) vs Tennis Players (T)	Swimmers (S) vs Non-competitors (N)	Tennis Players (T) vs Non-competitors (N)
Arm Flexion-Extension	F= 9.82**	t=1.52	t=4.34* S < N	t=2.05
Thigh Latero-medial Rotation	F=13.33**	t=5.10* S > T	t=2.55* S > N	t=3.57* T < N
Ankle Dorsi-Plantar Flexion	F= 0.67			

** Significant at the 0.025 level of confidence.

* Significant difference between the treatment groups at the 0.05 level of confidence (adjusted for multiple comparisons).

this study also showed that the three groups did not differ in the measurement of foot dorsi-plantar flexion at the ankle. This was in contrast to the finding of Bloomfield and Blanksby (1971) and may be due to the high degree of flexibility at the ankle joint naturally evident in the younger children in this study in comparison with the University students measured by Bloomfield and Blanksby (1971).

The results of the strength tests revealed that the non-competitors had greater thigh flexion strength than the swimmers (see Table IV) thus failing to support the finding of Bloomfield and Blanksby (1971) who found that University swimmers were stronger than adult non-competitors. In contrast, the swimmers displayed significantly greater grip strength than the non-competitors. This was similar to the finding of Cureton (1951) for adult swimmers. The fact that the tennis players were not different from the non-competitors on the grip strength measurement conflicts somewhat with the findings of Vodak et al (1980) and Powers and Walker (1982) for older tennis players. The age difference in the subjects may provide a possible explanation for the contrast between the children in the present study and the more mature athletes in previous studies.

TABLE IV

Group comparisons of the strength measurements and the vertical jump test

Variable	Treatment Effect	Swimmers (S) vs Tennis Players (T)	Swimmers (S) vs Non-competitors (N)	Tennis Players (T) vs Non-competitors (N)
Thigh Flexion Strength	F= 3.99**	t=0.09	t=2.46* S < N	t=2.02
Leg Extension Strength	F= 6.55**	t=3.60* S < T	t=1.56	t=2.70* T > N
Arm Extension Strength	F=37.13**	t=6.22* S > T	t=1.81	t=8.56* T < N
Grip Strength	F= 4.99**	t=0.85	t=3.06* S > N	t=1.69
Vertical Jump	F=11.31**	t=1.75	t=2.90 S > N	t=4.47* T > N

** Significant at the 0.025 level of confidence.

* Significant difference between the treatment groups at the 0.05 level of confidence (adjusted for multiple comparisons).

The tennis players recorded significantly greater leg exhaustion strength than the non-competitors and swimmers. The fact that these young sportsmen and women are involved in a weight-supporting activity which involves rapid acceleration and change of direction may provide an explantion for this result. When compared with the non-competitors and swimmers, the tennis players revealed lower arm extension strength scores. This was a surprising result, as tennis players might have been expected to be stronger or at least as strong as non-competitors, since the shoulder extension movement is required in the tennis serve and other strokes.

The swimming group demonstrated superior FVC to the non-competitors and tennis players (see Table V). This result was supported by the findings of a large number of studies (Newman et al, 1961; Åstrand et al, 1963; Magel and Andersen, 1969; Engstrom et al, 1971; Vaccaro et al, 1980), some of which reported that the swimmers were taller than the non-athletes, therefore providing an explanation for the greater FVC. However the subjects in this study did not differ in height and other factors must have been responsible for the greater FVC demonstrated by the swimmers. It is possible that the increased work required of the respiratory muscles due to immersion may have resulted in an increased FVC in the swimmers. This result is substantiated by Andrew et al (1972) who controlled for the effects of height and found swimmers to have a superior FVC when compared to the non-competitors. No significant difference was found between the groups in the measure of FEV_1.

TABLE V

Group comparisons of the pulmonary function and physical exercise capacity tests

Variable	Treatment Effect	Swimmers (S) vs Tennis Players (T)	Swimmers (S) vs Non-competitors (N)	Tennis Players (T) vs Non-competitors (N)
FVC	F=10.15**	t=3.51* S > T	t=4.28* S > N	t=0.25
FEV_1	F= 1.88			
PWC_{170} body $mass^{-1}$	F=21.57**	t=1.46	t=6.22* S > N	t=3.73* T > N

** Significant at the 0.025 level of confidence.

* Significant difference between the treatment groups at the 0.05 level of confidence (adjusted for multiple comparisons).

An examination of Table V shows that the swimmers and tennis players had superior physical exercise capacity scores relative to body mass when compared to the non-competitors. This finding was in agreement with a number of studies which had reported higher oxygen uptake and PWC_{170} values in young swimmers and tennis players when compared to untrained children of the same edges (Åstrand et al, 1963; Sobolova et al, 1971; Cunningham and Enyon, 1973; Robinson et al, 1978; Powers and Walker, 1982).

On the basis of the above results, it is clear that young competitive children in swimming and tennis show no body shape or size differences at this stage of development when compared with non-competitors. Apart from leg extension strength, there were no significant differences in the strength and flexibility measures for the competitors. This included measures relating to the shoulder girdle which is an important anatomical region for swimmers and tennis players and it could therefore have been expected that they would demonstrate a distinct superiority in this region. A significantly different finding did exist in leg extension strength where the tennis player exhibited greater strength than both the swimmers and the non-competitors. This is to be expected because the propping, jumping and explosive change-of-direction movements which are common in tennis, require more strength than the submaximal rhythmic motions carried out around the hip region in swimming, where the body mass is supported in water. The major difference however, occurs between the competitors and non-competitors in the PWC_{170} measurements. In the measurement of power, determined by the vertical jump, both swimmers and tennis players scored significantly higher than did the non-competitors.

It would appear that at these ages physical size, body shape, strength, flexibility and lung function are not important factors in high level performance as the subjects in this study showed few definitive differences in the tests which were considered to be valuable in differentiating competitors from non-competitors. It is well known however, that there are considerable size, body shape, strength and flexibility differences in post-adolescent males and females competing at a high level in swimming and tennis when they are compared to non-competitors (Bloomfield and Blanksby, 1971; Elliott et al, 1982). One question that arises is whether pre-adolescent children need the rigorous strength and flexibility training which many coaches feel is important for them at this time. Possibly it could be more valuable to develop technique during pre-adolescence and then concentrate on developing the above-mentioned physical capacities during adolescence when one could obtain increasing returns from strength training.

A further point which arises from the findings is related to the effect of training on the competitors. Firstly, the swimmers had less body fat and higher FVC than either the tennis players or the non-competitors, while both competitive groups had higher physical exercise capacities (PWC_{170}) than the control group who did not take part in intensive training for any particular sport. There is some contention among coaches as to whether there should be more sprint type training for pre-adolescent children or whether it should be mainly endurance in nature. While the principles of specificity of training are always important, it appears that pre-adolescent children can adapt to aerobic work in a similar fashion to adults (Eriksson, 1972). The maximal a-VO_2 differences are also similar for children and adults (Eriksson, 1972, 1978) and some evidence suggests that training during pre-adolescence and adolescence produces a greater increase in the size of the cardiorespiratory system organs than training in later life (Åstrand et al, 1963; Eriksson, 1972). However, aerobic work at 70% of maximal oxygen uptake for longer than one hour puts a child at a disadvantage because of the smaller relative and absolute storage capacity of muscle glycogen, the depletion of which is associated with fatigue (Eriksson, Karlsson and Saltin, 1971 (a), (b); Eriksson, 1972; and Eriksson working with Gollnick and Saltin, 1973).

A high correlation exists between maturity levels and the development of the lactacid energy capacity. Because children demonstrate lower maximal lactic acid levels in muscles and in blood after a maximal workload and lower lactic acid levels at all sub-maximal workloads when compared to adults (Eriksson, Karlsson and Saltin, 1971a; Karlsson, 1971), large amounts of anaerobic work for young children would appear to be contra-indicated. Further, children possess lower concentrations of phospho-fruktokinase (PFK) which is the rate limiting enzyme in glycolysis (Eriksson, Gollnick and Saltin, 1973). Therefore aerobic work with much more attention to the acquisition of an efficient technique would appear to be the most beneficial form of training for pre-adolescent children.

In as much as several authorities have expressed the opinion that vigorous training of young children can be inherently dangerous, the results of this study suggest that, in terms of growth at least, there were few differences between the groups and therefore normal growth patterns do not seem to be endangered. As the major

TABLE VI

Means and standard deviation results for measured variables

		Swimmers			Tennis Players			Non-competitors		
Variable		7&8yrs	9&10yrs	11&12yrs	7&8yrs	9&10yrs	11&12yrs	7&8yrs	9&10yrs	11&12yrs
Height (cm)	x	130.1	136.4	148.7	126.3	134.9	144.0	130.0	135.6	147.7
	SD	5.2	6.5	7.8	5.5	4.8	6.8	5.2	5.8	8.1
Body Mass (kg)	x	28.0	31.0	39.2	27.5	30.4	36.6	28.4	30.8	39.2
	SD	4.6	5.3	6.2	4.5	3.5	5.8	3.3	4.7	7.9
Body Fat (mm)	x	28.1	26.7	28.8	29.9	25.0	27.4	29.1	27.8	33.8
	SD	12.3	10.2	11.4	16.0	8.5	11.6	9.9	10.7	15.6
Endomorphy	x	2.9	2.6	2.9	2.9	2.5	2.7	2.9	2.8	3.4
	SD	1.0	1.1	1.2	1.5	0.9	1.1	1.1	1.1	1.5
Mesomorphy	x	4.3	4.0	3.9	4.6	4.1	3.9	4.2	4.1	3.9
	SD	0.8	0.8	0.8	0.7	0.7	0.9	0.9	0.9	0.9
Ectomorphy	x	2.4	3.3	3.6	2.3	3.1	3.3	2.7	3.1	3.4
	SD	1.0	1.1	1.0	1.1	0.8	1.0	1.0	1.0	1.1
Arm Flexion-Extension (deg)	x	230.0	233.0	234.0	238.0	240.0	231.0	238.0	237.0	230.0
	SD	16.0	16.0	16.0	9.0	14.0	14.0	19.0	19.0	21.0
Thigh latero-Medial Rotation (deg)	x	140.0	139.0	136.0	139.0	120.0	117.0	134.0	134.0	132.0
	SD	25.0	30.0	23.0	41.0	21.0	22.0	25.0	24.0	23.0
Ankle Dorsi-Plantar Flexion (deg)	x	79.0	79.0	82.0	77.0	79.0	73.0	81.0	80.0	77.0
	SD	8.0	9.0	10.0	10.0	9.0	10.0	14.0	12.0	10.0
Thigh Flexion Strength (kg)	x	23.0	29.2	35.7	22.4	28.8	33.5	27.1	29.2	34.6
	SD	3.3	5.6	8.2	2.9	4.6	9.0	8.8	8.4	10.6
Leg Extension Strength (kg)	x	24.9	31.0	35.8	26.9	32.1	36.4	25.2	28.1	35.0
	SD	5.1	6.6	8.8	5.3	5.9	8.2	7.6	7.1	10.9
Arm Extension Strength (kg)	x	19.0	21.2	27.6	15.8	18.8	20.4	19.2	20.2	25.5
	SD	5.4	5.4	7.6	3.2	3.7	4.8	5.4	6.0	8.6
Grip Strength (kg)	x	10.0	10.9	16.3	7.4	11.0	15.0	8.6	10.5	14.4
	SD	2.4	2.8	4.4	2.9	2.5	3.4	2.1	2.6	3.6
Vertical Jump (m)	x	20.0	0.24	0.27	0.20	0.25	0.28	0.20	0.22	0.25
	SD	0.04	0.03	0.04	0.04	0.05	0.06	0.04	0.05	0.05
FVC (litres)	x	1.70	2.02	2.52	1.43	1.88	2.30	1.56	1.83	2.32
	SD	0.35	0.42	0.57	0.34	0.31	0.46	0.19	0.31	0.42
FEV_1%	x	88.1	85.8	85.7	84.3	86.4	87.1	90.2	88.5	86.3
	SD	7.1	6.0	7.9	8.7	9.3	7.1	5.9	6.9	7.2
PWC_{170}.body mass^{-1} (kg.min.kg^{-1} min^{-1})	x	12.1	12.55	13.31	12.0	13.0	12.6	10.33	11.45	10.41
	SD	2.6	2.4	3.2	3.7	3.1	2.3	2.6	2.7	3.02

differences were in the improvement of cardiovascular endurance, the exercise programme can only be considered beneficial to the recipients.

In order to provide more definitive answers to several points which arise from this study it appears to be important that subjects in the various sub-populations of competitive swimming, competitive tennis and non-competitors should be tested regularly until they reach post-adolescence. It is also necessary to be aware of the fact that children enter these sports programmes randomly and therefore at early ages no sport-specific characteristics or adaptations are necessarily obvious. Thus the need for a longitudinal study is increased in order to note any changes in the participants who are successful, less successful or who drop out of the sport. Only then might it be possible to answer several of the questions raised above with more certainty.

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