EQUATION REGRESSION MODEL FOR THE 50 M FREESTYLE PERFORMANCE IN ELITE MASTER SWIMMERS

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This study was conducted during the 10th World Masters Championships, held in Riccione, Italy, June 3-11, 2004. The aim was to investigate, in male and female elite master swimmers, the relationships between performance time and age, anthropometric characteristics (weight, stature, arm and forearm lengths and forearm volume) and muscle strength (hand grip). Performance times were recorded during 50 m freestyle events. Anthropometric values and hand grip were collected the same day the competition in a field laboratory organised beside the swimming pool. For this study we considered twenty eight volunteers: 15 men aged 42-81 years and 13 women aged 41–73 years. Firstly, the anthropometrical characteristics, the hand grip strength and the performance time were used for a simple correlation analysis. Subsequently a multiple regression analysis was carried out to create a swimming time prediction model for the 50 freestyle performances. It revealed that in 50 m freestyle women race, age, weight and strength explained about 97% of the variance in performance. This study provided novel information which could be useful in designing training programs, optimizing swimmer's resources or capabilities.

KEY WORDS: Master swimmers, hand grip, anthropometric parameters.

INTRODUCTION: A number of studies demonstrated significant correlations between arm length, hand frontal area body surface, body form and height (Chatard JC, et.al. 1985; Clarys JP, et.al. 1974; Costill DL, et.al. 1985; Geladas ND, et.al. 2004), and swimming performance. Most of the previous studies on this topic focused on young subjects, while less is known about swimmers older than 40 years and more. In this study we analyzed masters swimmers of both genders aged 41 to 81 which represent, having trained for long period, and thus representing invaluable model for studying the impact of aging and physical activity on human performance.
Since the propulsive force is predominantly generated by the arms, which provide more than 85% (Smith L. 1978) of the total thrust in the crawl stroke, this study focused only on anthropometric parameters and strength (hand grip) which concern the upper extremity.
The purpose of the present investigation was to found a simple, easy prediction equation of the 50 m freestyle in master swimmers of both genders adopting conventional and anthropometric parameters and hand grip strength. These finding could be used for Master swimmer`s selection and help for describing the parameters of personal training program.

METHODS: The measurements were carried out during the 10th World Masters Championships, held in Riccione Italy, June 3-11, 2004.
The population under study included 28 individuals: 15 men, aged from 42 to 81 years, and 13 women aged 41–73. All participants were healthy and with no symptoms or signs of relevant pathologies affecting the neuromuscular system or the cardio-respiratory system. Written informed consent was obtained from all the subjects.
The swimming time expressed in seconds, was adopted as a measure of the 50 m freestyle performance. Time data were kept with the Automatic Officiating Equipment with S.E.L. (Sony Electronics) touch pads, belonging to Italian Timekeeping Federation (F.I.CR.) and processed with Software "Nuotoplus". These performance times were directly acquired during the competition.

Every subject was submitted to the following anthropometric measurements directly acquired before competition: stature, weight, arm and forearm lengths and forearm total volume.
Standing stature (m) was measured with precision of 0.1 cm with a stadiometer. Weight (kg) was recorded with a scale to the nearest 100 g.
For the arm and forearm measurements only the dominant upper arm was considered. Arm length (La) was calculated as the distance between acromion and radial styloid process. The forearm length (Lf) was considered as the distance between the olecranon and the radial styloid process.
We modelled forearm as constituted by two truncated cones whose areas and volumes can be easily calculated similarly to Hanavan (Seireg A & Arvikar R (ed). 1989). The first truncated cone was delimited by the two bases obtained by measuring two circumferences, one in correspondence of the styloid process and other of the largest forearm circumference. The second truncated cone, was consecutive to the first so that one base was the largest forearm circumference and the other was obtained at the level of the medial and lateral epicondyles.
The hand grip strength was measured using a Jamar Dynamometer (Asimov Engineering Co., Los Angeles, USA) which was calibrated at the start of each daily measurement session. The reliability of this device has been previously reported (American Society of Hand Therapists, 1992: Mathiowetz et al. 1984). The maximum grip strength, was determined maintaining the dominant hand in line with the forearm and hanging by the arm. Maximum grip strength was then determined in two consecutive attempts separated by at least 1 min resting interval. The subjects were instructed to produce a maximal effort and to maintain it for at least 3-4 seconds before relaxing. The mean value of two repeated measurements for the dominant hand was reported.
Analysis Methods: The mean and standard deviation (ANOVA) measured were calculated for all parametres and expressed in the table 1 in both sexes. After the normal distribution of data was verified, an unpaired symmetrical matrix of the Pearson's correlation coefficients, with their relative significance levels among all the variables and the race times was obtained, in order to evaluate their potential associations and to establish what parameters had to be introduced in a regression model. A multivariate linear regression model (MANOVA) was used assuming time (for every subject) as dependent variable calculated as a linear combination of the other variables.

RESULTS: The ANOVA statistical analysis of the anthropometric measurements, hand grip values and the performance times are presented in Table 1.

Table 1 All parameters considered for the 28 Master Swimmers.

subjects	n	A(yrs)	W(Kg)	h(m)	Hgm(N)	Lfa(cm)	La(cm)	Vct(cm^3)	*T50(sec)*
males	15	60.7 ± 12.2	79.8 ± 8.8	1.77 ± 0	503.3 ± 9.9	27.2 ± 0.9	59 ± 2.2	1337.3 ± 130	33.7 ± 5.9
females	13	57.6 ± 12.5	63.9 ± 10.3*	1.65 ± 0*	360.1 ± 6.1*	25 ± 1.5*	54.7 ± 3.6*	917.4 ± 116*	37.8 ± 6.3*

(A=age; W=weight; h=height; Hgm=hand grip strength; Lfa=forearm length; La=arm length; Vct=total volume forearm; T50=time of the 50 m freestyle performance. $p(t) < 0.05$*).

As expected men were heavier, taller, with longer arms and exhibited a better performance time than women.

Table 2 The correlation coefficient between the significant variables vs the time performance.

subjects	Time	Hgm	A	h	w
males	T50	-0.85 **	0.85**	-0.62*	-0.22
females	T50	-0.89 **	0.81**	-0.68*	0.55*

(A=age; W=weight; h=height; Hgm=hand grip strength; T50 = 50 m freestyle performance. $p(t) < 0.05$* and $p(t) < 0.01$**) .

The symmetrical matrices of the correlation coefficients among a part of the variables considered and the performance times have showed following results presented in the Table 2. We can be observe that:

- the correlation coefficients between the time of performance and hand grip strength and between the height and the performance time resulted both inversely correlated in females and males;
- the good correlation coefficient correlation is presented between performance times and age in both sexes, while in females we obtained a good coefficient between the time of performance and weight ($r = 0.55$);
- the correlation coefficient between the time of performance and Vct (forearm total volume) was positive in women ($r = 0.49$ $p(t) < 0.01$) and inverse in men ($r = - 0.46$ $p(t) < 0.01$).

The significant variables resulted to be age, weight, stature and mean hand grip (hgm) selected by a backwards multiple regression method which eliminates step by step the less significant variables, giving the lowest change of R^2, with to the higher probability of $p \leq 0.10$ (conventionally adopted) for the Fischer variable. With set of variables above mentioned the calculations gave the equations presented below.

The regression equation for males was:

T50 = 83.376 + 0.127 age + 0.058 weight – 26.198 height – 0.31 hgm **$R^2 = 0.84$**
(p=0.351) (p=0.545) (p=0.076) (p=0.064)

the regression equation for females was:

T50 = 59.471 + 0.123 age + 0.213 weight – 13.076 height – 0.577 hgm **$R^2 = 0.98$**
(p=0.018*) (p=0.001**) (p=0.191) (p=0.000**)

DISCUSSION: This study provides for the first time information on the relationship between anthropometry, muscle strength (hand grip) and swimming performances in a group of elite master swimmers but the correlation of anthropometric parameters, strength and performance is proved for both genders. In agreement with previous works, men swam faster than women.

In particular our study confirms the correlations by others authors found for young swimmers between height and performance in 50 m races, and between isometric strength and performance in short distance (Sprague HA. 1976; Strass D. 1988).

An interesting gender related difference was observed concerning the correlation between the forearm volume and time performances. In fact, the correlation was positive in women and inverse in men. These differences between genders could be due to a different production of drag and muscular strength (Rouard AH & Billat RP. 1990) .It could be that female swimmers who possess smaller forearm volumes develop a greater propulsive force. It has been, in fact shown, that swimmers with smaller hands can give a larger velocity to the water [13]. On the contrary, in males the forearm volume resulted inversely correlated with the performance time, perhaps because men realised an internal sweep shorter and less deep than females.

An original aspect of this study is that we proved the possibility to predict 50 mt freestyle races from anthropometric and hand strength parameters.

This study presented a optimal possibility of adopting a part of the variables considered as element to predict the swimming performance in older athletes.

This result could due to the fact which the short races could be require greater muscle strength. This type of strength training caused greater improvements in maximal explosive force production than in the maximal force. Several investigators have found [11] that improvements in explosive force production are accompanied by significant increase in the maximal rise of electrical activity of the EMG pattern. They suggested that neuromuscular adaptation with respect to firing frequency and /or in the recruitment. Besides it could be due to difference pattern of the activated motor units may have contributed to the improvement of the explosive force development. These phenomena may also have been responsible for the

present results. Moreover the variability of coefficient higher in females than males could be due at the difference of the freestyle velocity involved in both sexes and who requires different motor adaptations and modes of arm coordination (Koltyn KF, et.al. 1991; Seifert L, et.al. 2004).
In 50m performances weight was one of the most important time predictors for female but not male swimmers. It is well known that women require a 30 % lower rate of energy production than men to maintain a given velocity and it has been suggested (Touissaint HM, et.al. 2000) that women did not need to expend as much energy in staying afloat, because of their higher mean percentage at fatty tissue. Moreover women have a higher economy of swimming, attributed to smaller body size (resulting in smaller body drag), smaller body density and greater fat percentage, resulting in a more horizontal and streamlined position .
Interestingly, contrary to what can be found in literature about young swimmers, arm and forearm lengths did not reveal a significant influence on performance time.

CONCLUSIONS: The multiple regression analysis, has allowed to create a model for 50m freestyle in elite Master swimmers.
The most important findings were:
a) in 50m freestyle women race, age, weight and grip strength explained about 97% of the variance in performance.
b) the hand grip strength was a very important factor for to describe the 50 m freestyle performance.

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