RELATIVE FORCE AND PAP IN SWIMMING START PERFORMANCE

Francisco Cuenca-Fernández[1], Sonia Taladriz[1], Gracia López-Contreras[1], Blanca de la Fuente[2], Javier Argüelles[2] and Raúl Arellano[1]

Physical Education and Sport Department, University of Granada, Granada, Spain[1]
High Altitude Training Center, Spanish Sport Council, Sierra Nevada, Granada, Spain[2]

Firstly, it was studied the relationship between relative force (F_{rel}) of the lower limbs in a isotonic Lunge test, with the performance in a swimming kick start (SS). Afterwards, were applied two Postactivation-Potentiation (PAP) specific warm ups in order to analyze their effect in performance considering the F_{rel} of the subjects. Trained swimmers (n=14) volunteered in this study. *Pearson* product-moment correlation coefficients were used to verify the relationship between relative force and kinematic variables of a SS. Results revealed high correlation between relative force and performance in SS (Dive Distance: R^2=0.872, p<0.001; Horizontal Hip Velocity: R^2=0.308, p=0.049; Time to 15m: R^2=-0.813, p<0.001). After PAP, swimmers with higher relative force showed a higher improvement on the kinematic variables of SS than those with lower values of strength.

KEY WORDS: Warm-Up, swimming starts, PAP, YoYo Squat flywheel device.

INTRODUCTION: With the new starting blocks Omega (OSB11, Corgémont, Switzerland), block time is shorter than the time achieved with the old starting platforms (Honda, Sinclair, Mason, & Pease, 2010). However, results found in the recent literature show that it is preferable to achieve a good impulse adopting a rear weighted position, which implies higher muscle implication (Barlow, Halaki, Stuelcken, Greene, & Sinclair, 2014), than to try to get off the platform as quickly as possible. (Ozeki, Sakurai, Taguchi, & Takise, 2012).
Some studies have shown the relationship between lower body muscle force and swimming start performance (SS) (Beretic, Durovic, Okicic, & Dopsaj, 2013; West, Owen, Cunningham, Cook, & Kilduff, 2011), and the results suggests that swimmers who possess greater maximum force and specific rate of force development at absolute and relative levels, tend to be able to swim faster on initial meters of SS (Beretic et al., 2013; West et al., 2011).
Such relationship has lead the interest of some authors for optimizing the take-off parameters of a SS, providing specific warm up routines related to Postactivation Potentiation (PAP) method (Cuenca-Fernandez, Lopez-Contreras, & Arellano, 2014; Kilduff et al., 2011). PAP improves muscle contractility, in strength and speed, by having previously applied a combination between near maximal loads with an optimal recovery time after such conditioning activity. Studies claim that the bigger the specificity of the PAP stimulus, the more effective the PAP benefits are, and those benefits are larger when it is applied to trained subjects, because they overcome the fatigue better (Sale, 2004; Tillin & Bishop, 2009). However, comparisons are not possible if is unknown a value of that state of training. In this study we offer the relative force (F_{rel}), as a way of obtaining such categorization.
The purpose of this study was twofold. The first aim was to evaluate the relationship between lower limbs F_{rel} values obtained through a Lunge test and performance on a SS. To author's knowledge, no studies assesses this issue considering the asymmetric characteristics of the new block. The second aim was to evaluate such relationship after the application of two specific PAP protocols. If more strong individuals are considered to perform a swimming start in better conditions and PAP is more effective in trained athletes, it supposed that best trained swimmers would be able to react better after PAP application and perform a swimming start with better guarantees than weaker athletes.

METHOD: Fourteen trained swimmers (10 men and 4 women), with at least 5 years of participation in National competition, members of swimming clubs of Granada (Spain),

between 18 and 23 years of age, (height 176.3 ± 9.1 cm; weight 69 ± 11.4 Kg.), from whom written informed consent had been obtained, volunteered to take part in this study. Prior to the study, each swimmer visited the laboratory in order of collecting their strength values. Initially, they performed a repetition maximum (RM) isotonic Lunge test (values 68.84 ± 25.19 kg) in a Smith machine (Technogym, Spain). Swimmers were asked to place their legs in the same position that they used to perform the SS, in order to keep a control about which leg was placed front. It was requested to set the initial position with a 90º angle in front and rear knees, then leg extensions were performed. Afterwards, their lower limbs relative force values (F_{rel}) were calculated (0.95 ± 0.28), a coefficient obtained from each subject according the maximum values obtained in the previous RM test divided by their body weight.
On testing day, all participants performed a SS eight minutes after a standard warm up (SWA), consisting of a varied swimming followed by dynamic lower limb stretching. This protocol was considered the control situation. One hour later, swimmers were randomly halved in two groups in order of receiving two specific PAP methods. The first group performed the warm up with Lunge repetitions (LWU), which consisted of warming and dynamic stretching as in SWU, to which the PAP stimulus was added through the realization of the exercise Lunge in a "Smith Machine" device (Cuenca-Fernandez et al., 2014). Swimmers were asked to place their legs in the same asymmetric position that they performed the SS. All subjects had to perform four repetitions at maximum speed to 85% of 1RM. After 8 minutes of rest, swimmers performed a SS. The second group performed the warm up with repetitions in YoYo Squat flywheel device (YWU), which consisted of warming up and dynamic stretching as in SWU, to which the PAP stimulus was added through repetitions on the "YoYo Squat" flywheel device (Cuenca-Fernandez et al., 2014). The initial position consisted of the same position that it is performed by swimmers on the block, with the same front/behind placing of legs. Once the belt was attached, swimmers performed 4 maximum intensity repetitions. After 8 minutes of rest, the swimmers performed a SS. One hour later, that group order was reversed in order to avoid the "fatigue/learning" effect.
Kinematic measurements of SS were measured by recording each attempt with three digital video cameras; one of them was a high speed camera (Casio, HS Camera 300Hz) operating at a sampling rate of 300Hz; it was mounted on a tripod and focused to the block. This camera recorded the Horizontal Hip Velocity (VxH). The two other digital video cameras (Sony Video Camera, 50Hz) were fixed on the poolside; registering the Dive Distance (DD), and the time of the swim phase until 15 meters (T15m). Both block cameras were focused on the starting system to spot the light emitted by the starting signal. The starting system (Signal Frame, Sportmetrics) simultaneously emitted an audible signal and a strobe flash; this was used to synchronize the starting signal with the video image. All video files registered were analyzed by two different researchers who used the software Kinovea®, version 0.7.10., this software allowed the analysis of the reference points drawn on swimmers. The inter-observer ICC ranged from 0.98 (95% CI 0.97-0.98) to 0.99 (95% CI 0.99-0.99). These results showed a high correlation and reliability.
Standard statistical methods were used for the calculation of means, standard deviations (SD) and *Pearson* product-moment correlation coefficients to verify the relationship between relative force and kinematic variables of a SS. Analyses were performed using SPSS software version 21.0 (IBM, Chicago, IL, USA).

RESULTS and DISCUSSION: The analysis of the PAP effect applied in swimming start was primarily studied by Kilduff et al., (2013). In that study, PAP was proposed as an alternative to the regular warm up and they reported 8 minutes of rest as an optimal recovery time between PAP and SS. However, SS variables showed no significant improvements; maybe due to the PAP stimulus wasn't intense enough to cause potentiation. That detail was object of interest of this team and the addition of PAP to the standard warm up were evaluated in a subsequent study with the purpose of increasing such PAP stimulus (Cuenca-Fernandez et al., 2014). In order of making comparisons possible that procedure was carried out

considering the original procedure of 8 minutes of rest proposed by Kilduff et al., (2013) for all the participants. By schedule restrictions, all the protocols were performed the same day. Results showed that protocols which included specific PAP added to the regular warm up achieved better values (Table 1), than obtained after SWU (Cuenca-Fernandez et al., 2014).

Table 1
Mean and standard deviations of kinematic measurements after the three protocols (n=14)

	SWU	LWU	YWU
	Mean ± SD	**Mean ± SD**	**Mean ± SD**
Dive Distance (cm)	294.20 ± 8.67	300.29 ± 8.65	304.28 ± 9.06
Horizontal Hip Velocity (m/s)	3.63 ± 0.11	4.15 ± 0.12	4.89 ± 0.12
Time to 15m (s)	7.54 ± 0.23	7.40 ± 0.21	7.36 ± 0.22

Specifically, warm up which included the YoYo Squat repetitions (YWU) was showed as intense enough for causing the biggest improvement on performance (Table 1). However, no correlations of those data were made between the relative force of the subjects and the changes accounted in performance after PAP. Here is presented an updating of those results. Table 2 shows Pearson's correlation coefficient between baseline F_{rel} values and kinematic measurements of a SS after the changes occasioned in performance by PAP.

Table 2
Pearson's correlation coefficient between Relative Force values and SS variables (n=14)

	SWU		LWU		YWU	
	F_{rel}(N/Kg)	**P**	**F_{rel}(N/kg)**	**p**	**F_{rel}(N/kg)**	**p**
Dive Distance (cm)	.872	<.001	.840	<.001	.850	<.001
Horizontal Hip Velocity (m/s)	.308	.049	.422	.016	.601	.002
Time to 15m (s)	-.813	<.001	-.821	<.001	-.787	.001

Kinematic variables of the SS were positive correlated with baseline F_{rel} values obtained through the Lunge exercise. T15m was negatively correlated with F_{rel}. This means, individuals with stronger lower limbs performed the swimming start in better conditions than those who showed lower values in strength tests. These results are in agreement with those showed by Beretic et al., (2013) and West et al., (2011). Swimmers with higher values in F_{rel} after Lunge test achieved a higher VxH during flight (R^2 = 0.308, p<0.049), who allowed them to increase their DD (R^2 = 0.761, p<0.001) and reducing the T15m (R^2 = -0.813, p=0.001).

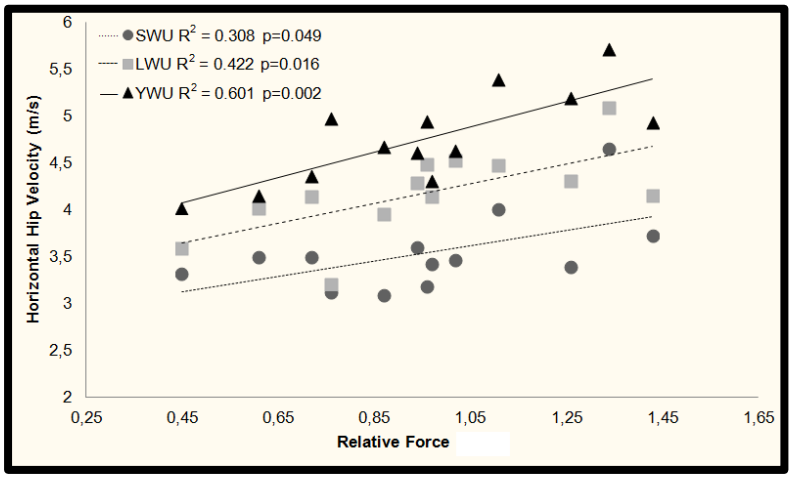

Figure 1: Regression analysis between Relative Force (F_{rel}) and Horizontal Hip Velocity (VxH).

However, in the strength test carried out in the study of Beretic et al., (2013), subjects performed isometric strength test with feet in parallel position. Meanwhile, in the study of

West et al., (2011), all the trials were performed by a swimming grab start. Thus, it was necessary to present an update in this field in view of an asymmetric feet placement.
When considering the changes occasioned in performance by PAP, correlations with baseline relative force values were still maintained, or they became even stronger depending on the intensity of the warm up applied, as the case of variable VxH (Table 2). A visual comparison to Figure 1, show an ascending tendency in the line regression after LWU compared with SWU, and even a higher inclination of the regression line after YWU when compared with LWU and SWU. This fact express two things; Firstly, the more F_{rel}, the higher the improvement occasioned by PAP (Tillin & Bishop, 2009). Secondly, the more strong PAP applied (Cuenca-Fernandez et al., 2014), the higher effect in swimmers with high level of F_{rel}.

CONCLUSION: The F_{rel} is a reliable factor for correlating the strength of the subjects with performance developed in an specific task as SS. It provides to the coach an easy tool for measuring the state of training of their subjects because it considers the body weight of the subject when mobilizing loads. Most trained individuals were able of performing a swimming start with better guarantees. To author's knowledge no one had measured this before considering the feet on an asymmetric placement. Subjects with higher values in F_{rel} showed to react better after PAP application, especially after YWU, which confirms that PAP effects are bigger the more specific is it applied and the more trained subjects are.

REFERENCES:
Barlow, H., Halaki, M., Stuelcken, M., Greene, A., & Sinclair, P. J. (2014). The effect of different kick start positions on OMEGA OSB11 blocks on free swimming time to 15m in developmental level swimmers. *Hum Mov Sci, 34*, 178-186. doi: 10.1016/j.humov.2014.02.002
Beretic, I., Durovic, M., Okicic, T., & Dopsaj, M. (2013). Relations between Lower Body Isometric Muscle Force Characteristics and Start Performance in Elite Male Sprint Swimmers. *Journal of Sports Science and Medicine, 12*(4), 639-645.
Cuenca-Fernandez, F., Lopez-Contreras, G., & Arellano, R. (2014). Effect on swimming start performance of two types of activation protocols: Lunge and YoYo Squat. *J Strength Cond Res*. doi: 10.1519/JSC.0000000000000696
Honda, Koji, Sinclair, Peter, Mason, Bruce, & Pease, David. (2010). *A biomechanical comparison of elite swimmers start performance using the traditional track start and the new kick start*. Paper presented at the Biomechanics and Medicine in Swimming XI, Oslo, Norway.
Kilduff, L. P., Cunningham, D. J., Owen, N. J., West, D. J., Bracken, R. M., & Cook, C. J. (2011). Effect of postactivation potentiation on swimming starts in international sprint swimmers. *J Strength Cond Res, 25*(9), 2418-2423. doi: 10.1519/JSC.0b013e318201bf7a
Ozeki, K., Sakurai, S., Taguchi, M., & Takise, S. (2012). *Kicking the back plate of the starting block improves start phase performance in competitive swimming*. Paper presented at the 30th Annual Conference of Biomechanics in Sports, Melbourne.
Sale, D. (2004). Postactivation potentiation: role in performance. *British Journal of Sports Medicine, 38*(4), 386-387.
Tillin, N. A., & Bishop, D. (2009). Factors modulating postactivation potentiation and its effect on subsequent explosive activities. *Sports Med, 39*(2), 147-166.
West, D. J., Owen, N. J., Cunningham, D. J., Cook, C. J., & Kilduff, L. P. (2011). Strength and Power Predictors of Swimming Starts in International Sprint Swimmers. *Journal of Strength and Conditioning Research, 25*(4), 950-955.

Acknowledgement
To the research group CTS-527:"Physical Activity and Sport in Aquatic Environment".