A COMPARISON CMJ, SIMULATED AND SWIMMING GRAB-START FORCE RECORDINGS AND THEIR RELATIONSHIPS WITH THE START PERFORMANCE

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Assuming that the forces recorded during the CMJ are related to the muscular leg force and power, the aim of our study is to investigate why in previous studies these recorded forces were not correlated with the forces recorded during the swimming start. A simulated start was recorded on land to try to find if a more similar jumping technique, showed a force related to the swimming start variables. To isolate the start variables in comparison to our previous studies, the swimmer performed only a gliding displacement until 10 m after the water entry without any type of propulsive underwater movements in our present study. We found no difference from the results of previous studies in spite of including simulated grab-start recordings in the lab. Only the horizontal force n the swimming start correlated to five-metre time and the first five-metre mean velocity. The difference and non-relationships when the swimmer applies force against gravity or with gravity have still not resolved.

KEY WORDS: swimming grab start, countermovement jump, horizontal force and velocity

INTRODUCTION: The swimming start is the initial technique used by the swimmer in competition. In spite of its short duration it can be crucial for obtaining top results, especially in short events. The combination of kinematics and kinetics data seems the most appropriate method for evaluating the swimming start performance (Arellano *et al.*, 2002; Blanksby *et al.*, 2002; Vilas-Boas *et al.*, 2003). However there are a few studies where the leg force or leg power tested on land is related to swimming start performance and their findings were controversial. In some cases the forces tested in a countermovement jump (CMJ) did not correlate with the forces applied in the swimming start or with swimming start performance (Fuente *et al.*, 2003). Similar results were found after developing a resistance training programme designed to improve vertical jumping ability; the CMJ measurements improved significantly while the kinetic and kinematic dive start variables did not change in most cases, except in the flight distance (Breed & Young, 2003). It has been said that the three requirements for a good start are a short reaction time, great jumping power and low resistance during underwater gliding (Maglischo, 1993). Surprisingly those recent studies have shown that jumping measured during the CMJ did not support that statement using the CMJ to measure the leg force.

Assuming that the forces recorded during the CMJ are related to the muscular leg force and power, the aim of our study is to investigate why in previous studies these recorded forces were not correlated with the forces recorded during the swimming start. A simulated start was recorded on land to try to find if a more similar jumping technique, showed a force related to the swimming start variables. To isolate the start variables in comparison to our previous studies, the swimmer performed only a gliding displacement until 10 m after the water entry without any type of propulsive underwater movements in our present study.

METHODS:

Subjects: Eleven university swimmers participating at state or national competitions were evaluated (six male and five female). Each subject signed an informed consent before they performed the experiment trials and training. Before the recording day all the subjects participated in two training sessions to adapt to the experimental environment and to remember the basics of grab-start technique. Each participant performed two swimming grab-starts, two countermovement jumps and two simulated swimming starts in randomized order. The better result of each trial was selected for the study.

Table 1 Average and standard deviation of basic characteristics of subjects that participated in the study and the Pearson product moment correlation with variables studied.

Variable	Mean	S.D.	r t5	r t7.5	r T5	r v1	r v2	r FvCMJ	r FvSS	r sFv	r sFh
Age (years)	21,4	2,2									
Height (cm)	175,5	7,9	-0,66*	-0,78**		0,66*	0,68*		0,61*		0,77**
Weight (kg)	70,9	8,3		-0,76**	-0,68**		0,79**	0,74**	0,79*	0,91**	0,62*
Arm Spam (cm)	181,7	10,9		-0,71*			065*		0,76*	0,64*	
Body length (cm)	233,1	13,8									

* p < 0,05 **p < 0,01

Instrumental: The swimming grab-start was performed gliding without any type of limb propulsion until the head crossed the 10 m line. A force plate (Kistler submergible model 9253, 200 Hz) was adapted in the starting block for recording the horizontal and vertical forces during the impulse phase of the swimming grab-start following the standard competitive swimming rules. Two video-cameras were placed in one side of the swimming pool, perpendicular to the sagittal plane of the body displacement during the start. One camera was placed on a tripod over water and another fixed in the lateral wall underwater (see Figure 1), one m and five m from the starting wall respectively. The image from these cameras was mixed in real time to see the over- and under-water phases of the start in the same frame (until 10 m). One reference system was placed in the sagittal plane of the swimmer's displacement and video recorded before the swimmer's performance. Thanks to this reference it was possible to draw vertical lines on the computer system desktop, overlaid on the captured digital video. The starting signal was synchronized with the video time-code and the force plate recording (analogue event marker). A specific data base software was developed to capture the time-code from the digitized video (.dv files, see Figure 1) on the specific database field and to calculate all the timing variables required in this type of analysis. Another force plate installed in the biomechanics lab of the Faculty of Physical Education and Sport Sciences, Granada University, around the faculty's swimming pool permitted the subjects to perform the vertical countermovement jump and a vertical simulation of the swimming grab-start. Thanks to this close location of both venues and force plates the subjects performed the randomized trials without any inconvenience for their performances, having at least more than five minutes of rest between their jumps.

Variables: Swimming start: Time of hand leaving the starting block (thb), block time or time of feet leaving the starting block (bt), time hands touching the water (thw), time the feet touching the water (tfw), five meters time measured when the head crossed the 5 m line (t5), seven and half meters time, (t7.5), ten meters time (t10), mean velocity between start and 5 m (v1), mean velocity between 5m and 7.5 m (v2) and mean velocity between 7.5 and 10 m (v3). Force recording variables: Typical force variables were obtained after analyzing the force recording curves of the countermovement and simulated jump. Peak vertical force (Fv), height of the jump (hj), vertical velocity of the take-off (vv), negative impulse (ni), eccentric impulse (ei), accelerative impulse (ai) and force related to body-weight (fb). At the swimming start the force variables were: Peak vertical force (sFv), peak horizontal force (sFh), vertical (svv) and horizontal (shv) velocities at the take-off, and angle of take-off (ato), vertical force related to the body-weight (vfrbw) and horizontal force related to the body-weigth (hfrbw).

The data from each performance was filed in a specifically designed database. Selected variables were exported to statistical computer software (STATISTICA/MAC, Statsoft™). Averages and standard deviations were determined for all variables as presented in Tables 2, 3 and 4. Pearson product moment correlation was calculated among variables. Partial correlation coefficients with subject weight partially out was calculated between selected variables and shown in Table 5. Coefficient of correlation and regression equations were calculated among variables. The level of significance was set at 0.05 (two-tailed).

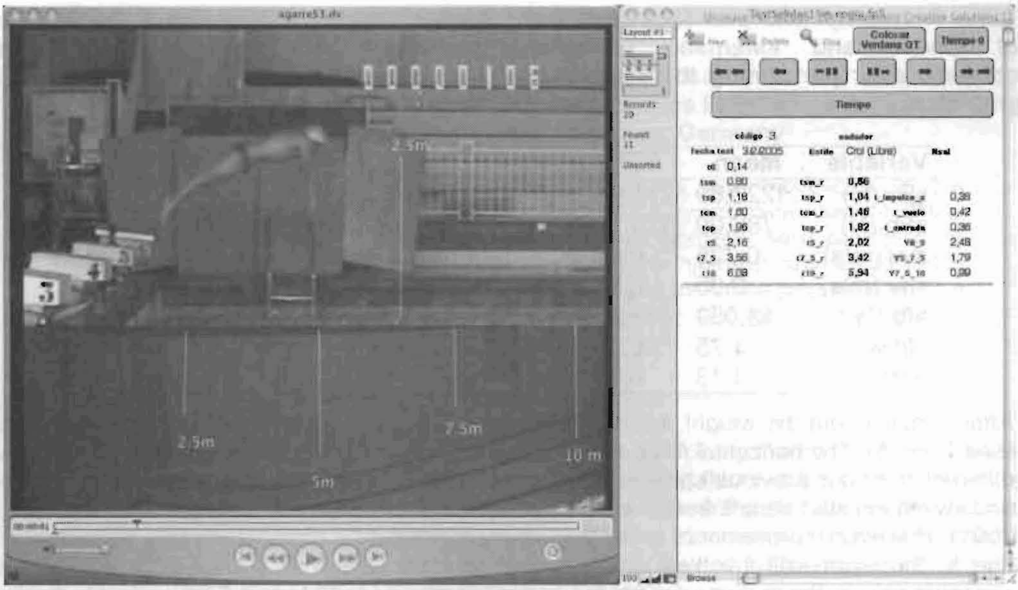

Figure 1 A descriptive view of the digital video (Quicktime .dv format) controlled from the data-base (Filemaker 6.0) thanks to scripted buttons. The biggest button inserts the digital time code in the specific data base field. The rest of the buttons control the video advance and video window position. The distance references are included in the video window; they were drawn on the operative system (Mac OSX 10.3.8) desktop using the Ultimate Pen™ application.

RESULTS AND DISCUSION: All the results are set out in Tables 1, 2, 3 and 4. The swimming start times and mean velocities obtained in the water phase showed the influence of lack of propulsive underwater movements Similar values were obtained in force recordings, height of jump, vertical velocity, accelerative impulse and peak force related to body weight between CMJ and SGS. The change of the body movements were not enough to modify the results or forces recorded. Forces recorded in the laboratory (CMJ and SGS) were significantly higher ($p < 0{,}01$) than swimming start forces (sFv and sFh) while body **shv** *was significantly faster than* ***vv*** *(CMJ and SGS).*

Table 2 Means and standard deviations of kinematics variables of swimming grab-start.

Variable	Mean	S.D.
Thb (s)	0,60	0,05
Bt (s)	0,95	0,06
Thw (s)	1,32	0,09
Tfw (s)	1,65	0,09
T5 (s)	1,90	0,11
T7_5 (s)	3,33	0,25
T10 (s)	6,09	0,64
V1 (m/s)	2,64	0,15
V2 (m/s)	1,77	0,23
V3 (m/s)	0,93	0,14

Table 3 Means and standard deviations of kinetic variables obtained after performing a CMJ and SGS in the laboratory.

	CMJ			
Variable	Mean	S.D.	Mean	S.D.
Fv (N)	1590,23	225,10	1472,91	228,31
hj (m)	0,34	0,06	0,36	0,06
vv (m/s)	2,59	0,22	2,64	0,24
ai (Ns)	183,39	26,67	186,94	27,70
Fb	2,29	0,22	2,12	0,19

Table 4 Average and standard deviation of kinetic and kinematic variables obtained after performing the swimming grab-start.

Variable	Mean	S.D.
sFv (N)	1222,89	214,43
sFh (N)	786,09	119,16
svv (m/s)	0,725	0,61
shv (m/s)	3,35	0,14
ato (¼	13,059	11,23
vfrbw	1,75	0,15
hfrbw	1,13	0,13

Table 5 Significant correlation coefficients with T5, T7.5, V1, V2, V3 and the kinetic variables.

	aiCMJ	sFh	shv
T5		-0,716*	
T7,5		-0,680*	
V1		0,729*	
V2	0,612*		
V3			-0,746**

* p<0,05 **p<0,01

After partialing out the weight, few variables correlated with the start performance variables (see Table 5). The horizontal force of the start correlated with T5, T7.5, and V1. This result is different from our previous studies. (Arellano *et al.*, 2000; Fuente et al., 2003). CMJ, SGS and swimming start benefit from the "stretch-shorten" cycle (Breed & Young, 2003; Linthorne, 2001). However improvements in jumping ability might not be observed in dive performance due to the extra skill involved in the swimming start (Breed & Young, 2003). After the eccentric phase, the swimmer's impulse is against gravity in CMJ and SGS and with gravity in the swimming start. And additional factor the need to find a proper take-off angle combined with the forward rotation of the body, all taken together could explain the non-correlation between force variables.

CONCLUSIONS: Our experiment was aimed at finding the cause of the lack of relationship between leg force and swimming start variables. We found no difference from the results of previous studies in spite of including simulated grab-start recordings in the lab. Only the horizontal force of the swimming start correlated to five-metre times and the first five m mean velocity. The difference and non-relationships when the swimmer applies force against gravity or with gravity have still not resolved.

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