The influence of kineanthropometrical profile in deep-water tethered running

Vila-Chã CJ, Morais JF, Barbosa TM
Polytechnic Institute of Bragança, Bragança, Portugal

1. Introduction

Aquatic jogging is a variant of head-out aquatic exercises characterised by the walking and/or running of a subject in aquatic environment. The main goal of this aquatic program is to promote an increase of physical fitness, specially the cardiorespiratory component.

In technical literature it is often described several benefits for aquatic jogging (e.g., Kinder and See, 1992). Some research was promoted in order to confirm the benefits described in aquatic activities textbooks. Investigations were performed analysing the physiological response to aquatic jogging (e.g., Butts et al., 1991; Demaere and Ruby, 1997; Shono et al., ...duce number of studies described the ...uromuscular activity during ...1; Kruel et al., 2002; Masumo o 2004; Ba... al., 2005). Moreover, most of t studies compared t... biomechanical behaviour jogging in land and in water (Moening et al., 1993; Kato, 2001; Kruel et al., 2002; Barela et al., 2005).

However the quantity and quality of investigations around dynamometrical issues are scare. Especially, in what concerns to deep water aquatic running, i.e., vertical locomotion without plantar contact with the bottom of the swi nming pool during the gait cycle.

One approach to perform a dynamometrical evaluation of deep-water aquatic running has its origins in the estimation of tethered swimming force (e.g., Maglicho et al., 1984; Taylor et al., 2001; Rouard et al., 2006). During tethered swimming of young practioners, the swimming force ranged proximally between 45 N for 10 years old and 90 N for 16 years old boys (Taylor et al., 2003). For adult swimmers, at freestyle, swimming force was reported as being 144.4 ± 34.5 N (Keskinen et al., 1989).

Some investigations attempted to identify significant relationships between tethered swimming and kineanthropometrical characteristics (Cabri et al., 1988; Llana et al., 2002; Taylor et al., 2003). Backward log-linear regression revealed that arm span explained 68.1 % of the variance in mean swimming force production (Taylor et al., 2003). Other results suggested that technical ability was determinant to transform strength capacity in specific swimming force (Rouard et al., 2006). Nevertheless, it seems that there is no study in the literature about deep-water tethered running and the identification of possible relationships with the kineanthropometrical profile of the runner.

The purpose of this study was to identify the kineanthropometrical parameters that best predict the maximal horizontal propulsive force during deep-water tethered running.

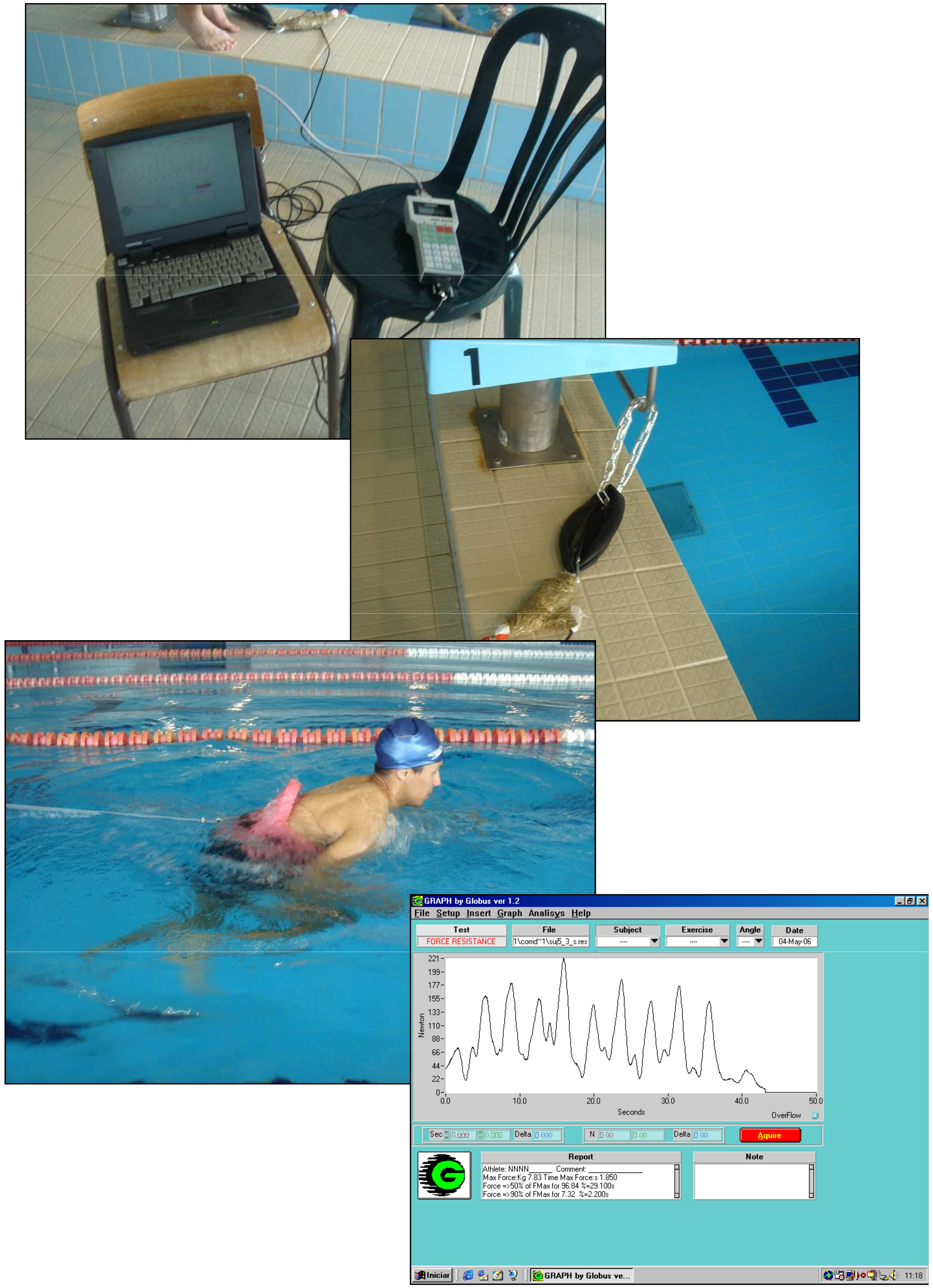
2. Methods

Subjects. Twenty-one young and healthy males with large experience in aquatic exercises (24.3 ± 2.7 years old, 191.9 ± 82.6 minutes of physical activity per week) were studied. They reported no previous history of orthopedic or muscle-skeletal injuries in the past 6 months.

Design. The subjects had a free aquatic jogging warm-up for 10 minutes. All subjects familiarized with the tethered apparatus for 5 minutes, performing 3 sub-maximal trials.

Each subject performed 3 maximal trials of deep-water running for 10-s with a 10 minutes rest period (Kjendle and Thorsvald, 2006) using a flotation vest (Golfinho, H-906, Coimbra, Portugal) in a 2.00-m depth swimming pool. The tethered test started with a low intensity running until the cable stretch and then they run at maximal intensity.

Data Collection. Subjects were connected to a strain gauge (Globus, Ergo Meter, Codigné, Italy) by a cable of steel with reduce elastic properties and 1.50-m of length. The other end of the cable was fasted to a rubber band and this to a swimming starting block. Dynamometrical data was recorded, exported and processed with Matlab (MathWorks, MatLab v. 6.0, Massachusetts, USA). All evaluations were made in the same day, reducing the internal consistency error of the force data as reported by Taylor et al. (2001).



It was evaluated the maximal tethered running force (Fmax) and computed the maximal horizontal tethered running force (Fx-max) using a trigonometric correction, as suggested by Taylor et al. (2003):

$$\text{Fx-max} = \text{Fmax} \cdot \cos \alpha \qquad \text{(eq. 1)}$$

Above-water images on the sagittal plane were recorded (JVC, SXM-26, Yokoama, Japan) in order to calculate the absolute angle between the cable and the horizontal plane [α]. The angle was calculated with a motion analysis software (Motion Analysis Tool v. 1.1, Otario, Canada). This specific software was adopted since it is less time consuming then other commercially available software packages. The [α] calculated with the Motion Analysis Tool presented a very high intra-class correlation with the same kinematical variable evaluated with Ariel Performance Analysis System (ICC = 0.98 ± 0.02).

Several anthropometrical variables, such as, body mass (SECA, 884, Hamburg, Germany), height (SECA, 242, Hamburg, Germany), body mass index (BMI) and fat mass (BIA 101, RJL Systems, Florence, Italy) were also measured. Surface area (SA) was calculated according to the procedure of Du Bois and Du Bois (Shuter and Aslani, 2000).

Hand grip (MIChand) of the dominant hand was evaluated during a maximal isometric contraction of the hand using a strain gauge (TSD 121C, Biopac Systems, California, USA) connected to an A/D converter (100B, Biopac System, California, USA. Maximal isometric contraction of the forearm's flexors (MICforearm) was also evaluated with a strain gauge (Globus Ergo Meter, Codigné, Italy).

Statistical procedures. It included the calculation of the descriptive statistics of all the variables studied (mean, 1 standard deviation, minimum and maximum). It was calculated the Correlation Coefficient of Pearson between Fx-max and the kineanthropometrical variables studied. Forward step-by-step regression model was computed, for prediction of Fx-max. For prediction of Fx-max, were included the independent variables that correspond the necessary procedures to enter in the model. The variables entered the equation if $F \geq 4.0$ and removed if $F \leq 3.96$. The level of statistical significance was set at $P \leq 0.05$.

3. Results and discussion

Figure 1 represents the intra-cyclic variations of Fx-max for normalized cycles. Intra-cyclic variation of the Fx-max presented a tetra-modal profile. The two higher peaks were synchronized with the arm's backward actions and the two smaller peaks to leg extension actions. Since the aquatic running action is an alternated one (Ritchie and Hopkins, 1991); the first peak was related to an arm action and the second peak to the leg extension of the opposite side. The third peak is associated to the backward action of the other arm and the fourth peak to the propulsion of the opposite leg.

Table 1 presents the descriptive statistics for the kineanthropometrical characteristics of the subjects and the maximal horizontal tethered running force produced. BMI was 23.10 ± 1.82 kg.m^{-2} and the fat mass 16.88 ± 5.86 %, within the range of values for subjects with a regular physical activity, as described in previous researches in similar aquatic fitness programs (Barbosa et al., in press). Mean MICforearm (314.40 ± 89.84 N) and MIChand (235.04 ± 56.30 N) was lower to the ones reported in previous investigation for young competitive swimmers (Geladas and Pavlicevic, 1999). Fx-max was 123.77 ± 55.30 N. For adult swimmers, at freestyle, swimming force was reported as being 144.4 ± 34.5 N (Keskinen et al., 1989). Peyrebrune et al. (2003) observed a mean value for the peak force output of 135.7 ± 23.2 N for self-selected breathing frequency at freestyle. In different competitive level swimmers, tethered force ranged between 130 ± 30 N and 150 ± 33N (Kjendle and Thorsvald, 2006). So, present mean Fx-max is close to the data reported for no-expert swimmers at freestyle

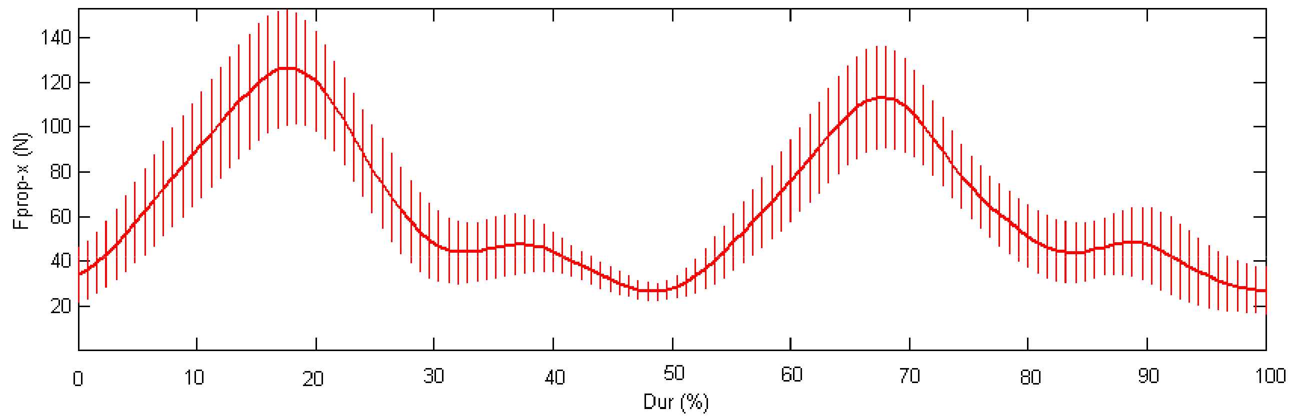


Figure 1. Intra-cyclic variations of maximal horizontal tethered running force (Fx-max) during a normalized cycle.

Table 1. The kineanthropometrical characteristics of the subjects and the maximal horizontal tethered running force.

	Body mass (kg)	Height (m)	BMI (kg.m^{-2})	SA (m^2)	Fat mass (%)	MIC forearm (N)	MIC hand (N)	Fx-max (N)
Mean	72.78	1.77	23.10	1.89	16.88	314.40	235.04	123.77
SD	10.44	0.10	1.82	0.18	5.86	89.84	56.30	55.30
Min	54.40	1.59	19.00	1.55	4.10	177.20	150.40	46.94
Max	91.00	1.95	27.50	2.18	26.60	485.90	324.10	243.58

Table 2 presents the correlation matrix between the kineanthropometrical variables and the maximal horizontal tethered running force. Fx-max only presented a significant association with the MICforearm ($R = 0.63$, $P < 0.01$). It was observed significant associations between MICforearm and body mass ($R = 0.57$, $P < 0.01$), height ($R = 0.62$, $P < 0.01$) and SA ($R = 0.63$, $P < 0.05$). Backward log-linear regression revealed that arm span explained 68.1% of the variance in mean swimming force production (Taylor et al., 2003). Other results suggested that technical ability was determinant to transform strength capacity in specific swimming force (Rouard et al., 2006).

Table 3 presents the step-by-step regression model for prediction of maximal horizontal tethered running force. The kineanthropometrical variables that entered the model for prediction of the Fx-max were the MICforearm, the BMI, the body mass and the SA ($R2 = 0.57$, $P = 0.01$). The first independent variable entering the model was the MICforearm explaining 40% of the Fx-max. Increases of the segmental strength promote significant increases of the tethered running force. Technical ability is determinant to transfer muscle strength in tethered force (Rouard et al., 2006). In the actual study, increases of MICforearm promoted increases in Fx-max. So, apparently, subjects of the sample were able to transfer segmental force in Fx-max, which can be explained by their high level of expertise with aquatic exercises. Body mass and SA also had a significant relationship with Fx-max. Increases in the body mass and decreases in the SA were related to increases of the tethered running force.

It is well documented in the literature that increases of the body mass, especially if related to lean mass were statistically associated to increases of muscle force and if associated to fat mass were associated to increases of the buoyancy force. Increases of the SA promoted decreases in the Fx-max due to an increase of drag force, namely the increase of surface area in direction of displacement. Evidences revealed that some kineanthropometrical parameters related to external forces submitted to body, such as, buoyancy force (e.g., BMI or fat mass), drag force (e.g., SA), weight force (e.g., body mass) and propulsive force (e.g., MICforearm) predicted the Fx-max.

Table 2. Correlation matrix between kineanthropometrical variables and maximal horizontal tethered running force.

	Body mass	Heig	BMI	SA	Fat mass	MIC $_{forearm}$	MIC $_{hand}$	Fx-max
Body mass	1	-	-	-	-	-	-	-
Height	0.84^{+}	1	-	-	-	-	-	-
BMI	0.62^{*}	0.10	1	-	-	-	-	-
SA	0.97^{+}	0.94^{+}	0.43^{*}	1	-	-	-	-
Fat mass	0.30	0.04	0.49^{*}	0.20	1	-	-	-
MIC $_{forearm}$	$0.57^{\#}$	$0.62^{\#}$	0.14	0.61^{*}	0.03	1	-	-
MIC $_{hand}$	0.01	0.18	0.23	0.09	0.22	0.19	1	-
Fx-max	0.24	0.40	0.16	0.31	0.32	$0.63^{\#}$	0.05	1

$*$ P≤ 0.05; # P≤ 0.01; + P≤ 0.001

Table 3. Step-by-step regression model for prediction of maximal horizontal tethered running force.

	Independ. Variables	R^2	R^2 adjust.	T	P	B	F	P
Fx-max	$MIC_{forearm}$ BMI Body mass SA	0.40 0.46 0.46 0.57	0.36 0.40 0.37 0.42	3.21 -2.19 1.98 -1.97	0.01 0.04 0.05 0.06	0.68 -2.44 8.61 -7.43	(4; 16) = 5.29	0.01

4. Conclusions

The main conclusion is that deep-water tethered running force is significantly associated to the kineanthropometrical profile of the runner. This means that, besides physical fitness and technical level, often described in the literature, kineanthropometrical characteristics of the practioners also affect significantly his performance during a deep-water aquatic jogging session. Instructors should understand that specific kineanthropometrical variables of the runners could affect their ability to correspond to his feedbacks and follow the physical tasks design by him for the class.

5. References

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