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Section III – Sports Training

The Effects of Two Different Resisted Swim Training Load Protocols on Swimming Strength and Performance

by

José María González Ravé[1], Alejandro Legaz-Arrese[2], Fernando González-Mohíno[1],
Inmaculada Yustres[1], Rubén Barragán[1], Francisco de Asís Fernández[1],
Daniel Juárez[1], Juan Jaime Arroyo-Toledo[3]

This study used a power rack device to evaluate the effects of 2 different approaches to resisted swim training loads on swimming strength and performance. Sixteen male, youth national-level swimmers (mean age, 16.22 ± 2.63 years; body height, 169 ± 10.20 cm; body mass, 61.33 ± 9.90 kg) completed a 6-week specific strength-training program, and were then randomly assigned to one of the two groups: a standard training group (GS, $n = 8$) and a flat pyramid-loading pattern group (GP, $n = 8$). Strength and power tests along with specific swimming tests (50-m crawl and 50-m competition-style time trials) were conducted at baseline (pre-test), before the third week (mid-test), and after 6 weeks of intervention (post-test). Isokinetic swim bench tests were conducted to obtain measurements of force production and power, and 1RM tests with the power rack system were conducted to measure the maximum drag load (MDL) and specific swimming power. Following 6 weeks of intervention, the mean MDL increased ($p < 0.05$) by 13.94%. Scores for the 50-m competition style and 50-m crawl time trials improved by 0.32% and 0.78%, respectively, in the GP; however, those changes were not statistically significant. The GS significantly increased their time in the 50-m competition style by 2.59%, and their isokinetic force production decreased by 14.47% ($p < 0.05$). The 6-week strength-training program performed with the power rack device in a pyramidal organization was more effective than a standard linear load organization in terms of producing improvements in the MDL; however, it did not produce significant improvements in performance. The use of a strength-training program with a pyramidal organization can be recommended for specific strength-training in young swimmers during a preparatory period. However, in our study, that program did not produce significant changes in 50-m crawl and main competition style performance.

Key words: *power rack, load organization, swimming performance.*

Introduction

Numerous studies have described the importance of muscle strength and power generated by the arms and legs in swimming performance and showed that those variables were highly correlated with the results of speed tests (Maglischo et al., 1985; Morrison et al., 2005; Maszczyk et al., 2012, 2014), mainly in short-distance events. Furthermore, a linear relationship has been reported between maximum power and performance in 25-m and 50-m swimming events (Hawley and Williams, 1991, 1992).

Previous studies have recommended that various training methods, such as dry-land training (which usually includes medicine ball throws and free weights), should be incorporated into the swim season (Girold et al., 2007;

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[1] - *Sport Training Lab, Faculty of Sport Sciences, University of Castilla-La Mancha, Toledo, Spain.*
[2] - *Section of Physical Education and Sports, University of Zaragoza, Zaragoza, Spain.*
[3] - *Danish Swimming Federation, Farum, Denmark.*

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Sadowski et al., 2012). Resistance training has been used in a wide variety of sports, and especially in swimming (Bishop et al., 2013; Garrido et al., 2010; Newton, 2007; Patnott et al., 2003) as a method for athletes to increase their strength while performing sport-specific movements. In-water resistance training using a power rack is a traditional method for increasing specific swimming strength.

Previous studies have evaluated the effects of different strength training protocols on swimmers. One such a protocol used by Garrido et al. (2010) examined the effects of 8 weeks of combined dry land strength and aerobic swim training on upper and lower body strength, power, and swimming performance in young competitive swimmers. However, the results of that study did not clearly show that strength training led to enhanced swimming performance. Moreover, Juarez et al. (2013) showed that resistance exercises did not affect swim times in 25-m swim trials. Furthermore, Sadowski et al. (2012) reported that power training did not lead to enhanced swim performance, although there was a tendency toward improved performance in tethered swimming.

Assisted and resisted training methods have been employed to concurrently increase swimming strength and speed (Dopsaj, 2000; Girold et al., 2006, 2007, 2008; Morrison et al., 2005; Patnott et al., 2003; Wright et al., 2009; Gołaś et al., 2016). Organized training that alternates heavy resistance and explosive loads is an alternative to programs that use standard organized sets (Murphy and Schwarzkopf, 1992), which apply a specific number of repetitions with the same load during a training session. In contrast, the flat pyramid-loading pattern provides maximum training benefits by providing the best neuromuscular adaptation for a given type of strength training by keeping the load within a single intensity level (Bompa et al., 2003).

Tethered swimming is one of the most specific swimming ergometers, as it simulates the swimmers physical environment and stroke mechanics, and is affected by the swimmer's physiological and morphological characteristics (Morouço et al., 2011a). Power racks (a weight stack that can be tethered to a belt placed around a swimmer's waist) play an important role in resistance training sessions because they enable swimmers to train using in-water exercises with added resistance, while performing any of the 4 basic swim strokes. Boelk et al. (1997) showed that training with a power rack was an important part of sprint training for freestyle swimmers. Juarez et al. (2013) described one of the methods that has gained widespread acceptance in functional swim training programs: the use of elastic bands for improving muscular strength and maximum power. However, the greatest effect of that exercise results from using a power rack, because high loads are required to elicit a potentiation effect. Gonzalez-Rave et al. (2011) analyzed specific power data gathered from crawl swimmers engaged in various performance tasks. However, few studies have examined the effects produced by using specific training loads in a power rack system. Therefore, this study was conducted to examine the effects produced by 2 different forms of organized resisted swim training loads (standard training vs. a flat pyramid loading pattern), maintained by use of a power rack device, on specific swimming strength as well as 50-m crawl and main competition style performance.

Methods

Participants

Sixteen young male national level swimmers (mean age, 16.22 ± 2.63 years; body height, 169 ± 10.20 cm; body mass, 61.33 ± 9.90 kg) from 2 local swimming teams were recruited to participate in this study. All swimmers were healthy and had at least 3 years of swimming experience. All participants were informed of the study's objectives and risks, and parents or a legal guardian of each participant signed a Parental Informed Consent Form. The study protocol was approved by the Ethics Committee of the Castilla-La Mancha University (Spain). The study was conducted in accordance with principles outlined in the Declaration of Helsinki (October 2008, Seoul).

Measures

The study took place during a 9-week period which included 6 weeks of training and 3 weeks during which various tests were conducted (Table 1). Each swimmer underwent a pretest (week 1), mid-test (week 5), and post-test (week 9) evaluation. Based on the mid-test results, the training loads were adjusted for subsequent training weeks.

Design and Procedures

The participants were randomly assigned to one of the two groups. One group performed standard resistance training (GS, n = 8), and the other group performed pyramidal training (GP, n = 8). The original intent was to recruit at least 8 participants for a control group, but not enough swimmers of the appropriate age were available. All swimmers were familiar with strength training, but none had experience with resistance training using a device such as the power rack. Thus, the swimmers performed familiarization sessions with the power rack equipment. The swimmers participated in a total of 5 training sessions per week (2 resistance and 3 swimming sessions) over a 6-week period. The swimmers were instructed not to perform any other resistance training exercises during the course of the study.

Testing procedures

After enrollment and before the pre-test, each participant performed a familiarization session 2 days prior to the baseline measurements in order to minimize any potential learning effects resulting from the training procedures. Each participant performed the tests at the same time of day, in the morning, throughout the study. The ambient conditions were held constant throughout the tests (22–24ºC in the laboratory and a water temperature of 27.5°C).

Strength and power test

The isokinetic swim bench test was used to obtain measurements of isokinetic force production (IFP) and isokinetic power (IP). Prior to the test, a 5-min warm-up session was performed with stationary cycling at an intensity of 150–160 bpm, followed by 5 min of dynamic stretching as described by Morouço et al. (2011b). A simultaneous maximum stroke (butterfly) was performed on each of the 9 levels of an isokinetic swim bench (Fahnemann, Germany). This exercise allowed for an acceleration adjustment in which level 1 provided an acceleration of 1.44 m/s^2, and level 9 provided an acceleration of 3.07 m/s^2. Once the resistance at which the participant displayed the greatest power was determined, there was a 5-min rest period before the next 2 attempts were made, with a 1-min recovery period in-between. The best result was recorded by the BioMeter swim bench (Sharp et al., 1982). While the participant rested between attempts, another swimmer completed their trial.

A 1 repetition maximum (1RM) test using the power rack system was performed to quantitate the training load. A power rack is a system of pulleys and weights tethered to a swimmer via a waist belt attached to a cable which in turn, is attached to a load. As the participant swims, the cable lifts the weight. A 1RM test in resisted swimming was performed in a 12.5-m swimming pool. Training equipment similar to the power rack had been used in other studies (Boelk et al., 1997; Wright et al., 2009). In this study, the participants were instructed to swim 12 m as quickly as possible from a stationary start position. To obtain measurements of the maximum drag load (MDL) and specific swimming power (SSP), the 1RM value in resisted swimming was calculated for each participant. This test was performed using a power rack (Telju S.A., Toledo, Spain). The protocol for the specific strength swimming test as standardized by Gonzalez-Rave et al. (2011) is as follows: while the swimmer fits the waist harness, the dragging load is set with the plates, starting at a minimum value of 15 kg. At the signal, the swimmer adopts a frontal extended position next to the edge of the pool with the legs extended, and then extends the pulley cable without raising the previously set weight plate. At the next signal, the swimmer swims at maximum speed for 12.5 m without pushing off from the wall. Two photocells measure the time required for the swimmer to swim 7 m. The first photocell starts the timing at 3.5 m, and the second is fixed at 10.5 m. The swimmer then rests for 5 min and repeats the procedure with a higher load until he/she is no longer able to complete the 12.5 m distance with a specific load. The heaviest load carried during a 12.5-m sprint is considered the maximum pulling/dragging load. All swimmers receive at least 5 load increases and are permitted a maximum of 10 attempts.

Swimming performance

Speed tests for the 50-m crawl and 50-m competition style time trial (TT) were performed. To obtain the needed measurements, the participants performed a warm-up with 200-m freestyle, followed by 200 m of kicks only (legs), alternating between 50 m of crawl and 50 m of the main competition style; 200 m of arms only, alternating between 50 m of crawl and 50 m of the main competition style; and finally, 4 x 25 m with a progressive increase in speed. After the warm-up, the 50-m crawl speed test was performed with a recovery time of 7 to 10 min. The swimmer's performance in the 50-m main competition style was then measured. The timer was started manually when the swimmer's feet left the starting block. Participants were instructed to swim at their maximum speed. The final time was measured by a timing plate (TP24, Alge Timing, Austria) that the swimmers touched at the end of the 50-m test.

Training distribution and test application

We analyzed the data obtained after 6 weeks of training. The study was initiated at the beginning of the preparatory period. Each swimmer had qualified and participated in the Winter Spanish National Championship by taking part in either one or two races. Except when performing the power rack workouts, both training groups performed the same weekly training sessions from Monday through Friday with the same training volumes and intensities. The daily workouts required a maximum of 60 min of training in which various tasks and objectives planned by the coach were performed. A weekly volume of 8000–8400 m was performed, and was mainly focused on endurance and swimming technique. The power rack workouts were more oriented toward an alactic speed regime, in which each participant performed a specific number of sets of alternating tasks interspersed with recovery periods. The rest periods provided 3 to 5 min of total passive recovery to facilitate and ensure complete recovery for the subsequent efforts. The participants were instructed to swim at their maximum speed in the power rack sets. The GS performed 6 sets of 12.5-m freestyle, swimming at 70% of 1RM in resisted swimming. The GP followed the flat pyramid loading pattern (1 set of 12.5-m freestyle swimming at 50% of 1RM, 1 set of 12.5-m freestyle swimming at 60% of 1RM, 2 sets of 12.5-m freestyle swimming at 70% of 1RM, 1 set of 12.5-m freestyle swimming at 60% of 1RM, and 1 set of 12.5-m freestyle swimming at 50% of 1RM). Therefore, both groups performed the same task with the same specific target using the power rack. Table 1 illustrates the training program performed by both groups.

Statistical Analysis

All data were analyzed using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY). The Shapiro-Wilk test was used to test the normality of data (each variable), and the Friedman test was used for the only nonparametric variable (MDL). For the parametric variables, we initially performed an analysis of variance for repeated measures (ANOVA) with *post hoc* Bonferroni tests for various pre-test, mid-test, and post-test assessments to identify differences between variables over time. Data were compared after calculating the percentage changes in each training program. Two-way ANOVA was performed with one within-subject factor (TIME: pre-test, mid-test or post-test) and one between-subject factor (GROUP: GS or GP); p-values < 0.05 were considered statistically significant. Cohen's D was calculated to assess the effect size (ES), which was interpreted as small (< 0.3), moderate (≥ 0.3 and < 0.5) or large (≥ 0.5).

Results

There were no significant differences between the two study groups (GS and GP) in terms of age, body height or mass. Furthermore, the GS and GP showed no significant differences in the measured variables at baseline (pretest). Table 2 shows the values obtained during the data collection phase. The interaction (group x time interaction) obtained with two-way repeated-measure ANOVA was significant for the 50-m competition style TT values ($p < 0.01$). The GP showed significant improvement in the MDL and IFP values ($p < 0.05$). However, there were no significant changes in the SSP and IP values or for the swim time in the 50-m crawl TT.

Discussion

This study investigated the effects of 2 different forms of organized resisted swim training loads (standard training vs. a flat pyramid loading pattern) with a power rack device on specific swimming strength and swimming performance. Our results showed that swimmers in the GS did not achieve significant changes in the MDL. However, swimmers in the GP presented a significant increase (13.94%) in the MDL ($p < 0.05$). This result is in accordance with a study conducted by Rahimi (2011), in which the flat pyramid loading pattern was more effective than the standard patterns. One possible reason for this improvement could be that the flat pyramid offers the advantage of providing a better neuromuscular adaptation for a given type of strength training, because it maintains the load within a single intensity level. In contrast, the pyramid system is characterized by its varying intensities, and may induce high mechanical tension due to variations in exercise intensity when compared with standard resistance training (Fleck and Kraemer 2014). This factor could increase the recruitment of fast motor units and cause changes in muscle strength in swimmers who receive pyramid resistance training (Schoenfeld 2010). Moreover, the pyramid system has not been extensively studied. In our study, improvements in the swimmers' maximum pulling load did not reflect increases in power and speed variables. This finding is in accordance with results reported by Campos et al. (2002), who found that while strength training improved strength, speed improvements could be developed throughout the competitive season. However, benefits of the flat pyramid pattern have not been demonstrated using a power rack during swim training sessions.

Table 1

Training program and weekly distribution of testing.

Week	Monday	Tuesday	Wednesday	Thursday	Friday
1		Familiarization		Pre-test	
2 to 4	AEL	Power-Rack training GS (6x70% 1RM) GP (1x50, 1x60, 2x70, 1x60, 1x50% 1RM)	AEM	Power-Rack training GS (6x70% 1RM) GP (1x50, 1x60, 2x70, 1x60, 1x50% 1RM)	PAL
5	AEL	Free swim	Free swim	INTER-TEST	PAL
6 to 8	AEL	Power-Rack training GS (6x70% 1RM) GP (1x50, 1x60, 2x70, 1x60, 1x50% 1RM)	AEM	Power-Rack training GS (6x70% 1RM) GP (1x50, 1x60, 2x70, 1x60, 1x50% 1RM)	PAL
9	AEL	Free swim	Free swim	POST-TEST	

AEL: training to improve aerobic threshold (e.g. 2 x 800 m crawl);
AEM: training to improve the anaerobic threshold (e.g. 4 x 400 m styles);
PAL: training to improve alactic power (e.g. 12 x 10 m; starts and turns);
GS: resisted standard training group; GP: resisted pyramid workout group.

Table 2

Data for the study variables by group. Data are expressed as the mean ± standard deviation and percentage changes between the pre-test, mid-test, and post-test results.

Variables	Group	F value	Pre-test (mean ± SD)	Mid-test (mean ± SD)	Post-test (mean ± SD)	% Change Pre-Mid	% Change Mid-Post	% Change Pre-Post
MDL (kg)	Standard	3.102	41.54 ± 17.67	43.75 ± 18.85	42.12 ± 18.21	5.32	-3.73	1.40
	Pyramidal		42.18 ± 21.6	45.62 ± 24.21	48.06 ± 22.28	8.16	5.35	13.94*
SSP (W)	Standard	0.152	27.3 ± 12.8	26.5 ± 10.15	28.5 ± 12.6	-2.23	-7.02	4.39
	Pyramidal		30.3 ± 13.06	30.12 ± 14.18	32.12 ± 14.5	-0.59	6,64	6.01
IFP (N)	Standard	2.426	75.62 ± 22.86	65.8 ± 16.63	64.68 ± 16.16	-12.99	-1.70	-14.47*
	Pyramidal		67.5 ± 23.12	63.62 ± 20.66	70.62 ± 17.57	-5.75	11.00	4.62
IP (W)	Standard	0.136	394.12 ± 175.01	354.62 ± 137.38	370.62 ± 119.85	-10.02	4.51	-5.96
	Pyramidal		424.62 ± 140.5	395.00 ± 146,72	416.75 ± 131.29	-6.98	5.51	-1.85
50-m crawl TT (s)	Standard	0.917	30.85 ± 2.92	31.00 ± 2.82	30.93 ± 2.63	0.49	-0.23	0.26
	Pyramidal		30.71 ± 2.33	30.44 ± 2.57	30.47 ± 2.37	-0.88	0.10	-0.78
50-m competition style TT (s)	Standard	5.518	34.34 ± 4.13	35.27 ± 3.52	35.23 ± 4.19	2.71	-0.11	2.59**
	Pyramidal		31.7 ± 2.35	31.3 ± 4.38	31.6 ± 2.27	-1.26	0.96	-0.32

MDL: Maximum Drag Load; SSP: Specific Swimming Power; IFP: Isokinetic Force Production; IP: Isokinetic Power; TT: Time Trial. *$p < 0.05$, ** $p < 0.01$

Although the total volume of work performed in the two groups was equal, the intensity was different. The mean intensities in the GS and GP were 70% and 60%, respectively. It is possible that training with lower intensities (and not just the pyramid method per se) produced a relatively better physiological adaptation, as shown by the results. One possible limitation of this study could be the difference between intensity programs; however, both programs were designed to achieve the same goal.

After 6 weeks of training, the mean SSP in both groups increased (4.4% and 6% in the GS and GP, respectively). There were no further significant improvements in SSP in the two groups after 6 weeks of training, but the effect sizes were moderate and large (d = 0.47 and d = 0.69 for the GS and GP, respectively). These results differ from those reported in the study by Wright et al. (2009), possibly because those authors set a specified work benchmark for peak power, while in our study, the percentage of the maximum pulling load served as a reference. The changes in SSP in our study were greater than those in the study by Patnott et al. (2003), who found SSP decreases of 9%. This difference could be due to our study participants, who were significantly different from the university swimmers enrolled in the prior study.

Muscle strength and power with the swim bench

Values for IFP and IP measurements obtained on an isokinetic swim bench showed that there were no significant changes in IP. However, there were significant changes in IFP in the GS, with a mean decrease of 14.47%. In contrast, the GP increased their IFP by 4.62%, and showed a large effect size (d = 0.80), although the change was not statistically significant. The specificity of training in both groups could also explain the lack of improvements in IFP found in our study. To date, no evidence for an effect of in-water resistance training has been found in terms of the variables measured on an isokinetic swim bench. Although the swim bench reproduces certain elements of regular swim training, it cannot replicate biomechanical aspects related to how swimmers feel the water (Aspenes and Karlsen, 2012). Given that there is no isokinetic phase in a swim stroke, training for this event did not develop isokinetic strength in any of the training sessions, suggesting that training on an isokinetic swim bench may adversely affect swimmer's performance. These results are in conflict with those reported by Counsilman and Counsilman (1994) and Maglischo et al. (1985), who found a significant relationship between strength and power as measured on an isokinetic bench and performance in a 25-m sprint swim. A consistent finding in both of our groups was that IP and IFP values were lowest at the beginning of the competitive season, during the preparatory period (high-volume training). During the preparatory period, competitive swimmers performed intense endurance training, which decreased their ability to exert maximum muscle power due to muscle fatigue or inhibition of neural and/or intrinsic muscle properties.

50-m crawl and main competition style TT

After 6 weeks of training, the mean 50-m crawl time in the GS increased by 0.26%, and times in the competition style TT increased significantly by 2.59%. Moreover, there was only a moderate effect size (d = 0.61), suggesting that the increased times reflected a reduction in swimming performance.

In the GP, both variables (time and speed) improved (decreased time and increased speed); however, the improvements were not statistically significant. The speed increase was 0.78% in the 50-m crawl TT, and there was a small effect size (d = 0.22). The speed increase in the 50-m competition style TT was 0.32%, which was similar to that reported in a study by Sadowski et al. (2012), which evaluated the effects of dry-land power training on swimming force, swimming performance, and strength in 26 young male swimmers. While these results do not clearly indicate that power training enhances swimming performance, a tendency toward improved performance in tethered swimming was definitely noticed. The GS achieved a significant increase ($p < 0.01$) in sprint times in the 50-m main competition style after training with the power rack (Table 2). This suggests that swimming performance became worse after training; causing swim times in the subsequent 25-m event to increase. Several studies have shown that > 80% of swimmer's performance in the 50-m crawl results from their ability to manifest increased swimming power (Dopsaj, 2000; Maglischo et al., 1985; Newton, 2007; Patnott et al., 2003). However, our results illustrate the influence that the maximum drag load can have on competition times in the 50-m swim. The differences between performance times primarily resulted from increased times in the GS, rather than significant improvements in the GP. Our results differ from those reported in the study by Smirniotou et al. (2008), in which participants who completed 4 weeks of resistance training improved their leg kick speed and maximum speed. In our opinion, the different results in our study occurred because the groups were comprised of novice swimmers with only 3 years of experience in competitive swimming, and no prior experience of training with the power rack system used in this study. Therefore, our results may differ from those that would be obtained with highly trained swimmers. Maglischo et al. (1985) criticized both resistance and assisted training for producing a negative stimulus on stroke mechanics, and suggested using these exercises with caution in young swimmers. However, another reason for the lack of improvement in the 50-m crawl TT could be the short duration of that swim test. Indeed, Toussaint et al. (1988) suggested that the effects of dry-land strength training could be transferred to swimming performance if the swimmer moves just as fast or faster than when swimming in water.

Thus, only one variable measured in our study (MDL) showed significant improvement after the training period, and this result was similar to those reported in previous studies (Girold et al., 2006, 2007, 2008; González Ravé et al., 2011; Schnitzler et al., 2002; Wright et al., 2009).

Based on the results of this study, resistance training performed using a flat pyramidal load pattern at the beginning of the competitive season, during the preparatory period, may produce a better adaptation to exercise. Furthermore, swimmers who received that type of training showed a tendency for improved performance in tethered swimming with a flat pyramidal load pattern. However, additional studies on the tapering phase (the time period of the presumed transformation of strength in terms of power and speed) may also provide additional relevant data. Future studies should focus on the periods of 15 and 21 days after the tapering phase. Other factors worth considering in future studies are larger sample sizes and higher levels of expertise among the participants.

We conclude that resisted swim training organized using a pyramidal approach is more effective than standard linear loads in terms of producing improvements in the maximum drag load as measured on a power rack device, but does not increase swimming performance. While it cannot be definitively stated that the protocol applied in the GP is more effective than the one of the GS for increasing 50-m crawl and main competition style performance, the participants of the GP tended to show improved swimming performance. However, any practical application of our findings will require caution and individual approach.

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Corresponding author:

González Ravé, José María
Faculty of Sport Sciences
Avenida Carlos III s/n
45071 Toledo (Spain)
Telephone: 0034 925 268800 ext (5519)
Fax: 0034 925 268846
Email address: JoseMaria.Gonzalez@uclm.es