Force, power and velocity in loaded tethered swimming

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Introduction :

The tethered swimming has been largely used for the evaluation of the swimmer, either in the full condition (the swimmer stayed fixed) or in the semi condition (the subject swam on few meters). Many authors measured the force developed by the swimmer (Alley, 1952 ; Counsilman, 1955). Other studies underlined the difference of propulsive forces in regard to the expertise level, the swimming velocity, the legs and arms actions and/or to the sex and /or to the stoke technique (Yeater et al, 1981) and /or the energy expenditure in relation to the body drag (Di Prampero et al, 1974). Results issue from full tethered swimming investigations were limited because the subject swam on the same place with a disturbing flow around his body. The semi-tethered swimming presented also few limits because of the steady velocity imposed to the swimmer. In regard to these previous results, the purpose of this study was to develop a new system which exerted a controlled resistive horizontal force to the swimmer and allow to measure the instantaneous force, velocity and power produced by the swimmer.

Methods :

Nine male student in physical education participated in this study. Their level of performance population was heterogeneous with the best swimming velocity ranging from 1.43m/s to 2.05m/s.. Their general characteristics were summarised in table 1.

	Age (years)	Height (cm)	Mass (kg)	25m time (s)
Mean	20.94	177.33	69.11	14.54
SD	2.49	5.52	7.47	1.98

Table 1 : General characteristics of the population

Test and data acquisition :

Each swimmer performed 50m swims in front crawl semi-tethered swimming against different resistive loads. A system (ERGOS) was developped to exert a constant horizontal resistive force on the swimmer. The swimmer was linked to a powder brake (Lenz) by a belt, a rope and two pulleys. Two transducers recorded the swimmer's instantaneous force (F (N)) and velocity (V (m/s)). The signal were stored on a PC computer using Labview software. The system was fixed on the block of the start area of the swimming pool. (figure 1). Seven values were studied : 0.1, 0.2, 0.4, 0.8, 1.2, 1.6 and 2kgf. For each load, the subject performed 50m with a rest of 10 minutes between each trial to avoid fatigue.

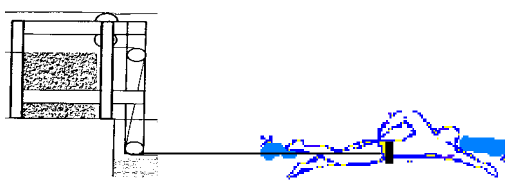
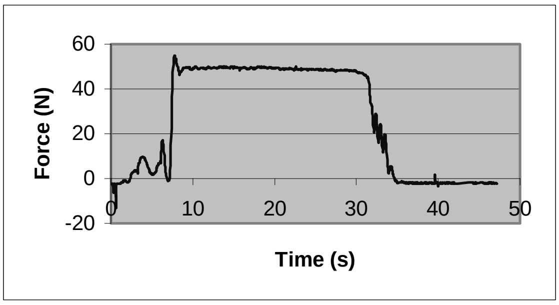


Figure 1 : Testing procedure

In the same time, a video was fixed alongside the pool to film the swimmer's movement during the central portion of the 50m (25Hz).

Data treatment :
The curves force-time, velocity-time, power-time for the50m swim was obtained for each load and each subject (figure 2).



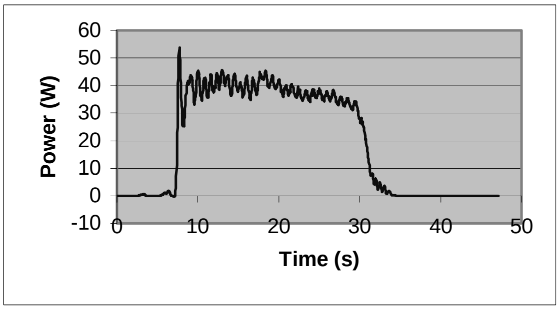


Figure 2 : force-time and power-time curves for one subject during the 50m swim with the load of 2kg.

The force and the power increased during the first 10s of the 50m due to the inertia of the subject and to the tension of the rope. The parameters remained stable during 20s of the central portion of the 50m and decrease at the end of the 50m.As a result, we calculated the mean force, velocity and power (F*V) for 10s during the central portion of each 50m.
The video were digitised to obtain the stroke length, stroke frequency and to observe the contribution of the kick legs.
For each trial, and each parameter we calculated mean, standard deviation for the total population (N=9) and the coefficient of correlation between force and velocity and power and velocity. A non parametric Mann-Witney test was used to compare F,V and P of the different loads ($p<0.05$)

Results :
For the low resistive loads, the swimmer velocity decreased significantly from 0.1kg to 0.2kg and remained stable from 0.2 to 0.8kg when force and power did not change significantly (figure3). The swimming velocity decreased for loads ranged from 0.8kgf to 2kgf when force and power strongly increased. The load of 0.8kg appeared to be determinant in the changes of force and power production.

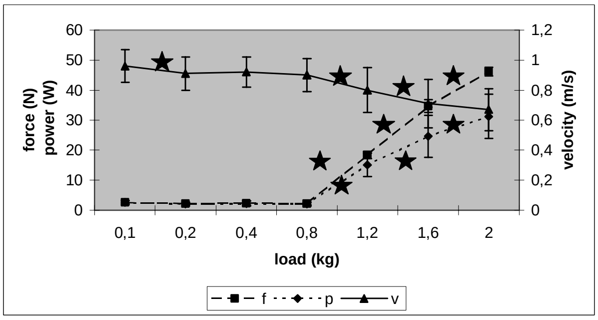


Figure 3 : Mean (SD) of force, power and velocity for each load ($p<0.05$ ★)
The correlation between force, power and velocity increased with the resistive loads (figure 4). The velocity was more related to the power than to the force which was significantly correlated only for 2 loads (1.2 and 2kg)

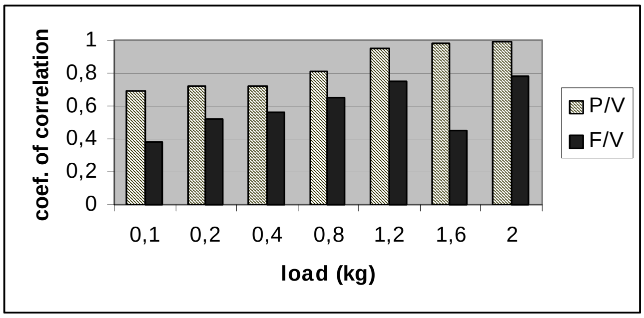


Figure 4 : coefficient of correlation between force, power and velocity for each load

Discussion:

The force -time curve confirmed previous studies (Yeater et al, 1981).

The velocity, force and power did not change significantly from 0.1 to 0.8kg. From 0.8kg to 2kg, force, power increased strongly when velocity decreased. The added load of 0.8kg appeared to be a critical value for the mechanical component of the swimmer. The video analysis indicated no significant changes in stroke frequency (50.25Hz for the load of 0.8kg to 51Hz for 1.2kg) when the stroke length decreased from 1.79m to 1.56m associated to greater kick legs. The increase in force and power production between 0.8 and 1.2kg appeared to be linked to legs actions. This conclusion could be related to Yeater 's results who observed greater tethered force with the legs only compared to the tethered force with the arms only (Yeater et al, 1981).

For the loads inferior to 0.8kg, the result did not confirm the linear relationships between force and velocity observed by many authors (Alley, 1952, Wirtz et al, 1999).The difference could be due to the studied loads which began with lower values in our study compared to the others and /or to the different testing equipment.

For low added drag (inferior to 8N), best swimmer presented the higher power but not the higher forces. When the drag increased, the propulsive force tended to be determinant although the velocity decreased confirming previous studies (Adams, 83-84, Toussaint, 88).

In conclusion, the force, power and velocity of free tethered swimming could be used to evaluate the technical, physical and training components of the swimming performance.

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