Contribution of physique and muscular strength to pull swimming force and swimming performance in school-boy swimmers.

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Abstract

Great interest in previous many studies has been directed mainly to skilled or competitive college swimmers, but hardly to unskilled or child swimmers. However, it will be very important to get information concerning the developmental process of swimming speed with age. This study was conducted to determine contribution of physique and muscular strength to swimming performance and pull swimming power from a growth-and developmental prospective.

One hundred and sixty healthy school-boy swimmers were selected as subjects, ranged with ages from 6 to 12 years. They parcticed swimming twice a week for at least 2 years and could swim crawl stroke more than 500m meters. Three kinds of crawl swimming speed tests, 3 pull swimming power tests in water, 3 physique tests, and 4 strength tests were administered to all of the subjects.

The main results can be summarized as follows;

1. Swimming speed and pull swimming power in crawl stroke in addition to physique and muscular strength develop significantly with age.
2. Pull swim speed contributes to total swim speed somewhat higher than kick swim speed, and this trend seems to be higher in age stages over 8 years.
3. Physique contributes to pull swimming power in 8 years and older children, but not to swimming speed.
4. Muscular strength contributes to pull swimming power in children from 6 to 12 years of age. Contribution of muscular strength is somewhat higher in 8 years and older children and than in 7 years and younger children.

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I. Introduction

Various factors including physical ones are considered to relate to the achievement of swimming. In speed swimming, especially big muscle power is needed to produce great impulsion in water. Therefore, some researchers[1 4 5 17 19 20]assert that muscular strength is the most important factor contributing to speed swimming. Previously, many comparative and correlative studies[2 7 8-11 16 22]have substantiated this fact, using skilled swimmers as subjects. Physique is also known as an important factor influencing swimming performance.[7 10-14 15 23 24 25]

Swimming has a different feature from many innate exercises such as running, throwing, jumping, etc. Namely, we must master swimming technique through practice in water, but anyone can do innate exercises when a certain age is reached.

Certainly, for skilled competitive swimmers, the size of muscular strength will be an important factor, because it is considered to relate closely to the success of swimming performance. In case of unskilled swimmers, however, it is doubtful whether strength is used to produce more impulsion, because they do not have the proper technique to convert their strength into impulsion.

The degree of acquired swimming skill may differ with the content of the practice program (intensity, duration and frequency). However, it is assumed that skill levels, which children can acquire, differ in accordance to their physical fitness levels in each growth and developmental stage, even if they do the same practice program. In short, various laws found out by reseach on skilled adolescent and adult swimmers can not be applied to unskilled school children.

Many studies have been carried out on skilled or competitive college swimmers, but only a few studies on child swimmers.[14] The purpose of this study is to determine the contribution of physique and muscular strength to swimming speed and pull swimming power in school-boy swimmers from a growth-and developmental perspective.

II. Methods

Subjects

A total of 161 school-boy swimmers aged from 6 to 12 years volunteered as subjects for this study. They practiced swimming at a swimming club twice a week for about 2 years and could

swim crawl stroke continuously for more than 500m. The sample size of each age group is shown in Table 1. In addition to an analysis of all subjects (GA), to examine from the growth and developmental prespective, the following 3 groups were analyzed : lower age group (6-7 yr, GL), middle age group (8-9yr, GM), higher age group (10-12yr, GH). These groups were arbitrarily classified.

Test variables

Three physique tests of stature, body weight, and chest girth were chosen as representing each physique domain of body linearity, body weight, and body bulk. For muscular strength tests, the following 4 tests were used. : back strength, grip strength, arm strength, leg strength. These strengths are assumed to costribute closely to the production of the impulsion in water. The sum of 4 strength values was used as a total strength score. Of the above 4 tests, arm and leg strength were tested according to Miyashita's method.[22] The other tests were performed according to general practice.

Three kinds of swimming speed tests of total swim(TS), pull swim(PS), and kick swim(KS) in crawl stroke were performed. In each speed test, a subject was instructed to swim 25 meters at his best. The time was measured between 15 meters from 5 to 20. In case of a pull swimming force test, a maximum pull force, which a subject exerted when he swam total swim(TF), pull swim(PF), and kick swim(KF) in crawl stroke, was measured. Details of these test methods were described in previous studies.[14]

Statistical procedures

The ANOVA was used to test the differences among means of 7 groups with different ages from 6 to 12. A simple correlation and a partial correlation were calculated for determining the inter-relationship between swimming speed, pull swimming force, physique, and muscular strength. Further, to examine the contribution of physique and muscular strength to swimming speed and pull swimming force, a multiple correlation analysis method was used.

III. Results and discussion

1. Development of swimming speed, physique, muscular strength and pull swimming force with age.

Table 1 shows means and standard deviations of each age group, and test results of mean

differences for all variables selected in this study. All variables show significant differences among age groups from 6 to 12 yr. Also Table 2 shows significant correlation coefficients, 0.533-0.852, between age and each variable.

Table 1. Means, standard deviations, and test results among means of 7 groups with different age levels for all variables.

age	6 (10)		7 (40)		8 (30)		9 (29)		10 (25)		11 (16)		12 (11)		(yr)
No vatiable	AV	SD	AV	SD	AV	SD	AV	SD	AV	SD	AV	SD	AV	SD	F-value
1. total speed	0.55	0.06	0.64	0.09	0.76	0.14	0.82	0.14	0.90	0.17	1.00	0.14	1.04	0.17	36.76**
2. pull speed	0.40	0.06	0.42	0.07	0.51	0.09	0.56	0.09	0.62	0.11	0.69	0.12	0.81	0.13	33.86**
3. kick speed	0.57	0.05	0.61	0.07	0.66	0.09	0.66	0.10	0.71	0.10	0.75	0.06	0.75	0.11	16.53**
4. total power	2.75	0.58	3.57	0.60	4.49	1.20	5.24	0.96	5.90	1.10	6.72	1.26	7.76	1.63	47.11**
5. pull power	2.01	0.35	2.42	0.52	3.24	0.68	3.37	0.89	4.15	1.03	4.96	1.27	6.32	1.32	39.19**
6. kick power	1.53	0.32	1.96	0.50	2.32	0.58	2.61	0.83	3.08	0.82	3.60	0.85	3.56	0.77	25.11**
7. stature	116.59	7.26	122.69	5.24	128.25	4.26	132.80	5.73	137.90	4.85	142.22	4.98	149.52	6.70	68.13**
8. body weight	21.66	3.90	23.69	3.38	27.18	4.61	29.42	5.07	32.99	5.89	36.31	7.14	40.38	7.75	21.89**
9. chest girth	58.85	2.64	60.23	2.88	63.54	4.95	64.53	4.31	67.83	4.71	70.34	6.96	72.09	6.28	19.15**
10 back strength	36.23	6.86	38.62	8.03	42.30	10.04	47.33	9.73	53.89	11.13	64.78	9.90	66.30	11.35	25.99**
11. grip strength	26.90	4.29	28.88	4.08	35.32	5.08	37.13	4.51	41.13	5.84	46.97	5.74	51.53	5.69	53.12**
12. arm strength	8.94	1.20	9.16	1.55	11.23	1.64	11.62	1.31	13.05	1.66	15.52	1.52	18.47	3.20	47.81**
13. leg strength	18.43	2.88	21.10	3.65	26.40	4.71	29.09	5.13	33.19	4.51	38.54	8.00	45.42	8.25	46.31**
14. total strength	90.49	11.31	97.77	11.93	115.25	16.41	125.17	15.43	141.26	18.94	165.81	19.08	181.72	22.80	58.76**

Note: Figures in a parentheses are sample sizes of each age group.
Strength values of grip, arm, and leg are the sum of right and left strength values, respectively.
Total strength value is the sum of back, grip, arm, and leg strength values.
A unit of each variable is as follows; variable numbers 1 to 3=m/s, 4 to 6, 8, and 10 to 14=kg, 7 and 9=cm.
**means significance at 1% level.

From these results, it is inferred that also swimming speed and pull swimming power in addition to physique and muscular strength develop with age in school children. And, if swimming practice of the same content is done, older children seem to get higher swimming ability than younger children.

Further, the developmental relationships of TS, PS, and KS in each age stage (see Fig. 1.) indicate that, more than the pull speed, the kick speed of the younger contributes to total speed, and the contribution of PS to TS increases with age. This could depend on the following; first, younger children, especially those below 7 years, feel difficultly in mastering complicated crawl-pull-technique with breathing, although to master crawl-kick-technique is relatively easy, because crawl kicking is a movement similar to man's walking movement.[14] Second, in the introduction stage of swimming teaching, generally, more practice of crawl kick is performed.

Consilman[5] [18]reported that in skilled competitive swimmers, about 70% of total speed depends on pull speed in crawl stroke. However, this is not the case in immature or unskilled swimmers in this study.

2. The relationships between swimming speed, pull power, physique, and muscular strength.

Table 2 shows means, standard deviations, a correlation matrix (under side) and a partial correlatiom matrix (upper side). Tables 3 through 5 show the results of the same content calculated in each age group of GL, GM, and GH.

Table 2. Means, standard deviations, correlation matrix (under side) and partial correlation matrix (upper side) for all subjects (GA) (NS=161).

No	variable	AV	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	total speed	0.80	0.20		716	638	395	342	351				186	233	246		240
2	pull speed	0.55	0.15	875		369	268	480	261				200	206	327		262
3	kick speed	0.67	0.10	758	610		363	215	400				180		170		214
4	total power	4.93	1.71	747	721	611		611	560	385	509	507	345	355	450	469	512
5	pull power	3.49	1.42	718	795	531	855		532	400	501	410	397	392	571	522	583
6	kick power	2.55	0.93	667	640	608	785	770		252	406	335	320	283	391	398	446
7	stature	131.17	10.25	654	705	471	803	798	668		707	516	288	447	474	386	480
8	body weight	29.01	7.39	561	593	426	783	775	687	865		859	338	467	545	614	596
9	chest girth	64.45	6.10	551	563	798	750	702	623	758	921		273	359	435	566	499
10	back strength	47.48	13.61	598	627	479	704	721	635	699	663	599		324	428	280	829
11	grip strength	36.60	8.66	689	707	509	777	781	668	831	769	687	701		543	472	704
12	arm strength	11.82	3.14	698	755	521	813	847	716	843	802	722	746	851		538	698
13	leg strength	28.54	9.00	634	680	496	816	827	717	812	829	778	682	824	849		685
14	total strength	124.45	31.15	707	744	548	842	857	743	856	824	751	904	908	909	902	
15	age	8.68	1.73	731	773	533	801	784	669	852	709	648	693	817	825	816	849

Note : Partial correlations were calculated by eliminating the influence of age.
Decimal points of each correlation coefficient are ommited.
Values over 155 in correlations (under side) and values over 156 in partial correlations (upper side) are significant at the 5% level, repectively.
Insignificant correlations are commited.

Because the correlation matrix in Table 2 was calculated for all subjects (GA), the influence of age is considered to reflect on each correlation coefficient strongly. Viewing a partial correlation matrix eliminating the influence of age, most coefficients show a great decrease, although some do not change as much as values of TS and PS (0.875 to 0.716).

Viewing correlations between age and each variable in Tables 3 through 5, GH shows significance in all of them, but GL and GM in some. In addition, the values of GH are somewhat higher than those of GL and GM.

This difference may be explained by the fact that GH as compared with the other groups

is a group with a relatively wide age range from 10-12yr, and especially this age stage is remarkable in the developmental change of various physical functions. Therefore, to examine the relationship between each variable in the same dimension, also for 3 age groups of GL, GM and GH, a partial correlation was calculated (see Tables 3 through 5).

First, viewing the partial correlations between each swimming speed of TS, PS and KS, for GA, all correlations are significant, while the correlation values between TS and PS are somewhat higher than those of TS and KS. The same trend is found in GM and GH, but the reverse in GL. Only GL shows an insignificant correlation between PS and KS. In the correlations between swimming speeds and pull forces, GM, GH and GA show significance in all of three correlations of TS and TF, PS and PF, and KS and KF, but GL only in a correlation between TS and TF.

The above results are considered to indicate that the contribution of pull speed to total speed is higher than that of kick speed, and significant inter-relationships between crawl swim speeds and pull forces exist. For example, a school child with faster pull speed or greater pull force can swim faster in crawl stroke.

Considering the growth and development standpoint, the contribution of pull speed to total speed is lower in a lower age stage below 7 yr than in age stages over 8 yr. Counsilman's report[5] seems to be supported especially in the older age group. Further, the results in this study also indicate that in a lower age stage, pull swimming power exerted by crawl pull and

Table 3. Means, standard deviations, correlation matrix (under side) and partial correlation matrix (upper side) for a lower age group (GL) (NS=50).

No	variable	AV	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	total swim	0.62	0.09		332	611	283										
2	pull swim	0.42	0.07	361											316		284
3	kick swim	0.60	0.07	632													
4	total power	3.39	0.68	422		273		371		279	362	293			427	288	355
5	pull power	2.33	0.52	276			466		418	417	466	346		333	617	369	469
6	kick power	1.87	0.50				342	485							377		352
7	stature	121.37	6.26		301		421	491	292		882	714	391		592	288	505
8	body weight	23.26	3.60		273		421	504		879		779	326		627		434
9	chest girth	59.93	2.88				347	385		720	789				563	379	366
10	back strength	38.11	7.85					277		406	344				396		777
11	grip strength	28.45	4.21					372		301					320	607	681
12	arm strength	9.11	1.48		321		401	603	374	566	623	563	400	325		399	617
13	leg strength	20.53	3.66				388	430	330	372	278	414		626	398		577
14	total strength	96.20	12.17		309		421	510	406	547	466	396	778	695	612	607	
15	age	6.78	0.41	395			497	324	355	401						301	

Note: Each sign is the same as that in table 2. Insignificant correlations are ommited.

Table 4. Means, standard deviations, correlation matrix (under side) and partial correlation matrix (upper side) for middle age group (GM) (NS=52).

No	variable	AV	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	total swim	0.79	0.14		754	696	489	330	384	279				332			309
2	pull swim	0.53	0.10	766		445	270	437					301				301
3	kick swim	0.66	0.09	685	440		479	338	508				365				382
4	total power	4.86	1.15	522	322	461		633	584	524	634	541	314	471	571	534	555
5	pull power	3.30	0.79	339	443	339	623		617	472	521	371	353	491	563	579	599
6	kick power	2.47	0.73	410	282	503	606	619		511	503			467	484	523	461
7	stature	130.49	5.53	337	267	206	586	462	539		693	505		580	504	452	470
8	body weight	28.28	4.97	288			657	524	524	708		882		570	612	725	581
9	chest girth	64.03	4.68	265			543	376	253	501	878			406	432	434	431
10	back strength	44.78	10.20	253	340	360	368	361		256					397	343	827
11	grip strength	36.21	4.89	358	250		498	496	487	596	587	416			629	500	646
12	arm strength	11.42	1.50				578	567	496	509	621	440	414	637		607	717
13	leg strength	27.72	5.16				573	578	547	506	741	636	386	523	615		729
14	total strength	120.12	16.69	352	347	373	598	594	491	531	607	441	839	661	718	750	
15	age	8.49	0.50				326			412						264	297

Note : Each sign is the same as that in Table 2. Insignificant correlations are ommited.

Table 5. Means, standard deviations, correlation matrix (under side) and partial correlation matrix (upper side) for higher age group (GH) (NS=52).

No	variable	AV	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	total swim	0.97	0.17		822	598	324	435	454						377		
2	pull swim	0.68	0.14	845		389		554	387						386		
3	kick swim	0.73	0.09	633	456		309		413						348		
4	total power	6.56	1.47	469	506	397		695	665	355	478	547	454	332	449	482	552
5	pull power	4.88	1.44	552	702	305	785		568	434	513	468	490	322	505	496	580
6	kick power	3.34	0.86	510	465	456	682	604			415	467	488		450	380	498
7	stature	141.76	6.97		384		572	654	236		701	490	370	521	490	441	550
8	body weight	35.63	7.32				569	604	474	737		868	442	501	538	658	662
9	chest girth	69.54	6.09				587	527	509	540	878		431	401	464	581	595
10	back strength	59.98	12.25	377	329		568	608	543	527	528	493		526	503	328	869
11	grip strength	45.20	7.13	371	439	287	545	570	315	707	595	476	634		585	379	763
12	arm strength	14.99	2.95	518	628	416	650	720	496	732	609	504	616	762		528	721
13	leg strength	37.51	8.18		404		642	678	460	655	712	615	489	603	728		675
14	total strength	157.69	25.83	419	477	310	697	742	547	736	710	618	874	854	847	798	
15	age	10.80	0.91	384	553		573	605	281	645	372	206	419	605	753	596	641

Note : Each sign is the same as that in Table 2. Insignificant correlations are ommited.

kick strokes do not necessarily reflect on respective crawl pull and kick speeds. This may depend on the fact that force exerted by arm pull and leg kick in water can not be converted into the production of the impulsion efficiency.

Viewing the partial correlations between swimming speed and pull force variables and physique and muscular strength variables in all subjects (see Table 2), all pull forces show

significant correlations with all physique and strength variables, but swimming speeds show significant correlations only with some strength variables. From tables 3 to 5, more significant correlations between pull forces and pysique and muscular strength are found in GM and GH than in GL. Swimming speeds hardly show significant correlations with physique and muscular strength in all 3 groups.

This seems to indicate that each physique and muscular strength element hardly relates to swimming speed, but to some extent to pull swimming forces, and the degree of contribution is somewhat higher in age groups over 8 years than in lower age groups below 7 years.

3. Contribution of physique and muscular strength to swimming performance and pull swimming power.

Tables 6 and 7 show multiple correlations and the test results. This analysis was done considering swimming speeds and pull forces as criterion variables, and 3 physique variables or 4 muscular strength variables as explanatory variables. These correlations were calculated by applying the multiple regression analysis method to each partial correlation matrix of Tables 2 through 5.

Table 6. Contribution of physique and muscular strength to swimming speed.

		TS				PS				KS			
		GA	GL	GM	GH	GA	GL	GM	GH	GA	GL	GM	GH
PH	R	182	274	310	217	180	270	207	204	87	208	285	214
	F	1.79	1.24	1.95	0.77	1.73	1.21	0.82	0.68	0.40	0.69	1.62	0.75
MS	R	294	179	364	444	341	338	351	435	216	117	423	360
	F	3.69*	0.37	2.06	2.82*	5.08*	1.45	1.89	2.68*	1.89	0.16	2.94*	1.72

Note: TS, PS and KS mean speeds of total swim, pull swim and kick swim in crawl stroke, respectively.
GA, GL, GM and GH mean groups of all subjects, lower age subjects (6-7 yr), middle age subjects (8-9 yr), and higher age subjects (10-12 yr), respectively.
PH=physique, MS=muscular strength, R=multiple correlation coefficient, F=F-value *<0.05

Table 7. Contribution of physique and muscular strength to pull swimming power.

		TF				PF				KF			
		GA	GL	GM	GH	GA	GL	GM	GH	GA	GL	GM	GH
PH	R	532	373	645	561	506	467	563	530	411	176	672	528
	F	20.64*	2.53	13.05	7.19*	17.99*	4.37*	8.50*	6.13*	10.64*	0.50	15.13*	6.05*
MS	R	548	455	630	586	644	637	658	630	476	410	586	600
	F	16.74*	3.01*	8.88*	6.01*	27.62*	7.85*	10.31*	7.59*	11.42*	2.33*	7.06*	6.47*

Note: TF, PF and KF mean maximum pull swimming forces exerted in total swim, pull swim, and kick swim in crawl stroke, respectively.
The other signs correspond to those in Table 6.

Significant correlations are found between swimming speeds except KS and muscular strength in GA and GH, and between KS and muscular strength in GM. No swimming speed shows a significant correlation with physique, but pull swimming forces show significant correlations with physique in all groups except GL, and with muscular strength in all groups.

These results are considered to indicate the following ; first, strength relates to swimming performances of total swim and pull swim in crawl stroke, especially in children over 10 years. However, physique does not have a relationship with swimming performance in school age. Second, strength and physique relate to pull swimming power in crawl stroke in children over 8 years.

Even if a swimmer has great strength, without having technique to convert it into pull swimming power or swimming speed, he can not produce great swimming pull power and speed. Therefore, these results can be interpreted as follows : The older children possessed higher skill than the younger children after about 2-years swimming practice. In addition, higher skills are needed to convert strength into swimming speed than into pull power.

Demura (1978, 1982, 1989) studied the relationship between swimming performance and physique and muscular strength in skilled swimmers, determining that many physical elements relate closely to swimming performance. Other researchers found similar results, using competitive swimmers as subjects. Demura and Matsuura (1983) also determined that the increase of swimming speed has a close relationship with the growth and development of body linearity and static strength. Considering the above reports, it can be concluded that physique and muscular strength relate to swimming performance significantly, also in school children. However, the results obtained in this study are not necessarily consistent with the results of previous studies, especially in a younger age stage.

In summary, physique contributes to pull swimming power in children over 8 years, but not to swimming speed. Muscular strength contributes to pull swimming power in school age, and also to swimming speed in children over 10 years. As has been hypothesized at the beginning of this study, the main reason of this inconsistency may be the difference of skill levels of the subjects.

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