ANALYSIS OF TETHERED SWIMMING FORCE, TETHERED SWIMMING POWER, SWIMMING SPEED AND ANTROPOMETRICAL CHARACTERISTICS OF YOUNG SWIMMERS IN CRAWL STROKE

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Propulsive forces, instantaneous power and swimming velocity in semi-tethered swimming were measured in a group of 69 competitive swimmers. Also, isometric force in laboratory, best 15 m swimming velocity and 100 m freestyle personal mark and anthropometric characteristics were recorded. The results show the high relationship between swimming speed and the propulsive forces, and the instantaneous power. Consequently, the above mentioned variables can be useful for the evaluation of the swimmers along a season.

KEY WORDS: tethered swimming force, tethered swimming power, tethered swimming, anthropometrical measurements, crawl stroke.

INTRODUCTION: Swimming speed depends on the interaction of propulsive and resistive forces (Takagi and Sanders, 2000). The swimmers can increase their speed by increasing the propulsive forces or reducing the resistive forces that retard the body at a given velocity. The direct measurement of propulsive forces without modifying the swimming technique needs a complex set of instruments (Takagi and Wilson, 1999). In preliminary studies, recording force and power during semi-tethered swimming showed a high correlation with performance in efforts of 30 seconds in the crawl stroke, for swimmers of both genders. (Llana, Tella, Benavent, & Brizuela, 2002). The aim of the present study is to validate those results with a greater sample of swimmers.

METHOD: A group of 69 competition swimmers of different ages, and both genders were divided in two groups according to their performance level (Elite=finalists in the Regional. Non-elite=who did not reach the qualification times). Table 1 shows how the groups were composed.

Table 1. Description of the group of swimmers participating in the research.

Gender	Categories	Performance level
Female (38)	9-10 years old (9)	E = 3; NE= 6
	11-12 years old (12)	E = 6; NE = 6
	13-14 years old (7)	E = 4; NE = 3
	15-16 years old (10)	E = 5; NE = 5
Male (31)	11-12 years old (8)	E = 5; NE = 3
	13-14 years old (12)	E = 7; NE = 5
	15-16 years old (11)	E = 5; NE = 6

The measurements consisted of:
1) Measured and calculated parameters:
- Records of semi-tethered propulsive forces. The force records were made by a strain gauge load cell. The subjects were wearing a belt - attached to an elastic cord, a tethered made up of: a) high resistance elastic cord with a force-deformation constant: def (m) = -1.776 + .502·F (kg) and r=.998, and b) less resistance elastic cord with a force-deformation constant: def (m)= -1.500 + 1.918·F (kg) and r=.999. Each swimmer performed one test at maximum intensity for 30 seconds, in each condition, with 20 minutes of rest between every condition. The force data was registered at 100 Hz.

- Calculation of displacement during the trial, by means of the previous calibration of the elastic cord.
- Calculation of the velocity of swimmng, depending on displacement.
- Calculation of the instantaneous tethered power delivered by the swimmer.

2) Records of isometric force in laboratory. Test of isometric global strengh to measure the "General Strengh" (GS) and a test of "Specific Strengh" (SS) with the swimmer face downward on a bank with the hands in the middle point of the subacuatic traction.
3) Swimming performance tests: swimming velocity test in over 15 m and the best personal mark in 100 m freestyle.
4) Anthropometric characteristics.

The record files were analysed with the software SPSS (v.8). The following statistical analyses were carried out:
- ANOVA's of one factor with Post hoc Scheffs test and with a significance level $g<.05$.
- A correlational study all the kinematic, kinetic and antropometrical variables. Pearson's correlation coefficients with a significance level $g<.05$.

RESULTS: - Female (Table 1). Significant differences ($p<.01$ and $p<.05$) were found between swimmers aged 9-10 and the other categories in all the swimming performance and kinetic variables. In the antropometric variables there were significant differences ($p<.01$ and $p<.05$) between swimming aged 9-10 and the rest of categories in the variables LM, AM, LP, AP, P and AS. There were also significant differences between the category of 11-12 years old and 15-16 years old categories in the performance variables; the Fmax and Pmax with rubbers tipe I and Fmax with rubbers tipe II of the kinetic variables and the LM, P and AS of the antropometric variables. The correlational analysis show high relationships ($r>.7$ and $p<.05$) between the swimming performance variables and all the kinetic variables. The number of statistically significant correlations between swimming performance variables and the antropometric ones, was very little.
- Male (Table 2). Significant differences ($p<.01$ and $p<.05$) were found between the swimmers aged 11-12 and the rest of categories in all the swimming performance and kinetic variables. In the antropometric variables, there were significant differences ($p<.01$ and $p<.05$) between the swimmers aged 11-12 and the rest of the categories in the variables LM, AM, AP, LP, P and T. The number of statistically significant correlations between swimming performance variables and the antropometric variables was very little. The correlational analysis between the swimming performance variables and the kinetic ones show high relationships ($r>.7$ and $p<.05$) in all the variables.

DISCUSSION: The kinetic studied variables show high correlations with the swimming performance, which coincides with the results reported by Magel, J.R. (1970) and Arellano, R. (1992). It is necessary to emphasize that the power determined with this methodology presented higher correlations with the force measured in water and with swimming performance more than with the isometric force measured in laboratory. On the other hand, there were found few correlations between the antropometric variables and the swimming performance, which coincides with the studies of Tella, V (1998) and Kheriff, T. Pelayo, P. Sydney, M. Chollet, D. And Toumy, C (1994).

CONCLUSIONS: The relationship between swimming velocity and the semi-tethered propulsive forces has been stated as other studies mentioned above. Besides, the variable instantaneous semi-tethered power has showed similar correlations. Those results indicate that, although this methodology neither registers propulsive force of the stroke nor the active drag force of the body, allows to register highly correlated variables with the swimming performance. Consequently, the above mentioned variables can be useful for the evaluation of the swimmers along a season.

Table 1. Average values of the swimming performance, kinetic and anthropometrical variables for categories in female. The numbers in superindex indicate the statistically significant differences ($p<.01$ and $p<.05$).

	11-12 years old ^{1}			9-10 years old ^{2}			13-14 years old ^{3}			15-16 years old ^{4}		
	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
M15 (s)	12	9.82	.29	9	11.06^{1,3,4}	.58	7	9.54	.44	10	9.28	.43
M100 (s)	12	73.02^{4}	3.45	9	89.09^{1,3,4}	6.79	7	68.38	3.06	10	66.57	3.34
GS (kg)	12	70.17	14.33	9	48.22^{1,4}	11.50	7	62.57	13.50	10	68.60	11.22
SS (kg)	12	24.33^{4}	7.44	9	16.67^{3,4}	6.08	7	34.14	8.47	10	36.30	8.55
Fmax rubbers I (kg)	12	6.09^{4}	.60	9	4.06^{1,3,4}	.45	7	6.97	1.18	10	7.95	.98
Pmax rubbers I (kg)	12	1.48^{4}	.25	9	.85^{1,3,4}	.14	7	1.76	.45	10	2.30	.82
Fmax rubbers II (kg)	12	8.00^{4}	.76	9	5.31^{1,3,4}	.66	7	9.00	1.59	10	10.00	1.17
Pmax rubbers II (kg)	12	12.06	2.20	9	5.65^{1,3,4}	2.09	7	12.07	2.78	10	14.58	3.01
LM (cm)	12	16.78^{4}	.65	9	15.42^{1,3,4}	.78	7	17.67	.97	10	18.05	1.08
AM (cm)	12	9.40	.41	9	8.70^{1,3,4}	.51	7	9.65	.46	10	9.92	.49
LP (cm)	12	22.53	.95	9	21.60^{3,4}	1.09	7	23.47	1.19	10	23.74	1.32
AP (cm)	12	8.87	.44	9	8.42^{4}	.37	7	8.92	.43	10	9.17	.59
W (kg)	12	47.75^{4}	6.39	9	35.88^{1,3,4}	5.67	7	50.78	6.86	10	59.75	7.07
AS (cm)	12	158.30$_{4}$	5.51	9	143.53^{1,3,4}	8.31	7	165.38	6.57	10	171.57	7.07

Table 2. Average values of the swimming performance, kinetic and anthropometrical variables for categories in male. The numbers in superindex indicate the statistically significant differences ($p<.01$ and $p<.05$).

	11-12 ^{1}			13-14 ^{2}			15-16 ^{3}		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
M15 (s)	12	8.53	.30	8	9.29^{1,3}	.41	11	8.47	.33
M100 (s)	12	63.32	2.69	8	72.22^{1,3}	3.84	11	60.66	2.78
GS (kg)	12	103.92	24.10	8	70.63^{1}	15.00	11	87.91	21.03
SS (kg)	12	39.00	8.57	8	27.38^{1,3}	6.63	11	41.36	9.15
Fmax rubbers I (kg)	12	9.51	1.11	8	6.86^{1,3}	1.07	11	10.43	1.08
Pmax rubbers I (kg)	12	3.68	1.37	8	1.81^{1,3}	.60	11	4.92	1.24
Fmax rubbers II (kg)	12	12.25	1.83	8	8.88^{1,3}	1.50	11	13.26	1.24
Pmax rubbers II (kg)	12	20.93	3.81	8	13.50^{1,3}	3.88	11	21.75	2.87
LM (cm)	12	19.05	.75	8	17.20^{1,3}	.81	11	18.91	.72
AM (cm)	12	11.13	.67	8	9.97^{1,3}	.70	11	11.08	.48
LP (cm)	12	25.65	1.01	8	24.10^{1,3}	1.36	11	25.50	1.07
P (cm)	12	60.87	8.79	8	47.18^{1,3}	6.34	11	65.18	7.06
T (cm)	12	170.40	4.75	8	158.2^{1,3}	6.51	11	173.75	6.26

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