Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

MUSCULAR AND ARM CRAWL STROKE POWER: EVALUATING THEIR RELATIONSHIP

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The aim of this study was to determine the relationships between dry-land power, swimming power delivered to an external weight and swimming performance. 18 swimmers performed 4 tests: 1RM bench press, 25m sprint velocity, bench press power and swimming power (both are relative to body mass power). Maximal bench press power was 5.41W/kg and it was obtained with 41.32%RM and a barbell velocity of 1.04m/s. Maximal arm crawl stroke power was 0.86W/kg and was developed with 47.07% of maximal load and a swimming velocity of 0.75m/s. A moderate relationship of r=0.538 ($p<0.05$) was found between bench press power and swimming power. There was a higher correlation between swimming power and sprint velocity (r=0.762, $p<0.01$).

KEY WORDS: 1RM, bench press, semi-tethered swimming, intracycle velocity.

INTRODUCTION: Power plays an essential role in many sports, including swimming. Swimming power has been measured by means of different methods (MAD, VPM, pulley-systems, etc.). On the other hand, bench press is an extended exercise for muscular power assessment in different sports, but not in swimming. The purpose of this study was to analyze the relationship between dry-land muscular power (bench press) and swimming power delivered to an external weight, which had been studied in very few previous articles (Shimonagata, Taguchi & Miura, 2002; Swaine & Doyle, 2000). We assessed swimming power by means of an updated protocol, which combined intracycle force and velocity and video recording.

METHODS: A group of 18 male swimmers (age 22.10±4.31years, stature 1.79±0.07m, arm span 1.85±0.08m and body mass 76.74±9.00kg) participated in our study. They gave written informed consent prior to participation in the study, which was given approval by the university ethics committee.
Four tests were performed: **1) One-repetition maximum (1RM) bench press (BP) test:** in a smith machine, swimmers should lift a higher load each trial until they were not able to complete a full repetition. The increase in load was 5 kg at the beginning of the test and 2.5kg later. They rested enough before each repetition. **2) 25m sprint velocity test:** with a water start. We used 2 subaquatic cameras (frontal and lateral views) and a touchpad to obtain mean sprint velocity (v). **3) Bench press power test:** participants did one repetition on a smith machine with each load at maximal velocity, starting with the barbell (17.5kg) and increasing load in 10kg until approximately the 1RM. Ascendant barbell velocity was measured with a linear wire encoder. Muscular power was calculated with the formula $P=m\cdot(a+g)\cdot v$, using the accelerating part of the curve, where $a>-g$ (i.e. $(a+g)>0$) (Sanchez-Medina, Perez & Gonzalez-Badillo, 2010). We determined maximal BPP (absolute and relative to body mass values) for each swimmer and calculated the mean of these values to have the maximal power value for the whole group (max BPP). Besides, to obtain the BPP curve, we calculated mean BPP for the complete group with each load. **4) Swimming arm stroke power test:** participants swam 12.5m sprint, pulling different loads by means of a pulley system. The test started with 1.5kg (load after correcting the pulley system effect) and continued with 0.5kg increases. Rest between 2 trials was 5min. The swimmer's feet were tied together, keeping a pull-buoy between his legs and isolating the upper limb action. The test was recorded from a frontal and two lateral underwater cameras (50 Hz), fixed to the pool wall. Instantaneous velocity and force were measured in each trial by means of an encoder and a load cell, respectively. We multiplied instantaneous force and velocity to obtain instantaneous power delivered to an external weight while swimming (SP), from which

we obtained mean SP (absolute and relative to body mass values) for each trial and swimmer. We looked for maximal SP for each participant and calculated the mean value for all the swimmers (max SP). Then, we represented the group mean SP for each load in a SP curve.

Some variables were not normal (Shapiro-Wilk test). Therefore, we used Spearman correlation coefficients to determine relationships among them. Level of significance was set at α=0.05.

RESULTS AND DISCUSSION: 1) Mean 1RM BP was 81.94kg (SD=21.27). **2)** Mean 25m sprint velocity was 1.70m/s (SD=0.14). **3)** Max BPP was 418.18W or 5.41W/kg (Table 1). The BPP curve is represented in Figure 1. **4)** Max SP for all the swimmers was 66.49W or 0.86W/kg (Table 1). The SP curve is represented in Figure 2.

Table 1
Maximal BPP and SP for the complete group, and percentages of load and velocities associated.

	max BPP (W/kg)	% RM-max BPP	v-max[a] BPP (m/s)	max SP (W/kg)	% max load-max SP[b]	v-max SP[c] (m/s)	%v max-max SP
MEAN	5.41	41.32	1.04	0.86	47.07	0.75	43.75
SD	1.47	14.64	0.26	0.21	9.45	0.18	8.94

[a]barbell velocity. [b]percentage of each swimmer´s maximal load; [c]swimming velocity.

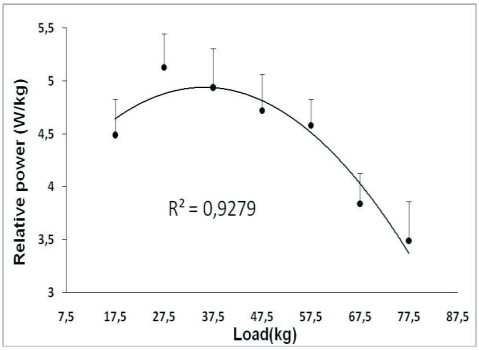

Figure 1. Relative BPP curve: group mean bench press power for each load.

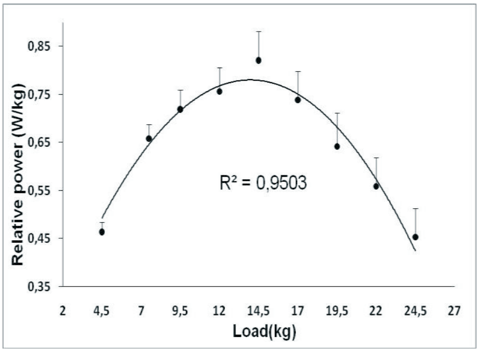

Figure 2. Relative SP curve: group mean swimming power for each load.

Values are expressed as means, and error bars are standard error of the mean.

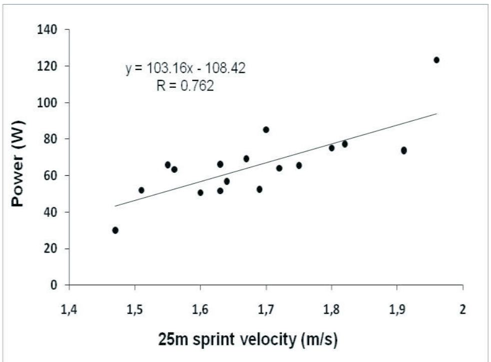

Figure 3. Linear regression of swimming power vs. swimming velocity.

We found high positive linear correlation between 1RM BP and max BPP (r=0.878, p<0.01) and a weaker one between 1RM BP and max SP (r=0.477, p<0.05). Besides, max SP was related to v25m (r=0.727, p<0.01) but, surprisingly, the correlation was a bit higher when absolute values of power were used (r=0.762, p<0.01) (Figure 3). Finally, we found a moderate correlation between max BPP and max SP when using absolute data (r=0.624, p<0.01). The relation becomes not significant when using relative ones.
BP exercise is used in different sports to evaluate upper limb power but, to our knowledge, it has not been used for swimmers. Izquierdo, Hakkinen, Gonzalez-Badillo, Ibañez and Gorostiaga (2002) reported that max BPP was developed with 30%RM for weightlifters and handball players and with 45%RM for road cyclists and runners. Gonzalez-Badillo and Ribas-Serna (2002) stated that max BPP corresponded to 40%RM for sport students. Our result (41%RM) agrees with these studies.
Similar values of BPP have been found in several studies (Table 2). Other authors reported higher or lower power values. This variety can be owing to the methods and participants used. In our study, we wanted to use bench press exercise to assess muscular power because it is a very extended method in many different sports. However, it would also be interesting to measure power developed by other muscles involved in swimming, like latissimus dorsi.
We have found articles concerning swimming power, among which there is diversity of results (Table 2). The variation is possibly explained by the different methods, not standardized in this field, and subjects.

Table 2
Maximal swimming power calculated in other studies.

Swimming power (66.49W or 0.86W/kg)*	
Authors	SP values
Costill et al. (1986)	55W or 0.656W/kg
Saijoh et al. (2008)	85.7W
Shimonagata, et al. (2002)	100.71W
Shionoya et al. (1999)	51.20W
Toussaint et al. (2004)	97.3W^
Toussaint et al. (2006a)	200W+
Toussaint et al. (2006b)	220W+

*In brackets, our own results; ^They only used one load; +On the MAD-system, without load.

Table 3 shows associated velocities to maximal BPP and SP. For BPP, our result (1.04m/s) is in keeping with these values. Our SP value (0.75m/s) is considerably lower than two of the references, probably because they used the MAD-system without load.

Table3
Associated velocities to maximal bench press and swimming power in other studies.

Authors	v-max BPP (m/s)	Authors	v-max SP (m/s)
Gonzalez-Badillo & Ribas-Serna (2002)	1.15 (sport students)	Costill et al. (1986)	0.93
Izquierdo et al. (2002)	1.34 (handball players) 0.90 (weightlifters, cyclists and runners)	Toussaint et al. (2006a)	1.8
		Toussaint et al. (2006b)	2.06

To the authors' knowledge, few studies have determined the relationship between dry-land and swimming power (Shimonagata, et al., 2002; Swaine & Doyle, 2000). In the first case, r=0.88 and in the second one, r=0.92. Both used a swim bench to measure dry-land power. Our result for these two variables was r=0.538. This reveals that swimming power delivered to an external weight is more related to dry-land power when the latter is assessed with a specific exercise. On the other hand, Shionoya, et al. (2001) found a relationship of r=0.88 between swimming power and crawl sprint velocity (22.86m), while in the study of Shimonagata, et al. (2002) it was r=0.92 (25m). These values confirm our result of r=0.762.

CONCLUSION: In this study, we have determined a significant correlation between swimming power and velocity. This result suggests that power training could play an important role in swimming performance. Not only have we calculated maximal bench press and swimming power values, but also the corresponding loads and velocities. This information can be very useful for coaches. They could set the desired working load or velocity for each swimmer to deliver maximal power. The method proposed allowed to control the underwater stroke technique and relate pulling phases with the power measured. Swimming power training is to a certain extent an unknown field where further investigations are needed.

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Acknowledgement
The authors would like to thank the group “Physical Activity and Sport in the Aquatic Environment” (CTS 527) and the Physical Education Department for providing all the necessary equipment and the Faculty of Physical Activity and Sport Sciences of the University of Granada for allowing the use of the swimming pool and the gymnasium. This study was possible thanks to a FPU fellowship (AP2008-03243), funded by the Spanish Ministry of Science and Innovation.