Physiological Characteristics of Chinese Pre-adolescent and Adolescent Swimmers

Frank H. Fu, Cen Hao-wang
Hong Kong Baptist University

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Frank H. Fu and Cen Hao-wang

Introduction

The success of Chinese swimmers in international competitions began in the early 1980's. The People's Republic of China is now producing world record holders in many swim events. Numerous studies have been conducted to find ways to develop world champions in different sports, and swimming is no exception. However, swimming is different from other land sports e.g., the athlete has to minimize water resistance and synchronize body movements (head, arms, trunk and legs) in order to produce effective strokes at optimal frequency. In order to assist in talent identification and improve the training methods, researches have been conducted to study various physiological and psychological factors associated with swimming performance. The present study will focus on the physiological characteristics of Chinese pre-adolescent and adolescent swimmers living in Hong Kong and Beijing.

Land versus water sports

Pulmonary functions of athletes and nonathletes have been investigated for over three decades. Newman et al. (1962) studied the effects of exercise, body and lung size on carbon monoxide diffusion of athletes and nonathletes. They concluded that athletes have significantly higher maximum oxygen uptake and pulmonary diffusing capacity. Their results were supported by Mostyn et al. (1963) who found that champion swimmers had higher high pulmonary diffusing capacity than those of comparable age at the same exercise level. Baxterjones et al. (1995) found that training in soccer, tennis, gymnastic and swimming resulted in different maturation rates for prepubertal athletes. They concluded that training did not affect these athletes' growth and development, and that their continued success in sport were related to inherited traits. In another study, it was found that submaximal swimming or running exercise induced lung cells proliferation in postnatal rats during the period of 30-60 days (Fu, 1996). Using female swimmers as subjects, Tipton et al. (1996) found that a combination of swimming and resistance exercise stimulated net muscle protein synthesis above resting levels. Tanaka et al. (1997) found that swim training at 60% maximal heart rate reserve for 45 min per day for 3 days per week for 10 weeks resulted in significant improvement of cardiovascular endurance, perceived exertion, and blood lactate. This finding is supported by Obert et al. (1997) who found an increase of 38% in maximal oxygen uptake in 10 year old children after one year of swim training (10-12 hrs/week).

It has been shown that swimming is an effective exercise in producing positive training effects e.g. in improving maximum oxygen uptake and in maintaining body weight. However, it is different from land sports and thus its specificity in training effects e.g. in pulmonary functions, must be noted.

Different Characteristics and Requirements of Swimmers

The use of swimming to keep fit is now becoming more and more popular e.g., with the introduction of water aerobics. Andrews et al. (1972) studied the cardiovascular functions of children engaged in swim training for three years. They found that swimmers were taller at a given age, had larger lung volumes and larger pulmonary diffusing capacity. They concluded that swim training has positive effects on physical growth rate and cardiorespiratory functions in children between 8 - 18 years. Engstrom et al. (1971) found that 12-16 year old girls could be trained to an exceptionally high functional capacity. They also suggested that increase in vital capacity without a corresponding increase in total lung capacity might be due to functional adaptation, e.g. a change in breathing pattern. Yost (1981) found significant improvement in pulmonary diffusing capacity and physical work capacity of swimmers during growth. Durny et al. (1997) studied the relationships between comportmental parameters, biological variables and characteristics of personality of 143 French swimmers with an average age of 16.9 years and 8.2 years of swimming at 8.8 hours/week. They found significant relationships between these different parameters, e.g. energy drink utilization was related to level of practice and anxiety; and between presence of tartar, anxiety, and level of practice. They concluded that these relationships have to be considered in assessing swimming performances.

To engage in serious swim training for competition, one requires the availability of a good-size all-season pool, a competent coach, individual dedication, commitment and talent, and time to train an average of 3-4 hours per day, 6 days per week. It was pointed out that for swimmers whose training programmes were interrupted or who were detraining, special attention must be given to the diet and body composition. Significant increase in fat mass has been observed during this period (Almeras, 1997). Trappe et al. (1997) indicated that high volume swim training of 5-6 hours/day, would lead to a negative energy balance. Unless this is rectified through the diet, fatigue and injuries might occur. The use of a relatively low dose of creatine (2g/day) supplement has no effect on muscle creatine concentration, muscle oxygen supply, or muscle aerobic or anaerobic metabolism during swim training (of endurance nature).

The effects of swim training on children have been briefly reviewed. Some characteristics of champion swimmers are also presented. Relationships of swim training with diet, weight control, oxygen uptake, pulmonary functions, level of anxiety, and use of ergogenic aids suggest that although it is unique, it is also quite similar to other sports.

Profiling of swimmers

Kleinova (1981) found a high correlation between swim performance and body height and vital capacity in 11-13 year old children. During the Australian age-group swimming championships in Perth, Bloomfield et al. (1984) studied 116 national level swimmers between the ages of 11 and 16 years. Tests carried out included pulmonary function, flexibility, body composition, power and strength. This marked one of the earlier attempts to establish profiles on young swimmers. Lavoie and Leone (1988) studied the maximal aerobic power and the arm stroke index of 292 swimmers between the age 11-15 years. Regression equations to predict best performance times at various distances were computed. Vikander and Solbakken (1997) extended their studies with Norwegian cross country ski champions to swimmers. They applied the Rushall Psychological Inventories and identified nine characteristics from testing 24 elite Norwegian swimmers. Physiological as well as psychological parameters of young and champion swimmers have been compiled in recent years. The present study would only focus on selected physiological parameters reported to be relevant in the literature.

Methods

The major objective of the present study is to assess and identify physiological characteristics of Chinese swimmers who have undergone training for a long period of time. Subjects were school children between the age of 8 and 17 years, living in Beijing and Hong Kong. Data were collected at the Human Performance Laboratory at the National Research Institute of Sports Science at Beijing and the Dr. Stephen Hui Research Centre at Hong Kong Baptist University during the months of May - August, 1997. The following physiological parameters were measured:

Height

Weight

Shoulder width

Palm length

Sole length

Forced vital capacity

Forced expiratory volume in 1 second

Grip strength

Maximum oxygen uptake (modified Astrand-Rhyming bicycle test) (Fu, 1976)

Physical work capacity (at 170 bpm)

Skinfolds (abdomen, calf, subscapularis, suprailiac, and triceps)

For each age group, swimmers and inactive students (nonswimmers) would be tested (about 40 Beijing and Hong Kong students). The difference in the numbers of the subjects form Beijing and Hong Kong was based on the number of residents of the two cities. A subject was classified as a swimmer if he/she swam regularly during the past year, at least 6-8 hours per week. The control group consisted of subjects who did not swim or engage in any sport activities for more than 2 hours per week. The number of years of swim training was also recorded. All testings were conducted at the laboratory under the supervision of the investigators and /or other qualified personnel. The Physical Activity Readiness Form (PAR-Q) was completed by subjects and parental consent was also obtained prior to the administration of test.

Results and Discussion

While every effort was made to recruit equal numbers of subjects to the different age categories, the availability of subjects in both cities made it impractical. The age distribution of the swimmers and control groups are presented in Table 1. The history of swim training of the subjects are presented in Table 2. Beijing swimmers have a longer history of swim training than Hong Kong swimmers by about one year. The mode for the Hong Kong subjects is 2 years while that of the Beijing subjects is 3 years.

Table 1: A table to show the numbers of subjects in different categories.

Category	Number	Category	Number	Category	Number
Swimmers	324	**Hong Kong**	271	**Males**	344
Nonswimmers	367	**Beijing**	420	**Females**	347
Total	691	**Total**	691	**Total**	691

Table 2: A table to show the history of the swimmers of swimming training by years.

	Hong Kong		**Beijing**	
Years of Training	**Male (No.)**	**Female (No.)**	**Male (No.)**	**Female (No.)**
1	8	5	17	13
2	15	16	9	12
3	10	6	22	24
4	8	11	15	11
5	10	1	5	0
6	5	1	12	10
7	3	3	3	16
8	1	2	6	6
9	2	0	4	8
10	1	0	7	1
11	0	1	3	1
12	0	0	1	3
13	0	0	0	0
14	0	0	1	0
Average	**3.80**	**3.47**	**4.67**	**4.68**

The effects of swim training, gender, and city of residence on the various independent variables were investigated with a 2 x 2 x 2 ANOVA design. The results are presented in the following paragraphs.

Height

The height of the subjects was measured in centimeter (Detecto 339). Results of the ANOVA are presented in Table 3 and analyses of mean differences are presented in Table 4. Hong Kong subjects were significantly taller than Beijing subjects (155.4 vs.145.9 cm) and males were taller than females (150.8 vs.148.5 cm). There was, however, no significant differences between swimmers and the control group (nonswimmers) (150.3 vs.149.0 cm). A significant F ratio was also obtained for the interaction factor for swimmer/nonswimmer and resident of Hong Kong/Beijing.

Table 3: ANOVA Results of Height of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	14592.10	3	4864.03	183.90	0.00
Train	1.88	1	1.88	0.01	0.93
Sex	1239.04	1	1239.04	4.68	0.03
Residence	13202.47	1	13202.47	49.91	0.00
Train & Sex	402.18	1	402.18	1.52	0.22
Train & Residence	10048.05	1	10048.05	37.99	0.00
Sex & Residence	316.23	1	316.23	1.20	0.28
Train & Sex & Residence	895.51	1	895.51	3.39	0.07
Explained	27933.46	7	3990.49	15.09	0.00
Residual	184048.87	682	264.53		
Total	**208342.33**	**689**	**302.38**		

Table 4: Student-Newman-Keuls test of Height of Subjects.

	Grp8	Grp6	Grp7	Grp3	Grp5	Grp1	Grp4	Grp2
Grp8								
Grp6								
Grp7	*	*						
Grp3	*	*						
Grp5	*	*						
Grp1	*	*						
Grp4	*	*						
Grp2	*	*	*	*	*	*	*	

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Weight

The weight of the subjects was measured in kilogram (Detecto 339). Results of the ANOVA and mean differences analyses are presented in Tables 5 and 6. Hong Kong subjects were found to be heavier than Beijing subjects (45.8 vs. 39.4 kg) while males were also heavier than females (43.4 vs. 40.4 kg). The difference between the swimmers and the control group was not significant (42.3 vs. 41.5 kg). The interaction between the swimmer/nonswimmer and resident of Hong Kong/Beijing factors was significant.

Table 5: ANOVA Results of Weight of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	8133.61	3	2711.20	13.78	0.00
Train	1.59	1	1.59	0.01	0.93
Sex	1828.96	1	1828.96	9.30	0.00
Residence	6201.86	1	6201.86	31.53	0.00
Train & Sex	41.29	1	41.29	0.21	0.65
Train & Residence	2984.79	1	2984.79	15.17	0.00
Sex & Residence	250.50	1	250.50	1.27	0.26
Train & Sex & Residence	350.59	1	350.59	1.78	0.18
Explained	12198.60	7	1742.66	8.86	0.00
Residual	134350.72	683	196.71		
Total	**146549.29**	**690**	**212.39**		

Table 6: Student-Newman-Keuls test of Weight of Subjects.

	Grp8	Grp6	Grp7	Grp3	Grp5	Grp4	Grp1	Grp2
Grp8								
Grp6								
Grp7								
Grp3								
Grp5	*	*						
Grp4	*	*						
Grp1	*	*						
Grp2	*	*	*	*	*	*	*	

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Shoulder Width

The width between the left and right acromion processes was measured with an anthropometer (Lafayette 1290) in centimeter. The results of the ANOVA and mean differences analyses are presented in Tables 7 and 8. It was found that shoulder width was larger in the males (332.8 vs.323.3 mm), in the swimmers (332.5 vs. 324.0 mm), and in Hong Kong subjects (354.4 vs. 311.2 mm). Interactions between the swimming / nonswimming and resident of Hong Kong/Beijing, and male/female and resident of Hong Kong/Beijing factors were also found to be significant.

Table 7: ANOVA Results of Shoulder Width of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	328005.66	3	109335.22	69.10	0.00
Train	11017.68	1	11017.68	6.96	0.01
Sex	19632.59	1	19632.59	12.41	0.00
Residence	302723.66	1	302723.66	191.31	0.00
Train & Sex	2319.29	1	2319.29	1.47	0.23
Train & Residence	22073.83	1	22073.82	13.95	0.00
Sex & Residence	11443.22	1	11443.22	7.23	0.01
Train & Sex & Residence	7291.91	1	7291.91	4.61	0.03
Explained	385674.01	7	55096.29	34.82	0.00
Residual	1074428.20	679	1582.37		
Total	**1460102.21**	**686**	**2128.43**		

Table 8: Student-Newman-Keuls test of Shoulder Width of Subjects.

	Grp6	Grp8	Grp7	Grp5	Grp4	Grp3	Grp1	Grp2
Grp6								
Grp8								
Grp7	*	*						
Grp5	*	*						
Grp4	*	*						
Grp3	*	*						
Grp1	*	*						
Grp2	*	*	*	*	*	*	*	

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Palm Length

The palm lengths of both hands were measured in millimetre with an anthropometer (Lafayette 1290) and the average figure was used in analyses. Results of ANOVA and mean differences analyses were presented in Tables 9 & 10. While there were no differences between swimmers and nonswimmers (163.8 vs. 161.1 mm), males have longer palm than females (164.0 vs. 160.8 mm) and Hong Kong subjects also have longer palm (169.6 vs. 157.7 mm). The only significant interaction was between the swimmer/nonswimmer and resident of Hong Kong/Beijing factors.

Table 9: ANOVA Results of Palm Length of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	24460.38	3	8153.46	25.57	0.00
Train	477.66	1	477.66	1.50	0.22
Sex	2053.24	1	2053.24	6.44	0.01
Residence	22126.03	1	22126.03	69.39	0.00
Train & Sex	990.71	1	990.70	3.11	0.08
Train & Residence	8171.97	1	8171.97	25.63	0.00
Sex & Residence	534.89	1	534.89	1.68	0.20
Train & Sex & Residence	806.14	1	806.13	2.53	1.11
Explained	37349.44	7	5335.63	16.73	0.00
Residual	217772.48	683	318.85		
Total	**255121.91**	**690**	**369.74**		

Table 10: Student-Newman-Keuls test of Palm Length of Subjects.

	Grp8	Grp6	Grp7	Grp5	Grp3	Grp1	Grp4	Grp2
Grp8								
Grp6								
Grp7	*	*						
Grp5	*	*						
Grp3	*	*						
Grp1	*	*						
Grp4	*	*						
Grp2	*	*	*	*	*	*	*	

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Sole Length

The sole lengths of both feet were measured with an anthropometer (Lafayette 1290) in millimetre. They were averaged and then analysed accordingly. The results of the ANOVA and mean differences comparisons are presented in Tables 11 and 12. They are similar to those found with palm length - no differences between swimmers and nonswimmers (223.4 vs. 222.3 mm), males have longer sole than females (227.8 vs. 217.8 mm), Hong Kong subjects have longer sole (229.5 vs. 218.4 mm), and significant interaction between the swimmer/nonswimmer and resident of Hong Kong/Beijing factors.

Table 11: ANOVA Results of Sole Length of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	36245.91	3	12081.97	24.72	0.00
Train	0.10	1	0.10	0.00	0.99
Sex	17036.61	1	17036.61	34.85	0.00
Residence	18717.57	1	18717.57	38.29	0.00
Train & Sex	449.59	1	449.59	0.92	0.34
Train & Residence	6865.68	1	6865.68	14.05	0.00
Sex & Residence	81.38	1	81.38	0.17	0.69
Train & Sex & Residence	690.71	1	690.71	1.41	0.24
Explained	46104.63	7	6586.38	13.48	0.00
Residual	33862.12	683	488.82		
Total	**379966.76**	**690**	**550.68**		

Table 12: Student-Newman-Keuls test of Sole Length of Subjects.

	Grp8	Grp7	Grp6	Grp3	Grp4	Grp5	Grp1	Grp2
Grp8								
Grp7	*							
Grp6	*							
Grp3	*							
Grp4	*	*						
Grp5	*	*						
Grp1	*	*	*					
Grp2	*	*	*	*	*	*	*	

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Forced Vital Capacity

Forced vital capacities of subjects were measured in litre with the spirometer (Pony, Cosmed). Results of ANOVA and mean difference comparisons are presented in Tables 13 and 14. It was found that swimmers have larger vital capacities than nonswimmers (2.79 vs. 2.33 litre), males have larger volumes than females (2.74 vs. 2.36 litre), and Hong Kong subjects have larger volumes than Beijing subjects (2.76 vs. 2.41 litre). A significant interaction was also found between the swimming /nonswimming and resident of Hong Kong/Beijing factors.

Table 13: ANOVA Results of Forced VC of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	66.80	3	22.27	24.79	0.00
Train	23.51	1	23.51	26.18	0.00
Sex	23.41	1	23.14	25.76	0.00
Residence	20.48	1	20.48	22.80	0.00
Train & Sex	0.13	1	0.13	0.14	0.70
Train & Residence	26.58	1	26.58	29.59	0.00
Sex & Residence	0.10	1	0.10	0.11	0.74
Train & Sex & Residence	1.01	1	1.01	1.13	0.29
Explained	112.02	7	16.00	17.82	0.00
Residual	612.60	682	0.90		
Total	**724.62**	**689**	**1.05**		

Table 14: Student-Newman-Keuls test of Forced VC of Subjects.

	Grp8	Grp6	Grp4	Grp7	Grp3	Grp1	Grp5	Grp2
Grp8								
Grp6	*							
Grp4	*	*						
Grp7	*	*						
Grp3	*	*						
Grp1	*	*						
Grp5	*	*	*	*	*	*		
Grp2	*	*	*	*	*			

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Forced Expiratory Volume in the first second

The forced expiratory volumes during the first second were measured with the spirometer (Pony, Cosmed). Results of the ANOVA and mean difference comparisons are presented in Tables 15 and 16. It was found that swimmers have larger volumes than nonswimmers (2.33 vs. 2.02 litre), males have larger volumes than females (2.33 vs. 1.99 litre), and Hong Kong subjects have larger volumes than Beijing subjects (2.43 vs. 1.99 litre). Significant interactions were found between the three factors - swimming/nonswimming, male/female, resident of Hong Kong/Beijing.

Table 15: ANOVA Results of FEV_1 of Subjects.

Source of Variation	**Sum of Squares**	**DF**	**Mean Square**	**F**	**P**
Main Effects	57.35	3	19.12	27.39	0.00
Train	10.30	1	10.30	14.76	0.00
Sex	17.65	1	17.65	25.30	0.00
Residence	30.43	1	30.43	43.60	0.00
Train & Sex	0.55	1	0.55	0.78	0.38
Train & Residence	20.02	1	20.02	28.69	0.00
Sex & Residence	0.00	1	0.00	0.00	0.95
Train & Sex & Residence	2.72	1	2.72	3.90	0.50
Explained	93.23	7	13.32	19.09	0.00
Residual	474.54	680	0.70		
Total	**567.77**	**687**	**0.83**		

Table 16: Student-Newman-Keuls test of FEV_1 of Subjects.

	Grp8	Grp6	Grp7	Grp4	Grp3	Grp1	Grp5	Grp2
Grp8								
Grp6	*							
Grp7	*	*						
Grp4	*	*						
Grp3	*	*						
Grp1	*	*	*					
Grp5	*	*	*					
Grp2	*	*	*	*	*			

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Percentage of Vital Capacity expired during the first second

The percentage of vital capacity expired during the first second was measured with the spirometer (Pony, Cosmed). Results of the ANOVA are presented in Table 17. F ratios obtained are not significant except one - Hong Kong subjects have a higher percentage than Beijing subjects (88.0 vs. 84.2%).

Table 17: ANOVA Results of Percentage of Vital capacity Expired in 1 sec of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	2513.79	3	837.93	3.19	0.02
Train	91.08	1	91.08	0.35	0.56
Sex	14.41	1	14.41	0.55	0.82
Residence	2289.09	1	2289.10	8.73	0.00
Train & Sex	119.42	1	119.42	0.46	0.50
Train & Residence	281.74	1	281.74	1.07	0.30
Sex & Residence	91.16	1	91.16	0.35	0.56
Train & Sex & Residence	482.80	1	482.80	1.84	0.18
Explained	3369.93	7	481.42	1.84	0.08
Residual	178359.60	680	262.30		
Total	**181729.53**	**687**	**264.53**		

Physical Work Capacity

The heart rates obtained during the modified Astrand-Rhyming bicycle test (Monark 818E) were used to calculate the physical work capacity (at a heart rate of 170 bpm) of subjects. Results of ANOVA are presented in Tables 18 and 19. Swimmers have significantly higher physical work capacities than nonswimmers (822.5 vs. 549.1 kgm) with the Beijing female swimmers having the highest score of 915.1 kgm, followed by the Hong Kong male swimmers 853.4 kgm. A significant interaction was also obtained for the swimmer/ nonswimmer, male/female and resident of Hong Kong/Beijing factors.

Table 18: ANOVA Result of PWC_{170} of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	10418779	3	3472926.33	17.50	0.00
Train		1	444568.96	2.24	0.14
Sex		1	617741.58	3.11	0.08
Residence		1	9510895.43	47.92	0.00
Train & Sex	3352464	1	3352464.30	16.89	0.00
Train & Residence	1080373	1	1080372.89	5.44	0.02
Sex & Residence	1279298	1	1279298.34	6.45	0.01
Train & Sex & Residence	82123	1	82123.15	0.41	0.52
Explained	17473749	7	2496249.86	12.58	0.00
Residual	108765989	548	198478.08		
Total	**126239737**	**555**	**227458.99**		

Table 19: Student-Newman-Keuls test of PWC_{170} of Subjects.

	Grp6	Grp4	Grp8	Grp5	Grp3	Grp2	Grp1	Grp7
Grp6								
Grp4								
Grp8								
Grp5	*	*	*					
Grp3	*	*	*					
Grp2	*	*	*					
Grp1	*	*	*					
Grp7	*	*	*					

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Maximum Oxygen Uptake

Maximum oxygen uptakes of subjects were calculated using hearts rates obtained from the modified Astrand-Rhyming bicycle test (Monark 818E). Results of ANOVA are presented in Table 20. It was found that swimmers have higher values than nonswimmers (66.66 vs. 55.67 ml/kg/min) and males have higher values than females (75.76 vs. 49.25 ml/kg/min). There were no significant interactions among the three factors. The predicted maximum oxygen uptake values of male swimmers are very high (Hong Kong males - 82.8 ml/kg/min and Beijing males - 79.9 ml/kg/min) although their performance are not as good as the females in competition. This suggests that other factors need to be considered as well.

Table 20: ANOVA Results of MAX VO_2 of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	84633.69	3	28211.23	84.63	0.00
Train	8299.15	1	8299.15	24.90	0.00
Sex	70456.31	1	70456.31	211.30	0.00
Residence	582.23	1	582.23	1.75	0.19
Train & Sex	536.14	1	536.14	1.61	0.21
Train & Residence	1177.27	1	1177.27	3.53	0.06
Sex & Residence	68.62	1	68.62	0.21	0.65
Train & Sex & Residence	132.89	1	132.89	0.40	0.53
Explained	87751.41	7	12535.91	37.61	0.00
Residual	141662.88	425	333.32		
Total	**229414.29**	**432**	**531.05**		

Triceps Skinfolds

The triceps skinfolds was measured millimetre with a caliper (Harpenden, BodyCare). Results of ANOVA and mean difference analyses are presented in Tables 21 and 22. Thicker skinfolds were found in nonswimmers (12.83 vs. 9.85 mm), females (12.82 vs. 10.03 mm), and Hong Kong subjects (12.49 vs. 10.76 mm). Significant interactions were also found between the swimmer/nonswimmer and male/female, and male/female and resident of Hong Kong/Beijing factors.

Table 21: ANOVA Results of Triceps Skinfolds of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	3014.22	3	1004.74	61.25	0.00
Train	1223.72	1	1223.72	74.60	0.00
Sex	1199.65	1	1199.65	73.13	0.00
Residence	304.06	1	304.06	18.54	0.00
Train & Sex	163.16	1	163.16	9.95	0.00
Train & Residence	3.42	1	3.42	0.21	0.65
Sex & Residence	112.37	1	112.36	6.85	0.00
Train & Sex & Residence	85.43	1	85.43	5.21	0.02
Explained	3477.80	7	496.83	30.29	0.00
Residual	11171.00	681	16.40		
Total	**14648.80**	**688**	**21.29**		

Table 22: Student-Newman-Keuls test of Triceps Skinfolds of Subjects.

	Grp5	Grp1	Grp7	Grp2	Grp6	Grp3	Grp8	Grp4
Grp5								
Grp1								
Grp7	*							
Grp2	*							
Grp6	*							
Grp3	*							
Grp8	*	*	*	*	*	*		
Grp4	*	*	*	*	*	*	*	

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Suprailiac Skinfolds

The suprailiac skinfolds was measured in millimetre. Results of ANOVA and mean difference analyses are presented in Tables 23 and 24. Thicker skinfolds were found in nonswimmers (11.00 vs. 8.37 mm), females (10.64 vs. 8.89 mm), and Hong Kong subjects (11.68 vs. 8.55). A significant interaction was found between the three factors.

Table 23: ANOVA Result of Suprailiac Skinfolds of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	2976.95	3	992.32	38.18	0.00
Train	979.80	1	979.80	37.70	0.00
Sex	449.63	1	449.63	17.30	0.00
Residence	1218.96	1	1218.96	46.90	0.00
Train & Sex	92.77	1	92.77	3.57	0.06
Train & Residence	90.40	1	90.40	3.48	0.06
Sex & Residence	96.61	1	96.61	3.72	0.05
Train & Sex & Residence	151.10	1	151.10	5.81	0.02
Explained	3482.47	7	497.50	19.14	0.00
Residual	17697.79	681	25.99		
Total	**21180.26**	**688**	**30.79**		

Table 24: Student-Newman-Keuls test of Suprailiac Skinfolds of Subjects.

	Grp5	Grp7	Grp6	Grp1	Grp8	Grp3	Grp2	Grp4
Grp5								
Grp7								
Grp6	*							
Grp1	*							
Grp8	*							
Grp3	*							
Grp2	*	*						
Grp4	*	*	*	*	*	*	*	

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Subscapularis Skinfolds

The subscapularis skinfolds was measured in millimetre. Results of ANOVA and mean difference analyses are presented in Tables 25 and 26. Thicker skinfolds were found in nonswimmers (10.05 vs. 7.53 mm), females (9.63 vs. 8.10 mm), and Hong Kong subjects (10.83 vs. 7.61 mm). A significant interaction was also found between the swimmer / nonswimmer and male/female factors.

Table 25: ANOVA Results of Subscapularis Skinfolds of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	2844.05	3	948.02	58.31	0.00
Train	851.31	1	851.31	52.36	0.00
Sex	301.46	1	301.46	18.54	0.00
Residence	1382.42	1	1382.42	85.02	0.00
Train & Sex	130.00	1	130.00	8.00	0.00
Train & Residence	19.66	1	19.66	1.21	0.27
Sex & Residence	4.00	1	4.00	0.25	0.62
Train & Sex & Residence	6.21	1	6.20	0.39	0.54
Explained	3097.61	7	442.52	27.22	0.00
Residual	11072.79	681	16.26		
Total	**14170.40**	**688**	**20.60**		

Table 26: Student-Newman-Keuls test of Subscapularis Skinfolds of Subjects.

	Grp5	Grp7	Grp6	Grp1	Grp3	Grp8	Grp2	Grp4
Grp5								
Grp7								
Grp6								
Grp1	*	*	*					
Grp3	*	*	*					
Grp8	*	*	*					
Grp2	*	*	*					
Grp4	*	*	*	*	*	*	*	

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Abdomen Skinfolds

The abdomen skinfolds was measured in millimetre. Results of ANOVA and mean difference analyses are presented in Tables 27 and 28. Thicker skinfolds were found in nonswimmers (10.73 vs. 8.12 mm), females (10.37 vs. 8.63 mm), and Hong Kong subjects (10.35 vs. 8.97 mm). The interaction between swimmer/nonswimmer and male/female factors was also found to be significant.

Table 27: ANOVA Results of Abdomen Skinfolds of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	1702.72	3	567.57	18.50	0.00
Train	903.48	1	903.49	29.44	0.00
Sex	425.68	1	425.68	13.88	0.00
Residence	199.57	1	199.57	6.50	0.01
Train & Sex	124.02	1	124.02	4.04	0.45
Train & Residence	15.65	1	15.65	0.51	0.48
Sex & Residence	25.50	1	25.50	0.83	0.37
Train & Sex & Residence	115.64	1	115.63	3.77	0.06
Explained	2116.30	7	302.33	9.85	0.00
Residual	20897.86	681	30.69		
Total	**23014.16**	**688**	**33.45**		

Table 28: Student-Newman-Keuls test of Abdomen Skinfolds of Subjects.

	Grp5	Grp7	Grp1	Grp3	Grp2	Grp6	Grp8	Grp4
Grp5								
Grp7								
Grp1								
Grp3								
Grp2								
Grp6	*							
Grp8	*	*						
Grp4	*	*	*	*	*	*	*	

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Calf Skinfolds

The calf skinfolds was measured in millimetre. Results of ANOVA and mean difference analyses are presented in Tables 29 and 30. Thicker skinfolds were found in nonswimmers (13.78 vs. 9.93 mm) and females (13.12 vs. 10.82 mm). The interaction between swimmer/nonswimmer and male/female factors was also found to be significant.

Table 29: ANOVA Results of Calf Skinfolds of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	3068.21	3	1022.74	42.42	0.00
Train	2132.36	1	2132.36	88.44	0.00
Sex	769.66	1	769.66	31.92	0.00
Residence	2.10	1	2.10	0.09	0.77
Train & Sex	252.27	1	252.27	10.47	0.00
Train & Residence	39.47	1	39.47	1.64	0.20
Sex & Residence	41.19	1	41.19	1.71	0.19
Train & Sex & Residence	18.09	1	18.08	0.75	0.39
Explained	3706.43	7	529.50	21.96	0.00
Residual	16419.21	681	24.11		
Total	**20125.64**	**688**	**29.26**		

Table 30: Student-Newman-Keuls test of Calf Skinfolds of Subjects.

	Grp5	Grp1	Grp7	Grp3	Grp2	Grp6	Grp8	Grp4
Grp5								
Grp1								
Grp7								
Grp3								
Grp2								
Grp6	*	*	*					
Grp8	*	*	*	*	*	*		
Grp4	*	*	*	*	*	*		

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Sum of Five Skinfolds

Skinfolds data were summed and analysed in a similar manner. Results are presented in Tables 31 and 32. The skinfolds of the nonswimmers were found to be thicker than swimmers (58.38 vs. 43.79 mm), females were thicker than males (56.58 vs. 46.48 mm), Hong Kong subjects were thicker than Beijing subjects (57.49 vs. 47.77 mm), with the Hong Kong female nonswimmers having the highest score (72.92 mm). The interaction between the swimmer/ nonswimmer and male/female factors was also found to be significant.

Table 31: ANOVA Results of Sum of Skinfolds of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	61261.21	3	20420.40	47.55	0.00
Train	29479.54	1	29479.54	68.64	0.00
Sex	14781.11	1	14791.11	34.42	0.00
Residence	10446.92	1	10446.92	24.32	0.00
Train & Sex	3699.81	1	3699.81	8.62	0.00
Train & Residence	30.83	1	30.83	0.07	0.79
Sex & Residence	1149.00	1	1149.00	2.68	0.10
Train & Sex & Residence	1523.49	1	1523.49	3.55	0.06
Explained	70306.50	7	10043.79	23.39	0.00
Residual	292478.98	681	429.49		
Total	**362785.48**	**688**	**527.30**		

Table 32: Student-Newman-Keuls test of Sum of Skinfolds of Subjects.

	Grp5	Grp7	Grp1	Grp6	Grp3	Grp2	Grp8	Grp4
Grp5								
Grp7								
Grp1	*							
Grp6	*							
Grp3	*							
Grp2	*	*						
Grp8	*	*	*	*				
Grp4	*	*	*	*	*	*	*	

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Grip Strength

Grip strength was measured in kilogram with a dynamometer (Takei 5001). Results of ANOVA and mean difference comparisons are presented in Tables 33 and 34. The dominant arm strength of swimmers was found to be higher than nonswimmers (22.65 vs. 19.72 kg), males were higher than females (23.17 vs. 19.01 kg), and Hong Kong subjects were higher than Beijing subjects (22.49 vs. 20.23 kg). The highest score (26.38 kg for dominant arm and 24.59 kg for nondominant arm) was obtained from the Hong Kong male nonswimmer group. A significant interaction was found between the swimmer/nonswimmer and resident of Hong Kong/Beijing factors. Similar results in ANOVA and mean difference comparisons were obtained with data of the nondominant arm (see Tables 35 and 36).

Table 33: ANOVA Results of Grip Strength dominant arm of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	4623.89	3	1541.30	16.86	0.00
Train	873.81	1	873.81	9.46	0.00
Sex	2795.56	1	2975.56	30.59	0.00
Residence	854.57	1	854.60	9.35	0.00
Train & Sex	110.24	1	110.24	1.21	0.27
Train & Residence	1018.11	1	1018.11	11.14	0.00
Sex & Residence	122.00	1	122.00	1.34	0.25
Train & Sex & Residence	382.78	1	382.78	4.19	0.04
Explained	6860.53	7	980.08	10.72	0.00
Residual	61695.21	675	91.40		
Total	**68555.74**	**682**	**100.52**		

Table 34: Student-Newman-Keuls test of Grip Strength dominant arm of Subjects.

	Grp8	Grp4	Grp6	Grp7	Grp3	Grp1	Grp5	Grp2
Grp8								
Grp4								
Grp6								
Grp7	*							
Grp3	*							
Grp1	*	*	*					
Grp5	*	*	*	*				
Grp2	*	*	*	*	*			

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

Table 35: ANOVA Results of Grip Strength non-dominant arm of Subjects.

Source of Variation	Sum of Squares	DF	Mean Square	F	P
Main Effects	4270.87	3	1423.62	16.68	0.00
Train	866.33	1	866.33	10.15	0.00
Sex	2754.25	1	2754.25	32.26	0.00
Residence	532.12	1	532.12	6.23	0.01
Train & Sex	61.21	1	61.21	0.72	0.40
Train & Residence	1156.16	1	1156.16	13.54	0.00
Sex & Residence	102.10	1	102.10	1.20	0.28
Train & Sex & Residence	270.93	1	270.93	3.17	0.08
Explained	6493.77	7	927.69	10.87	0.00
Residual	5762.91	675	85.37		
Total	**64118.69**	**682**	**94.02**		

Table 36: Student-Newman-Keuls test of Grip Strength non-dominant arm of Subjects.

	Grp8	Grp4	Grp6	Grp3	Grp7	Grp1	Grp5	Grp2
Grp8								
Grp4								
Grp6								
Grp3								
Grp7	*							
Grp1	*	*	*					
Grp5	*	*	*	*				
Grp2	*	*	*	*				

Grp1 Male Hong Kong Swimmer
Grp2 Male Hong Kong Nonswimmer
Grp3 Female Hong Kong Swimmer
Grp4 Female Hong Kong Nonswimmer
Grp5 Male Beijing Swimmer
Grp6 Male Beijing Nonswimmer
Grp7 Female Beijing Swimmer
Grp8 Female Beijing Nonswimmer
* Significant at 0.05 level

A summary of the findings are presented in Table 37 (Details are provided in Tables 38, 39 and 40). Hong Kong subjects scored higher in most of the tests administered except in physical work capacity, maximum oxygen uptake and calf skinfolds. One possible explanation might be the diet of the Hong Kong subjects. The higher intake of protein and fat might contribute to earlier development of various physiological parameters when compared to the Beijing subjects. However, Hong Kong subjects were also fatter. Regional differences within the Mainland should be considered in future interpretations and comparisons of data.

Swimmers were found to be slimmer than nonswimmers and the measurement of the skinfolds provided a good discriminating tool. The grip strength of both arms were also found to be stronger in swimmers. Cardiorespiratory functions such as forced vital capacity, forced expiratory volume, physical work capacity, and maximum oxygen uptake were also found to be higher in swimmers. Beijing female swimmers have the highest physical work capacity (915.0 kgm) while Hong Kong male swimmers have the highest maximum oxygen uptake (82.8 ml/kg/min). Measuring these characteristics of swimmers would be desirable since they can provide valuable information in talent identification.

The differences between the gender were also identified. The males were not only taller, heavier, stronger, they also have larger frame, larger lung capacity, better endurance and less fat than the females. It is important that gender differences be considered in assessing athletes and making comparisons in the future.

Table 37: A summary of the effects of various factors - Training, gender and residence.

Factor	Swimmer/ Non-swimmer (1)	Male/ Female (2)	Hong Kong/ Beijing (3)	Significant Interaction ($p < 0.05$)
Height	--	Male	Hong Kong	1&3
Weight	--	Male	Hong Kong	1&3
Shoulder Width	--	Male	Hong Kong	1&3, 2&3
Palm Length	--	Male	Hong Kong	1&3
Sole Length	--	Male	Hong Kong	1&3
Forced VC	Swimmer	Male	Hong Kong	1&3
FEV_1	Swimmer	Male	Hong Kong	1&3
Percentage VC_{1sec}	--		Hong Kong	--
PWC_{170}	Swimmer	--	--	1&3, 1&2, 2&3
Max VO_2	Swimmer	Male	--	--
Triceps Skinfolds	Nonswimmer	Female	Hong Kong	1&2, 2&3
Suprailiac Skinfolds	Nonswimmer	Female	Hong Kong	1&2&3
Subscapularis Skinfolds	Nonswimmer	Female	Hong Kong	1&2
Abdomen Skinfolds	Nonswimmer	Female	Hong Kong	1&2
Calf Skinfolds	Nonswimmer	Female	--	1&2
Sum of Skinfolds	Nonswimmer	Female	Hong Kong	1&2
Grip Strength Dominant arm	Swimmer	Male	Hong Kong	1&3
Grip Strength Nondominant arm	Swimmer	Male	Hong Kong	1&3

Table 38: A table to show the means and standard deviations of physiological data of male and female.

Factors	Male		Female	
	Mean	S.D.	Mean	S.D.
Height (cm)	150.82	18.69	148.45	15.94
Weight (kg)	43.42	15.75	40.39	13.16
Shoulder Width (mm)	332.76	50.86	323.26	40.44
Palm Length (mm)	163.98	20.63	160.78	17.62
Sole Length (mm)	227.82	25.40	217.77	20.20
Forced VC (litre)	2.74	1.13	2.36	0.87
FEV_1 (litre)	2.33	1.00	1.99	0.78
Percentage VC_{1sec}	86.00	16.27	85.46	16.28
PWC_{170} (kgm)	709.88	409.81	633.13	450.24
Max VO_2 (ml/kg/min)	56.85	14.80	61.79	20.52
Triceps Skinfolds (mm)	10.03	4.23	12.82	4.57
Suprailiac Skinfolds (mm)	8.89	5.27	10.64	5.68
Subscapularis Skinfolds (mm)	8.10	4.08	9.63	4.84
Abdomen Skinfolds (mm)	8.63	5.91	10.37	5.54
Calf Skinfolds (mm)	10.82	4.88	13.12	5.67
Sum of Skinfolds (mm)	46.48	21.31	56.58	23.45
Grip Strength Dominant arm (kg)	23.16	11.75	19.01	7.37
Grip Strength Nondominant arm (kg)	21.86	11.36	17.76	7.11

Table 39: A table to show the means and standard deviations of physiological data of Hong Kong and Beijing.

Factors	Hong Kong		Beijing	
	Mean	S.D.	Mean	S.D.
Height (cm)	155.40	14.14	145.92	18.27
Weight (kg)	45.80	12.36	39.38	15.33
Shoulder Width (mm)	354.40	35.84	311.21	44.08
Palm Length (mm)	169.59	15.51	157.71	19.96
Sole Length (mm)	229.49	19.94	218.44	24.55
Forced VC (litre)	2.76	0.80	2.41	1.13
FEV_1 (litre)	2.43	0.73	1.99	0.97
Percentage VC_{1sec}	88.07	10.67	84.24	18.85
PWC_{170} (kgm)	679.20	414.41	663.34	447.78
Max VO_2 (ml/kg/min)	58.73	15.98	60.35	20.37
Triceps Skinfolds (mm)	12.49	4.75	10.76	4.40
Suprailiac Skinfolds (mm)	11.68	5.69	8.55	5.16
Subscapularis Skinfolds (mm)	10.83	4.58	7.61	4.04
Abdomen Skinfolds (mm)	10.35	5.16	8.97	6.09
Calf Skinfolds (mm)	12.13	4.90	11.88	5.71
Sum of Skinfolds (mm)	57.49	22.39	47.47	22.54
Grip Strength Dominant arm (kg)	22.49	8.61	20.23	10.74
Grip Strength Nondominant arm (kg)	20.93	8.34	19.13	10.41

Table 40: A table to show the means and standard deviations of physiological data of Chinese (Hong Kong & Beijing) swimmers and nonswimmers.

Factors	**Swimmer**		**Non-swimmer**	
	Mean	**S.D.**	**Mean**	**S.D.**
Height (cm)	150.34	17.25	149.01	17.51
Weight (kg)	42.30	14.68	41.54	14.49
Shoulder Width (mm)	332.47	47.17	324.04	44.90
Palm Length (mm)	163.76	19.16	161.14	19.23
Sole Length (mm)	223.35	24.17	222.27	22.85
Forced VC (litre)	2.79	1.13	2.33	0.87
FEV_1 (litre)	2.33	0.95	2.02	0.85
Percentage VC_{1sec}	85.32	17.08	86.09	15.52
PWC_{170} (kgm)	805.89	443.94	549.10	383.25
Max VO_2 (ml/kg/min)	66.84	16.30	51.69	17.02
Triceps Skinfolds (mm)	9.85	3.41	12.83	5.07
Suprailiac Skinfolds (mm)	8.37	4.18	11.00	6.27
Subscapularis Skinfolds (mm)	7.53	3.33	10.05	5.10
Abdomen Skinfolds (mm)	8.12	4.05	10.73	6.73
Calf Skinfolds (mm)	9.93	3.40	13.78	6.16
Sum of Skinfolds (mm)	43.79	15.73	58.38	25.97
Grip Strength Dominant arm (kg)	22.65	10.74	19.72	9.14
Grip Strength Nondominant arm (kg)	21.41	10.54	18.41	8.65

Conclusions

The present project was conducted to provide more information on Chinese pre-adolescent and adolescent swimmers living in Hong Kong and Beijing. Within the limitations of the testing protocols, seasonal changes, and size/recruitment of the sample, several interesting facts were revealed.

There are significant differences between Hong Kong and Beijing subjects which might be attributed to a richer diet (protein and fat) in Hong Kong and thus, leading to faster growth and maturation. Significant interactions with the swimming/nonswimming and gender factors suggest that the relationship is complex and multi-dimensional. Although Hong Kong subjects score significantly higher in the test items, not all of them are desirable e.g. thicker skinfolds suggest more body fat. Some adjustments will be necessary in interpreting and comparing data from different regions in the Mainland in the future.

The differences between the gender are also identified. The males score better in nearly all the physiological parameters measured. Future investigations should focus on the relationships of these parameters with performance within each gender. The differences in the performance of Chinese male and female swimmers in international competitions suggest that other factors might be important in contributing to the overall success of the swimmers. Future studies should be conducted to establish a profile for each gender in this area.

The assessment of grip strength, forced vital capacity or forced expiratory volume, physical work capacity or maximum oxygen uptake, and skinfolds in talent identification was shown to be valid and effective. The feasibility to conduct field versus laboratory testings would affect the quality of the data collected and thus the overall interpretations. Future testing should consider e.g., underwater filming, measuring of swimming efficiency and its relationship to stroke frequency and water resistance, evaluating lactate level at different phases of training and competition, and other psychological data. The role of field tests, however, is still important since they can provide meaningful data and better understanding of the profile of the swimmer very quickly and economically.

Results of the present study support earlier findings on the physiological characteristics of swimmers. The importance of conducting testings of swimmers is confirmed and an expansion in the scope of profiling swimmers is suggested e.g., the use of swim-training profiles and performance data to assess the effectiveness of training (Mujika et. al., 1996). It is only through continuous research on a longitudinal basis can we understand the various factors which contribute to the making of a world champion, in swimming or any sport.

Table 41: A table to show the means and standard deviations of the Height data of Chinese swimmers (N=279).

Age	Height (cm)					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	132.51	6.25	16	131.85	3.29	10
9	136.78	3.49	15	131.79	3.91	14
10	141.02	8.67	16	144.21	5.68	16
11	150.35	6.02	15	151.05	5.58	19
12	154.12	7.65	24	155.26	8.05	18
13	161.03	6.81	20	158.60	6.19	20
14	170.90	11.36	16	165.99	5.87	14
15	172.99	7.34	10	165.18	5.67	08
16	176.10	4.29	07	163.59	10.93	09
17	181.57	6.51	06	170.15	3.87	06

Table 42: A table to show the means and standard deviations of the Weight data of Chinese swimmers (N=280).

Age	Weight (cm)					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	28.19	3.59	16	26.30	1.62	10
9	30.91	3.92	15	31.79	3.91	14
10	34.98	6.43	16	34.86	7.83	16
11	40.73	5.28	16	38.26	5.44	19
12	44.14	8.28	24	42.86	7.98	18
13	47.92	4.77	20	47.44	6.42	20
14	58.37	10.43	16	47.44	6.42	20
15	65.75	9.46	10	53.36	5.56	08
16	70.26	7.12	07	58.03	7.30	09
17	77.63	11.68	06	60.67	6.01	06

Table 43: A table to show the means and standard deviations of the Shoulder Width data of Chinese swimmers (N=280).

Age	**Shoulder Width (mm)**					
	Males			**Females**		
	Mean	**S.D.**	**N**	**Mean**	**S.D.**	**N**
8	289.25	20.45	16	274.90	28.01	10
9	304.47	16.62	15	300.07	18.86	14
10	309.20	16.59	15	319.60	27.96	15
11	331.50	16.96	16	326.47	14.26	19
12	344.38	30.21	24	344.56	20.34	18
13	355.05	20.75	20	348.10	19.01	20
14	375.75	25.93	16	366.73	16.29	14
15	402.40	22.01	10	375.38	19.82	08
16	416.86	18.31	07	374.00	7.91	09
17	421.33	22.22	06	383.17	14.41	06

Table 44: A table to show the means and standard deviations of the Palm Length data of Chinese swimmers (N=280).

Age	**Palm Length (mm)**					
	Males			**Females**		
	Mean	**S.D.**	**N**	**Mean**	**S.D.**	**N**
8	145.53	7.23	16	143.60	5.82	10
9	149.20	5.26	15	151.54	4.95	14
10	154.94	9.14	16	160.16	15.14	16
11	163.53	6.44	16	163.82	7.14	19
12	168.61	11.95	24	170.33	10.66	18
13	177.33	9.67	20	170.60	6.14	20
14	179.41	22.93	16	179.93	6.74	14
15	187.05	7.99	10	174.50	9.52	08
16	192.07	5.22	07	178.17	7.91	09
17	199.08	14.50	06	184.17	1.72	06

Table 45: A table to show the means and standard deviations of the Sole Length data of Chinese swimmers (N=280).

Age	**Sole Length (mm)**					
	Males			**Females**		
	Mean	**S.D.**	**N**	**Mean**	**S.D.**	**N**
8	200.59	8.81	16	199.70	8.12	10
9	207.57	11.73	15	211.39	9.05	14
10	213.59	12.66	16	209.88	14.66	16
11	232.69	9.06	16	224.84	7.07	19
12	236.06	12.69	24	226.58	13.78	18
13	245.38	12.24	20	227.70	9.89	20
14	249.53	13.77	16	235.46	8.93	14
15	255.10	10.77	10	234.31	8.59	08
16	256.64	5.45	07	236.89	12.48	09
17	266.92	18.70	06	239.00	9.25	06

Table 46: A table be show the means and standard deviations of the Forced VC data of Chinese swimmers (N=280).

Age	**Forced VC (litre)**					
	Males			**Females**		
	Mean	**S.D.**	**N**	**Mean**	**S.D.**	**N**
8	1.91	0.37	16	1.66	0.28	10
9	2.17	0.30	15	2.00	0.31	14
10	2.44	0.56	16	2.14	0.33	16
11	2.76	0.57	16	2.56	0.48	19
12	3.03	0.50	24	2.81	0.69	18
13	3.19	0.51	20	3.09	0.61	20
14	4.05	0.85	16	3.48	0.39	14
15	4.13	1.35	10	3.45	0.69	08
16	4.96	0.60	07	3.82	0.70	09
17	5.67	0.88	06	4.25	0.63	06

Table 47: A table to show the means and standard deviations of the FEV_1 data of Chinese swimmers (N=278).

Age	FEV_1 (litre)					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	1.65	0.29	16	1.63	0.20	10
9	1.84	0.29	15	1.69	0.24	14
10	1.79	0.54	16	1.91	0.36	16
11	2.21	0.73	16	1.78	0.55	19
12	2.45	0.53	24	2.21	0.57	18
13	2.85	0.30	20	2.61	0.63	20
14	3.52	0.62	16	2.94	0.57	14
15	3.74	0.90	10	3.00	0.52	08
16	4.00	0.54	07	3.15	0.64	09
17	4.59	0.57	06	3.44	0.43	06

Table 48: A table to show the means and standard deviations of the Percentage of Vital Capacity expired in 1 second data of Chinese swimmers (N=279).

Age	% VC_{1sec}					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	87.30	8.45	16	92.82*	15.68*	10
9	86.99	12.94	14	85.50	13.31	14
10	74.52	17.35	16	89.45	8.97	16
11	80.36	19.10	16	71.97	24.07	19
12	81.54	15.13	24	79.28	14.07	18
13	90.59	12.62	20	87.12	22.11	20
14	87.76	7.35	16	85.20	16.88	14
15	97.79	36.12	10	87.85	8.65	08
16	80.82	9.31	07	82.56	7.33	09
17	81.63	8.64	06	81.68	8.33	06

* Adjustments were made.

Table 49: A table to show the means and standard deviations of the PWC_{170} data of Chinese swimmers (N=258).

Age	PWC_{170} (kgm)					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	458.33	122.03	15	348.70	251.95	10
9	553.75	124.22	12	405.23	143.53	13
10	516.78	159.90	14	569.06	146.70	15
11	512.58	114.92	12	755.57	289.13	19
12	674.90	269.22	24	863.99	443.09	17
13	733.25	203.46	19	902.94	444.77	19
14	1085.67	327.48	15	1181.15	571.93	13
15	1417.40	600.94	10	1366.63	608.46	08
16	1259.67	218.18	06	1109.33	189.55	06
17	1489.67	256.11	06	1177.40	528.20	05

Table 50: A table to show the means and standard deviations of the Max VO_2 data of Chinese swimmers (N=222).

Age	Max VO_2 (ml/kg/min)					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	79.66	19.78	10	69.81	4.86	03
9	68.12	8.30	12	69.56	15.65	11
10	65.24	16.19	10	73.83	17.98	16
11	56.33	15.47	11	76.90	12.83	19
12	60.47	12.87	18	72.31	16.78	15
13	53.97	10.77	19	72.13	19.05	18
14	60.63	13.48	15	70.82	14.10	12
15	57.29	8.95	06	78.72	14.28	08
16	56.55	6.11	04	59.04	18.52	07
17	45.73	4.82	03	65.00	11.11	05

Table 51: A table to show the means and standard deviations of the Triceps Skinfolds data of Chinese swimmers (N=278).

Age	Triceps Skinfolds (mm)					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	9.31	2.30	15	9.49	3.63	10
9	8.43	2.64	15	9.81	5.28	14
10	9.16	3.70	15	10.84	3.97	16
11	12.29	4.46	16	9.31	2.42	19
12	9.15	3.01	24	9.01	2.95	18
13	8.29	1.94	20	11.65	3.43	20
14	8.15	2.30	16	11.97	3.87	14
15	9.08	5.16	10	10.53	2.35	08
16	6.86	0.57	07	12.65	3.11	09
17	7.11	1.21	06	13.24	2.82	06

Table 52: A table to show the means and standard deviations of the Suprailiac Skinfolds data of Chinese swimmers (N=278).

Age	Suprailiac Skinfolds (mm)					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	6.04	2.08	15	6.53	2.84	10
9	5.98	4.07	15	9.81	5.28	14
10	6.93	5.33	15	7.56	4.60	16
11	9.66	4.51	16	7.32	2.74	19
12	8.66	4.61	24	9.01	2.95	18
13	8.29	1.94	20	11.65	3.43	20
14	8.15	2.30	16	11.09	4.24	14
15	11.84	5.84	10	10.71	3.17	08
16	10.31	4.88	07	11.81	2.95	09
17	6.98	1.23	06	10.18	2.16	06

Table 53: A table to show the means and standard deviations of the Subscapularis Skinfolds data of Chinese swimmers (N=278).

Age	Subscapularis Skinfolds (mm)					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	5.34	0.90	15	5.50	1.43	10
9	6.05	3.89	15	6.90	2.75	14
10	6.83	4.68	15	7.05	3.89	16
11	8.23	4.07	16	6.47	1.48	19
12	7.61	3.23	24	7.34	1.56	18
13	7.39	2.15	20	9.43	3.05	20
14	8.03	3.14	16	9.32	3.41	14
15	10.57	5.87	10	9.39	2.17	08
16	10.02	3.98	07	10.83	2.70	09
17	8.57	1.06	06	9.89	1.87	06

Table 54: A table to show the means and standard deviations of the Abdomen Skinfolds data of Chinese swimmers (N=278).

Age	Abdomen Skinfolds (mm)					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	6.01	2.14	15	6.13	3.15	10
9	6.07	3.89	15	7.78	3.69	14
10	6.62	4.50	15	7.52	5.23	16
11	10.06	5.44	16	6.84	2.20	19
12	8.23	4.15	24	7.99	3.32	18
13	8.48	3.38	20	12.41	4.39	20
14	8.01	3.14	16	10.58	4.32	14
15	9.00	5.53	10	10.04	4.36	08
16	8.91	5.38	07	10.63	3.59	09
17	8.24	1.71	06	10.02	1.12	06

Table 55: A table to show the means and standard deviations of the Calf Skinfolds data of Chinese swimmers (N=278).

Age	Calf Skinfolds (mm)					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	8.16	2.62	15	9.06	2.69	10
9	8.20	2.87	15	9.64	3.08	14
10	9.61	2.28	15	9.52	2.85	16
11	10.75	3.73	16	8.72	2.59	19
12	10.00	3.02	24	10.30	2.36	18
13	10.53	3.19	20	11.55	3.06	20
14	10.36	3.31	16	11.84	3.29	14
15	9.99	5.53	10	9.16	4.36	08
16	7.26	0.98	07	13.93	5.05	09
17	7.71	1.47	06	10.49	1.12	06

Table 56: A table to show the means and standard deviations of the Sum of Skinfolds data of Chinese swimmers (N=278).

Age	Sum of Skinfolds (mm)					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	34.85	8.31	15	36.71	11.79	10
9	34.74	16.51	15	45.21	14.74	14
10	39.16	17.39	15	42.50	18.32	16
11	50.99	20.77	16	38.66	9.77	19
12	43.66	15.90	24	43.23	10.04	18
13	42.69	11.74	20	56.03	14.34	20
14	43.73	13.90	16	54.80	16.97	14
15	50.47	23.65	10	49.83	12.35	08
16	43.36	14.57	07	59.84	10.09	09
17	38.60	4.38	06	53.83	9.21	06

Table 57: A table to show the means and standard deviations of the Grip Strength dominant arm data of Chinese swimmers (N=277).

Age	Grip Strength Dominant arm (kg)					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	12.41	2.09	16	13.70	2.63	10
9	16.13.	2.31	15	14.88	2.67	14
10	18.00	3.73	15	17.64	3.20	16
11	19.48	3.61	16	19.47	2.47	19
12	24.00	5.02	24	24.78	6.76	17
13	26.50	4.30	20	24.95	4.32	20
14	36.45	8.58	16	29.93	5.15	13
15	40.28	6.79	10	28.00	3.94	08
16	43.57	5.35	07	29.56	2.49	09
17	54.83	11.41	06	32.42	4.35	06

Table 58: A table to show the means and standard deviations of the Grip Strength non-dominant arm data of Chinese swimmers (N=277).

Age	Grip Strength Nondominant arm (kg)					
	Males			Females		
	Mean	S.D.	N	Mean	S.D.	N
8	11.48	2.25	16	13.40	2.29	10
9	15.22	1.77	15	13.29	2.61	14
10	16.85	3.47	15	16.39	3.94	16
11	17.92	3.10	16	17.74	2.64	19
12	23.18	5.50	24	22.32	5.59	17
13	25.43	5.54	20	23.83	5.07	20
14	34.37	8.67	16	28.90	5.61	13
15	38.05	5.72	10	27.06	3.72	08
16	42.64	5.38	07	28.33	2.37	09
17	52.25	14.40	06	30.92	3.63	06

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Professor Frank H. Fu
Hong Kong Baptist University
Hong Kong, China

Professor Cen Hao-wang
National Research Institute of Sports Science
Beijing, China

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