IESS PAPER REVIEW

REFERENCE: Acute effects of two resisted exercises on 25m swimming performance.

The following features of the paper are rated on a 1 - 5 scale from 1 (very poor) to 5 (excellent):
1. Originality 4
2. Apparent thoroughness of literature review 4
3. Relevance to the journal's readership 2
4. Design and handling of data 3
5. Appropriate discussion of the results 4

Overall rating: 3 (minor revision)

Written comments:
1. Language correction should be performed through the whole paper.
   A native English speaker has thoroughly reviewed and edited this manuscript to correct the language expression.
2. Load for RS must be specified (30% 1RM?).
   This has been added to the manuscript.
3. Specify numeric resistance of elastic bands and describe in detail the type of exercise they are used for.
   A more detailed explanation of the exercise performed has been added. The resistance at 100% elongation of the elastic band used was 3.2 kg.
4. There are remarkable differences in swimming time between RS and the other groups (0.3s) and between repetitions in the RS group (0.2s), attending to the magnitudes of performance in swimming sport. If ANOVA test does not show significant differences then the use of a more powerful statistical test is advised. If not, it should be discussed as a weakness of the study, along with the need of higher numbers of subjects.
   The differences between RS and the other groups remain with some evidence during the repetitions. We have added the calculation of effect size (partial $\eta^2$). This suggestion has been considered and a comment added in the manuscript.
Title page:

Acute effects of two resisted exercises on 25m swimming performance.

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Abstract
The aim of this study was to examine the acute effects of two resistance exercises on 25m freestyle swimming performance. Twenty-eight regional and national male swimmers volunteered and were randomly assigned to one of three groups: Resistance Swimming Group (RS): (n=9; 16.2 ± 3.8 yr), Elastic Band Group (EB): (n=9; 15.9 ± 4.0 yr.), and Control Group (C) (n=10; 15.7 ± 2.2 yr). Swimmers completed a 25m swim trial at baseline. Subsequently, RS performed resisted crawl swimming with 30% of maximum load (1RM) in a power rack for 12m and 30 seconds later a 25m maximal swim trial. EB performed 10 seconds of arm freestyle strokes with elastic bands and 30 seconds later a 25m maximal swim trial. C performed only the second 25m maximal swim trial. Each group repeated this protocol four times, with two minutes of rest between repetitions. A two-way ANOVA revealed no significant differences in 25m swimming times between groups for any of the repetitions performed, and there were no significant differences in 25m swimming times between the repetitions within each group. The results showed that the resistance exercises performed in this study before the 25m swim trials did not affect swimming times.

Key words: power, strength, swimmers.
1. Introduction.

In swimming the development of muscular power is an important training component and a major success factor in competition [1, 2], mainly in short-distance events. A linear relationship between maximal power and performance has been previously reported for 25m and 50m swimming [1, 3, 4, 5].

One method that has gained widespread acceptance in functional training programs is the use of elastic bands [6] in tandem with specific training programs. This type of variable resistance exercise is an effective training method for improving muscular strength and maximal power [7]. Thus we hypothesized that elastic bands could be incorporated in swimming training programs as a useful tool to improve maximal power. Previous research has determined that effects of dry-land strength training are transferred to swimming when the strength exercise is performed as fast as or faster than when swimming in water [8]. Another training method which is commonly used is resisted swimming. The Power Rack is a specific device for training swimming power [9] and can provide this form of resistance. The use of commercially available semi-tethered resistive swim training devices as a means of introducing in-water "overload" during training in competitive swimming has been reported as advisable to the development of muscular power [10] and improved swim performance. Recently, a number of studies have illustrated the significant acute effect that resistance training has on power performance, possibly caused by postactivation potentiation (PAP) as shown McCann and Flanagan [11], González-Ravé et al. [12] and Scott and Docherty [13]. The principles of potentiation have been applied by athletes to enhance performance and optimize training or competition [13]. The most common means of inducing PAP are high load squat or bench press exercises [14, 15, 16] and maximal voluntary isometric
contractions [17, 18]. However, other exercises and training methods, such as lighter load but high power exercises, which have demonstrated their effectiveness in chronically improving performance [19, 20], may also have potential for eliciting PAP [10, 21, 22, 23]. Hilfiker et al. [21] and Masamoto et al. [22], found improved 1RM squat (maximum weight lifted in 1 RM squat) and countermovement jump (CMJ) by previously performed drop jumps. Smilios et al. [10] found that contrast loading with the use of low and moderate loads can cause a short-term increase in CMJ performance.

On the other hand, Till and Cooke [23] carried out a study in which no significant differences were found at 10 and 20m sprint and vertical jump performance between four different warm up protocols: deadlift (5 repetitions at 5 repetitions maximum), tuck jump (5 repetitions) and isometric maximal voluntary knee extensions (3 repetitions for 3 s). This leads to the question of whether a greater or lesser external load (i.e., percentage of body weight or percentage of 1RM) might elicit a different response in subsequent power performance. To our knowledge, no previous studies have focused on PAP using the Power Rack in swimming.

Despite several studies examining the application of PAP in sports training and performance in recent years [24, 25, 26] the results thus far regarding the enhancement of acute performance in powerful movements are equivocal. Factors such as training experience, physical fitness and strength levels, exercise type, load, or rest time are considered important in determining whether high load exercise produces PAP and fatigue [10, 15, 18].

While heavy resistance exercise is usually applied to produce the PAP effect, to our knowledge, no studies have been performed on the application of PAP and the acute effects of different resistance power exercises in swimming. Therefore, the aim of this
study was to analyse the acute effects of two power exercises (dry-land strength training using elastic bands and resisted swimming using a Power Rack) on 25m freestyle swimming performance. It was hypothesized that 25m freestyle swimming performance would significantly improve acutely after these power exercises.

2. Material and methods.

2.1. Participants.

Twenty-eight male swimmers volunteered to participate in this study, and were randomly assigned to one of three groups: Resisted Swimming Group (RS): (n=9; 16.2 ± 3.8 yr; 1.77 ± 0.10 m; 66.3 ± 7.7 kg), Elastic Band Group (EB): (n=9; 15.9 ± 4.0 yr; 1.76 ± 0.10 m; 65.6 ± 8.2 kg), and Control Group (C) (n=10; 15.7 ± 2.2 yr; 1.76 ± 0.11 m.; 66.2 ± 10.1 kg). These swimmers had approximately six years of experience in swimming and two years resistance training experience. At the time of the study, the swimmers were training 2.5 hours per day, with one rest day a week. All participants were taking part in regional or national competitions. University ethics approval was obtained. The present study meets the Ethical Standards in Sport and Exercise Science Research [13]. Each participant’s parent gave written informed consent before participating in any of the tests. All participants were free of any injuries or illnesses that could hinder their ability to provide maximal effort.

2.2. Procedures.

Three days before performing the 25m swimming test, a resisted swimming test was carried out for each participant; the purpose being to determine the optimal relationship between load and speed in this exercise to use this load during the subsequent evaluation. Maximum load (1RM) that subjects could displace was also registered. This test was performed using a Power Rack (Telju S.A., Toledo, Spain) which was
developed specifically for power training in swimming [28]. Training equipment similar to the Power Rack has been used in other studies [28, 29]. In order to provide a better understanding of the equipment used, Power Rack is a system of pulleys and weights that allows a swimmer to be tethered via a waist belt to the resisting load while swimming. Participants swim while tethered by a belt attached to a cable which raises a weight. The test was performed in a 12m swimming pool. Participants were instructed to swim 12m as quickly as possible from a stationary start position. First, the following warm-up was performed: 300m freestyle low intensity swimming, 2x100m legs only swimming, 2x100m arms only swimming, 4x50m swimming increasing the speed of each repetition, 4x25m swimming increasing the speed of each repetition, 200m low intensity swimming.

The test protocol was as follows: Set the stack on the first weight (10 kg) and have the swimmer put on the belt. The swimmer, starting in a horizontal position, begins to swim 12m, (that is the distance of the swimming pool in which the test was performed) as quickly as possible after pushing off the wall. After a 3-4 minutes rest, the swimmer repeats the same exercise, but with a higher load. The increase in applied load was 5kg with each attempt. The test was stopped when the participant was unable to complete the repetition with a given load. The successfully completed attempt with the highest load is selected as 1RM for this test. The purpose being to determine 30% of 1 RM, the load to be used during the subsequent evaluation. The participants in this study were familiar with the test protocol because they had been regularly evaluated during the previous year.

On the testing day, three days after the pre-test, the participants warmed up with a 1000m freestyle swim at low intensity, 100m at higher intensity, and 100m at low
intensity. This is the usual warm-up that the participants in this study use before a competition. They then performed a 25m swim at maximum speed. The participants began to swim in the water and the chronometer was started manually when their feet left the starting block of the pool. Participants were instructed to swim at their maximum speed. The chronometer was stopped as soon as the swimmer touched the swimming pool wall with his hand. Time control was manual but was registered by an experienced swimming trainer [17]. Two minutes after, the participants carried out a different protocol depending on the group to which they were assigned. The RS performed 12m freestyle swimming with resistance using the load determined in the initial test (30% of 1RM), and 30 seconds after, repeated the 25m freestyle swimming trial. This sequence was repeated four times, with two minutes rest between repetitions. 12m is the maximum distance possible in the training pool for this test and thirty seconds was the minimum time needed by the swimmers to be prepared to perform the 25m swim. The participants were familiar with this exercise because they had routinely used it in their strength and power training sessions over the last year. The EB group performed an exercise that simulates the arm action of front crawl. Holding the end of an elastic band (Flexaband) in each hand the participant walked backward until the band was tensioned and the arms extended with the hands facing down. They stood with the feet together and the legs slightly bent, pushed the hips back and then bent forward at the waist while simultaneously extending the arms behind the body. The band was held away from the shoulders and the body was positioned parallel to the floor at this point. The shoulder extension movement was repeated using an alternating arm action. This exercise was performed over 10 second periods with the moderate-high resistance elastic bands (the band is made
of natural rubber latex, which is durable and highly elastic), and after a rest of 30 seconds, performed the maximal 25m freestyle swimming trial. This sequence was repeated four times, with two minutes rest between repetitions. The elastic band is commonly used in swimming training, and the swimmers were familiar with its use. The resistance at 100% elongation of the elastic band used was 3.2 kg.

The C group performed four repetitions of 25m freestyle swimming with two minutes rest between repetitions. The testing protocol schedule is shown in figure 1.

Figure 1 to be inserted around here.

2.3. Statistical analysis

SPSS 17.0 (SPSS Inc., Chicago, IL) was used for the statistical analysis. Mean ± standard deviation of the data was calculated. A one-way ANOVA was applied to analyse the differences between groups in age, stature, body mass, and 1RM resisted swimming. A two-way repeated-measures ANOVA was performed to analyse the interaction effect between the group (between-participant variance) and the repetition (within-subject variance) in the 25m swim time. Bonferroni post hoc comparisons were used to locate differences between groups and between repetitions. Pearson correlation analysis was applied to study the relationship between the 1RM in resisted swimming tests and the percentage of change between repetitions in the 25m swimming time (time pre-time1, time1-time2, time2-time3, time3-time4, and time pre-time4). Statistical significance was set at p<0.05. In addition, partial eta squared ($\eta^2$) was calculated as an index of effect size.

3. Results.
There were no significant differences between groups in age, stature, body mass, 1RM at resisted swimming and 25m freestyle swimming time at pre-test. The results recorded for each group in all the repetitions performed in the 25m swimming trials are shown in Table 1. The interaction (group x repetition) effect (F-value) obtained with the two-way repeated-measures ANOVA was not significant for swimming time. **Partial eta squared (η²) was 0.02 and 0.01 for the within-subjects and between-subjects factors, respectively.**

Table 1 to be inserted around here.

Time was 0.75%, 0.41%, 1.37% and 1.37% lower post 1, 2, 3 and 4, swim trials respectively, when compared with the pre-test in the RS group. The EB group showed an increase of 0.95%, 0.67% and 0.95% when comparing post 1, 2 and 4 with the pre-test, while the post 3 time was 0.20% lower when compared with the pre-test. Finally, time was 0.87%, 0.33%, 0.06% and 0.26% lower when post 1, 2, 3 and 4 swim trials were compared with the pre-test in the C group.

Individual changes (%) between repetitions of 25m freestyle swimming time are presented in figures 2.1, 2.2 and 2.3. The positive numbers indicate an increase of the time between a repetition and the following one, or between the initial repetition (pre) and the last repetition. The negative changes indicate a decrease in time, that is, an improvement of the performance.

Figures 2.1, 2.2 and 2.3 to be inserted around here.

No significant correlations were found between the 1RM in resisted swimming tests and the percentages of change between repetitions in the 25m swimming time (time pre-time1: r = 0.18, time1-time2: r = -0.38, time2-time3: r = 0.26, time3-time4: r = -0.10, and time pre-time4: r = -0.02).
4. Discussion.

This study was performed to determine the acute effects of two resisted exercises on 25m freestyle swimming performance. To the best of our knowledge, no other study has examined the acute effects of elastic band exercises in a session compared with resisted swimming exercises on time in 25m freestyle swimming performance. It was hypothesized that swimming performance would significantly improve as a result of prior resistance exercises. To analyse the possible cumulative effect, measures were carried out after each repetition.

The non significant interaction effect between the treatment factor and the repetition factor indicates that there were no significant differences in 25m swimming times between groups in any of the repetitions performed and further there were no significant differences in 25m swimming times when comparing repetitions within each group. Therefore, converse to our hypothesis, the resisted exercises performed in this study before 25m swimming trials did not improve the performance at all, so, this study indicates that high velocity moderate load seems to not improve the acute performance in 25m freestyle swimming. However, given that there was no decrease in performance, the treatments carried out in the present study, especially the RS protocol, could be used in power training for swimming without concern for acute reduction in swimming performance. Till and Cooke [23] also found no significant differences at 10 and 20m sprint and vertical jump performance between four different warm up protocols: deadlift (5 repetitions at 5 repetitions maximum), tuck jump (5 repetitions) and isometric maximal voluntary contractions knee extensions (3 repetitions for 3 s). It is likely that the trend toward improved performance is caused by similar mechanisms as for the weight training exercise, with the explosive-type loading of the plyometric exercise...
enhancing the excitability of the fast twitch motor units and therefore priming these units to play a more significant role in performance [22]. However, intensity of exercise in the current study may not have been great enough to create a PAP effect [23]. In this study the rest period between repetitions was sufficient to avoid causing fatigue because the 25m swimming times did not decrease for the control group and even a tendency for improvement was observed in the RS group. It may be the case that significant enhancements could be achieved with longer rest time. However, there are also studies which have not found significant speed improvements in sprints performed several minutes after a high load exercise [23, 30]. In the study of Chatzopoulos et al. [31], improvements were only observed when the sprint was performed 5 minutes after the squat exercise, but not after 3 minutes.

On the other hand, the effect sizes obtained can be considered low in according to Cohen [32]. Regardless, for swim competitions, minimum differences can be decisive for the result. As such, even such small differences found in this study should be taken considered practically important. Therefore it is recommended to replicate this study with a higher sample of participants and with more manipulations of exercise type, intensity and rest periods.

Analyzing the individual responses, high variability was observed in all groups as in every repetition, there were participants that decreased and others that increased their swimming times. Thus, it seems that an individual analysis is required when these training methods are applied [11, 13, 23, 33, 34, 35]. Only in the last repetition of the RS group did all participants enhance their performance in relation to the pre-test. This fact suggests that the greatest effect of the exercise is produced after four repetitions using the Power Rack.
It is necessary to take into account that a research limitation of this study was the subject characteristics that have been suggested to affect an individual’s PAP-fatigue response. These include muscular strength, fibre-type distribution, training level and power-strength ratio and it appears the best performers become more neurologically prepared to make use of a facilitation effect and swim the 25m faster.

Studies such as the one performed by Jo et al. [15] have observed that stronger subjects might potentiate with less rest after a stimulus, whereas weaker subjects require longer periods of rest. However, in the study by Till and Cooke [23], no significant differences were found between the strongest and weakest subjects. The Pearson correlation analysis in our study suggests that no relationship exists between the 1RM in resisted swimming tests and the percentage of change between repetitions in the 25m swimming times. This was the case for the times between each repetition and the one following it (time pre-time1, time1-time2, time2-time3, time3-time4), as well as for the initial attempt and the last repetition (timepre-time4). This lack of relationship suggests that those swimmers that were stronger in the 1RM test performed in our study were not the subjects which had the greatest improvements in 25m swimming times. However, maximal strength as measured by traditional resistance training methods might have revealed such a relationship but was not included in this study.

Finally, it is also necessary to consider that, although the band used produced an intermediate tension, as established by Shoepe et al. [7], the possible individual differences in the tension created by the exercise could mean a different relative load for each subject. It is also necessary to take into account that the elastic band exercise only included the arms, but not the legs, which also have an important role in swimming.
This study lends further support to previous research suggesting that high loads are required to elicit a potentiation effect. A very small reduction in time in short distance swimming competitions is essential for success. The fact that performance did not decrease and the tendency for improvement observed in the RS group suggest that this protocol may be effective for power training in swimming. Coaches must consider the individual responses of the swimmers to find the most suitable application of these exercises to improve performance.

5. Conclusion

In the general sense, the strength and power exercises performed in this study prior to 25m swimming did not enhance 25m swimming times, although there were swimmers that did see improvements, mainly in the resisted swimming group. There seems to be a tendency to improve after performing several repetitions of resisted swimming. Nevertheless, individual variability in the results suggests an individual analysis of the effects is needed to find the most suitable application of this method (exercise, load, repetitions, sets, rests etc) to improve performance.

6. Acknowledgments.

The authors thank the Toledo Swimming Club for participating in this study.

7. References.


Table 1. Results of 1RM resisted swimming and times (mean ± standard deviation) at 25-m freestyle swimming. Data are mean ±SD.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>1RM resisted swimming (kg)</th>
<th>Pretest (s)</th>
<th>Post 1 (s)</th>
<th>Post 2 (s)</th>
<th>Post 3 (s)</th>
<th>Post 4 (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resisted Swimming (n = 9)</td>
<td>44.4 ± 1.71</td>
<td>14.55 ± 1.54</td>
<td>14.44 ± 1.49</td>
<td>14.49 ± 1.66</td>
<td>14.35 ± 1.49</td>
<td>14.35 ± 1.52</td>
</tr>
<tr>
<td>Elastic Band (n = 11)</td>
<td>41.1 ± 1.90</td>
<td>14.71 ± 1.52</td>
<td>14.85 ± 1.41</td>
<td>14.81 ± 1.35</td>
<td>14.68 ± 1.33</td>
<td>14.85 ± 1.20</td>
</tr>
<tr>
<td>Control (n = 10)</td>
<td>40.0 ± 1.65</td>
<td>14.85 ± 1.72</td>
<td>14.72 ± 1.61</td>
<td>14.80 ± 1.68</td>
<td>14.84 ± 1.72</td>
<td>14.81 ± 1.60</td>
</tr>
</tbody>
</table>
FIGURES.

Figure 1. Testing protocol schedule.

Warm up 1200-m freestyle swimming
Figure 2. Individual changes (%) between repetitions at 25-m freestyle swimming.
Figure 2.1. Individual changes (%) between repetitions at 25m freestyle swimming in Elastic Band group.

Figure 2.2. Individual changes (%) between repetitions at 25m freestyle swimming in Resisted Swimming group.

Figure 2.3. Individual changes (%) between repetitions at 25m freestyle swimming in Control group.