Effects of Specific Strength Training on Sprint Swim Performance.

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**Abstract:** Swimming is a popular competitive sport, considered highly influenced by the endurance and muscle-strength. The aim of the present research is to study effects of eight weeks training two different protocols of specific strength swimming training, tethered to external loads: linear set (SST\textsuperscript{linear}) compared to pyramidal set and their influence on sprint 50m front crawl style (t50c). There were 16 female volunteer participants (age 16.22 ± 2.63 years; height 169 ± 10.20cm; body mass 61.33 ± 9.90kg), divided in two groups. Results at the end of eight weeks of study exhibit superiority of (SST\textsuperscript{pyramidal}) than (SST\textsuperscript{linear}). Besides, the demands of specific strength swimming training can variate in a wave form; decreasing before reaching strength or power improvements; with a low improvement effects of swim performance.

**KEYWORDS:** Periodization, Strength-training, Maximal-strength, Power-strength.

**INTRODUCTION:**
Periodization of athletic training is conceptualized as a pedagogical process, which involves varying volume, intensity and frequency of training in attempt to optimize sport performance.\[^1\] Training periodization, means dividing long training cycles (semester, year) into segments. Thus, programing is to schedule the tasks of the different intermediate cycles (months), then the short cycles (weeks), and finally the training unit.\[^2\]

Although the most effective periodization is yet to be determined; multiple studies show how determinant is the influence of muscle strength on performance.\[^3-4\]

Swimming is a popular competitive sport, considered highly influenced by the endurance training. However, swimming races being decided by only fractions of a second. To this reason, different training methods have been devised to improve performance. Resistance training is a specialized strength training program, utilizing a range of resistive loads and a variety of training modalities designed to enhance health, fitness, muscle-strength and sports performance.

Different studies reported the importance of muscular strength and power propulsion generated by the action of the arms and legs, in speed tests and the shortest distance event of 50m freestyle.\[^2-3-4\]

Resistance training has been used in a wide variety of sports and frequently in swimming. Some examples of specific resistance training on swimming is to swim dressed with drag-suit, shorts, attached to parachute or elastics bands and the method more trustworthy and very extended into coaches and researches atmosphere is it swimming attached to external loads.\[^5\] This is a workout designed to swimmers to increase strength while performing specific pattern of movements.\[^2-6-7\]

The theory of training and logical reasoning states that: heavy resistance load, would have a positive effect on the development of maximum-strength, whereas that low and medium resistance load trained at high intensities would represent a stimuli for development of strength-power,\[^1-8\] the typical standard workout description used a determined number of repetitions with the same percentage of load all-out of training session e.g. 6 x 80% or 4 x 90% for a maximum-strength training whereas that 12 x 30% or 10 x 40% for strength-power.

Verkhoshansky, statements that: “in a single session, pyramidal set would represent physiological advantage of providing the best neuromuscular adaptation through stimuli both, maximum and power-strength requirements”.\[^9\]

Despite the coherence of that logical reasoning, to our best knowledge, is yet poorly studied, resisted training tethered to external loads and this comparison of linear set to pyramidal workout session.

The aim of the present research is to study effects of eight weeks training two different protocols of specific strength swimming training, tethered to external loads: linear set (SST\textsuperscript{linear}) compared to pyramidal set (SST\textsuperscript{pyramidal}) and their influence on sprint 50m front crawl style (t50c).
MATERIALS AND METHOD:

Participants

The participants were recruited by regional competitive program with average 3 years of experience training for a competition; but without previous experience in tethered swimming training. In this study, there were 16 female volunteer participants (age 16.22 ± 2.63 years; height 169 ± 10.20cm; body mass 61.33 ± 9.90kg), divided in two groups of 8 swimmers each group; subjects did not report any characteristics that would impede their participation in SST swimming training. Each participant and his parents were informed about the purpose of the study and possible risks before start the investigation and signed an informed consent document approved by Castilla-La Mancha University’s ethics research committee. All procedures were in accordance with the Declaration of Helsinki.

The control group participated in the strength swimming training, tethered to external loads of linear set (SST\textsuperscript{linear}) and the experimental group participated in the pyramidal set (SST\textsuperscript{pyramidal}), this research lasted 8 weeks in which 3 assessments were made. They Consisted of a baseline (T1) and two post-tests: at 4th week (T2) at 8th week (T3).

Testing protocols

Volume and intensity were strictly controlled, both groups perform the same swimming program separated only at time to realize the SST; in the same way that all participants received nutritional information and were required to do not eat food supplements during the study. An attempt was made to control physical activity outside of the training program. All subjects performed a familiarization with the various test and assessment tools, 2 days before the first test and beginning of the study.

(a) Stroke Force.

Stroke force of arms, were measured on isokinetic swim bench (BioMeter®, Fahnemann; Hbg, Germany); this tool is described as generator producing an isokinetic resistance for swim-specific dry land training in 9 levels of acceleration in proportion to force applied by the user. Participants practice a single stroke in each resistance level to detect where resistance level the participant reaches the highest values of force. After five minutes of passive rest, the data was collected in the following procedure: the subjects were held in a position with a strap around their hips; the hands were placed in the paddles and the arms extended in horizontal position. Participants were encouraged to make three attempts at maximum effort with a minute rest between each attempt and recording the average as a sample. By stroke force test, were obtained the variables of Isokinetic Force (F\textsuperscript{Force}) and Isokinetic Power (P\textsuperscript{Power}).

(b) Swimming Performance.

In each application of the tests all swimmers performed a warmup that consisted of 600m swim followed by rest period of 5 to 7 minutes before the test. The test consisted in a maximal 50m front crawl underwater start, performed in an indoor 25m swimming pool. Data times of 0m crawl (t50c), were recorded with a Colorado Timing System (Loveland, CO, USA) consisting in Infinity Start System INF-SSM; Aqua grip touchpad (188.5 x 90 cm) TP-188.5G and System 6 timing Console SYS6, and data was imported to a personal laptop with the Meet-Manager program of competition.

(c) Swimming tethered to external loads.

To obtain the variables of specific swim power (SSP) and maximum drag charge (MDC) was required a concentric tool of tethered swimming training named Power-rack. The test’s protocol follows the next procedure previously described by Patnott et al. (2003) and Arroyo-Toledo et al. (2016). Each participant used a belt connected to external weights load by non-elastic cable, the swimmer should start into the pool in a supine position, without any force applied to the wall they swim 10 m maximum effort starting with the less load (15kg) and increasing load in each try, participants resting in passive form almost 4 minutes between each repetition until can complete the distance test (10m) in attempt to swim attached to the maximal external load as possible.

Two photocells of precision measure Newtest 300 (Newtest Oy, Oulu, Finlandia) attached at the arms of power-rack tool register time in a Palm Zire tablet, 1 m between photocells equivalent to 7 m. MDC is expressed from the highest kg mobilized and complete the distance of each swimmer. SSP is obtained from the time, distance between photocells of precision and kg completed in each attempt and calculated by the procedure expressed in figure 1.
Training and assessment protocols
The participants commenced the study into a competitive period and after completed a preparatory period of six weeks' technique and aerobic basic training. During the 8 weeks of the study intervention, three evaluations were applied, baseline (T1) and two post-tests: at 4th week (T2) and adjustment of load intervention. Final test was at 8th week (T3) it's comprises two mesocycles.

Subjects trained five days per week. Two session per week were performed the strength swimming training, attached to external loads; The SST\textsuperscript{linear} group intervention consisted in 6 Repetitions at 70% of MDC. To the SST\textsuperscript{pyramidal} group the intervention was asset 1st repetition at 50%, 2th repetition at 60%, 3th and 4th reps at 70%, 5th repetition at 60%, and last 6th repetition at 50%, all-out in percentage of a personal MDC. For both groups the rest time was stablished between reps of a minimum 3 to maximum 4 minutes of total passive recovery, to ensure complete recovery at same time to don't exceeded rest to lost the warm-up.

Three sessions training per week was performed in attendance to the technique, aerobic and anaerobic threshold and complementary regenerative training. The daily workouts required or a maximum of 60 minutes of training in which the different tasks and objectives planned by the coach were developed. A weekly training between 8000-8400 meters Three zones of training were required to control and quantify volume and intensity of training(Arroyo-Toledo): Zone 1= Low Intensity training (LIT) <2 mM/L Zone 2 of Threshold Training (ThT) 2–4 mM/L and Zone 3 of High intensity of Training (HIT) >4mM/L.[2]

Statistical analysis
Values (Table 1), are presented as mean ± SD. The normality of data was checked using Shapiro-wilk’s test. All variables presented normal distribution and homoscedasticity, and data was analyzed using analysis of variance for repeated measures (ANOVA) and between-group per moment comparisons with Tukey’s post hoc test. Significance level was accepted at p≤0.05.

Cohen’s D; was calculated to compare outcomes magnitude of effects between groups, effect size (ES) and was interpreted as small (<0.3), moderate (≥0.3 and <0.5) and large (≥0.5).[10]

Results
No significant differences were found between groups in age, height and weight.
No significantly differences in the variables in basal sample were found between groups. The interaction (group per moment) obtained with the two-way repeated-measures ANOVA was significant (p<0.05) for MDC and significant (p<0.01) for t50c values.
No significant differences were found for SSP, I_{\text{Force}}, \text{ and I}_{\text{Power}}.
Table 1. Summary of assessments to 8 weeks.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Groups</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>% of change</th>
<th>T1 to T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDC (kg)</td>
<td>SST&lt;sub&gt;linear&lt;/sub&gt;</td>
<td>41.54 ± 17.67</td>
<td>43.75 ± 18.85</td>
<td>42.12 ± 18.21</td>
<td>↓ 1.40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SST&lt;sub&gt;pyramidal&lt;/sub&gt;</td>
<td>42.18 ± 21.60</td>
<td>45.62 ± 24.21</td>
<td>48.06 ± 22.28</td>
<td>↑ 13.94*</td>
<td></td>
</tr>
<tr>
<td>SSP (w)</td>
<td>SST&lt;sub&gt;linear&lt;/sub&gt;</td>
<td>27.30 ± 12.80</td>
<td>26.50 ± 10.15</td>
<td>28.50 ± 12.60</td>
<td>↓ 4.39</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SST&lt;sub&gt;pyramidal&lt;/sub&gt;</td>
<td>30.30 ± 13.06</td>
<td>30.12 ± 14.18</td>
<td>32.12 ± 14.50</td>
<td>↓ 6.01</td>
<td></td>
</tr>
<tr>
<td>I&lt;sub&gt;force&lt;/sub&gt; (N)</td>
<td>SST&lt;sub&gt;linear&lt;/sub&gt;</td>
<td>75.62 ± 22.86</td>
<td>65.80 ± 16.63</td>
<td>64.68 ± 16.16</td>
<td>↓ 14.47</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SST&lt;sub&gt;pyramidal&lt;/sub&gt;</td>
<td>67.50 ± 23.12</td>
<td>63.62 ± 20.66</td>
<td>70.62 ± 17.57</td>
<td>↓ 14.62</td>
<td></td>
</tr>
<tr>
<td>I&lt;sub&gt;power&lt;/sub&gt; (w)</td>
<td>SST&lt;sub&gt;linear&lt;/sub&gt;</td>
<td>394.12 ± 175.01</td>
<td>354.62 ± 137.38</td>
<td>370.62 ± 119.85</td>
<td>↓ 5.96</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SST&lt;sub&gt;pyramidal&lt;/sub&gt;</td>
<td>424.62 ± 140.50</td>
<td>395.00 ± 146.72</td>
<td>416.75 ± 131.29</td>
<td>↓ 1.85</td>
<td></td>
</tr>
<tr>
<td>t50c (s)</td>
<td>SST&lt;sub&gt;linear&lt;/sub&gt;</td>
<td>30.85 ± 2.92</td>
<td>31.00 ± 2.82</td>
<td>31.33 ± 2.63</td>
<td>↑ 1.55†</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SST&lt;sub&gt;pyramidal&lt;/sub&gt;</td>
<td>30.71 ± 2.33</td>
<td>30.44 ± 2.57</td>
<td>30.47 ± 2.37</td>
<td>↓ 0.78</td>
<td></td>
</tr>
</tbody>
</table>

Data are expressed as mean and standard deviation. MDC=Maximum Drag Charge; SSP=Specific Swimming Power; I<sub>force</sub>=Isokinetic Force; I<sub>power</sub>=Isokinetic Power; t50c= time 50m crawl. *P<0.05, † P<0.01 significance level.

Discussion

The first aim of the study was to determine the effects of eight weeks training two different protocols of specific strength swimming training, tethered to external loads: linear set (SST<sub>linear</sub>) compared to pyramidal set (SST<sub>pyramidal</sub>).

To the best of our knowledge, no previous study has examined the effects of two different programming of workout resisted swimming training attached to loads. The results of this study make evident superiority of the SST<sub>linear</sub> program, above SST<sub>pyramidal</sub>; notwithstanding that SST<sub>linear</sub> gather 14% more workout compared to the amount training of SST<sub>pyramidal</sub>. This finding confirms the Verkonshansky’s statements: “in a single session, pyramidal set would represent physiological advantage of providing the best neuromuscular adaptation through stimuli both, maximum and power strength requirements”. [9]

Swimming tethered to external loads

Maximum Drag Charge (MDC)

The data collected show that the SST<sub>linear</sub> group after eight weeks of training did not obtain significant differences in the MDC. Conversely the SST<sub>pyramidal</sub> group showed a significant increase (13.94%) of the MDC (p<0.05).

Examining the data progression of SST<sub>linear</sub> is observed that the group obtain improvements at the first four weeks of the study (5.3%) evidenced at the T2; however, at the end of the study, these group lost partially the improvements reached during the first half of the total period of this research.

In the opposite case, SST<sub>pyramidal</sub> group show progressions at the T2 and T3 (8.3 and 5.2% respectively) statistically significant (p<0.05) and with moderate effect size (ES= 0.47).

We can interpret these results as: in a single workout, as in a period of eight weeks, pyramidal set would represent advantage and improvements of maximum strength training; probably attributed to the frequent variation of workout and neuromuscular stimulus. This result agrees with Bompa, (1994) [8] and Verkhoshansky (2006) statements, [9] where programs organized on pyramids loading set was more effective than the linear.

Specific Swim Power (SSP)

The interaction groups per moment didn’t show significant differences to the variable of SSP. Nevertheless, SST<sub>pyramidal</sub> group showed higher improvements as the SST<sub>linear</sub> group (6.01 vs 4.39 respectively) with a large size effect (ES= 0.69).

Both intervention programs show similar statistical variations with reductions between baseline and second test (T1 to T2) and then increase between intermediate and final test (T2 to T3) the data obtained to SST<sub>linear</sub> group, decrease 3% at the first four weeks of intervention for to finally increase a 7.5% between the four and eighth week of the program. The data of SST<sub>pyramidal</sub> group, set a decrease of 0.5% at the fourth week; than increase of 6.6%.

This fact Could be interpreted as: the demands of specific strength swimming training tethered to external loads; can variate in a wave form; decreasing before reach power increments. Furthermore, we can observe, the decrease of SST<sub>linear</sub> is deeper compared to the data of SST<sub>pyramidal</sub> group; but the second and crescent undulation; has higher progress of SST<sub>linear</sub> above the data of the SST<sub>pyramidal</sub>. In that case, we can asset the hypothesis of: initiate interventions of SST<sub>pyramidal</sub> and then SST<sub>linear</sub> would represent the best benefits of both programs, to develop SSP.
This pattern of decrease then increase is coincident to the reports of Patnott et al. (2003). [6] But to the present study the values obtained are shorter compared to the 21% increases of SSP described to the aforementioned author. We attribute this differences to that; in the present research, the interventions plan take eight weeks and shorter of the 20 weeks’ study of Patnott (2003). [6] At same time the present study differs to the data expressed of five weeks study of Wright et al (2009). [7] Who exclusively recorded SSP increases.

**Stroke Force**

Isokinetic Force evaluated on a Swim Bench show similar behave as the data of SSP. Reduction on the intermediate test and then increases at the end of the study. But nevertheless, no significant differences were found to isokinetic Force (F\text{Force}), neither in Isokinetic Power (P\text{Power}).

The total of eight weeks treatment SST\text{linear} group decrease of 14.47%; and SST\text{pyramidal} increased 4.62%, although the effect size results small (ES=0.20) and not statistically significant. The specificity of training in both groups can also explain the lack of enhancements found in this study for these variables. Because there is no isokinetic phase in swim stroke; up to the date, no evidence of the effect of in-water training were found on the variables measured on biokinetic swim bench. Even so the swim bench is suggested on a regular training; it cannot adopt the biomechanical aspects related to what swimmers feel on the water. [11]

These results are not necessarily opposites to the correlations obtained by Maglischo, Maglischo, Zier and Santos (1985). [5] about strength and power outcomes data of isokinetic bench and the performance in swimming 25m. the difference among the mentioned studies and the present research is it, in an official competition calendar, the shorter distance is 50 and not 25m. taking in consideration this fact, swim bench and 25m freestyle swimming can be well correlated on laboratory; but no with official distances of competition. Other factors that differs and influence to the low correlation of the isokinetic swim bench and the competition swimming are: The beginning of the races from the block-start; propulsive action of legs; the subaquatic diving of 15m distance officially allowed; and the body rotation coordinated to the action movement of the stroke thrust. [11-12]

**Swimming Performance**

**time 50m crawl (t50c)**

After eight weeks of training the data obtained to the SST\text{linear} results statistically high significant (p<0.01) for the variable of t50c (1.55%) with a large effect size (ES=0.61) the tendency of these variables show a constant decrease 0.4% between the T1 and T2 then 1.0% between T2 to T3. This data would interpret as follow: The Specific strength training attached to external loads as a linear set; affects negatively the sprint performance on a 50m front crawl style of competition.

On the other side of the comparison; the data of the SST\text{pyramidal} show discreet improvement of 150m with a 0.78% for the eight weeks of intervention. However no significant changes were found and with small effect size (ES=0.22).

The literature previously review states that, more of the 80% of the 50m crawl performance occurs high influenced to the ability of swimmers to manifest a higher power swimming. [2-5-6-11-12] Furthermore, Verkoshansky statements, establishes that; power output would train around the 30 to 70 of maximal strength. [9]

The results obtained on this research can attributed to: The SST\text{pyramidal} program exhibit superiority in increase of MDC; SSP; and improvements in competitive performance of 150m, above the SST\text{linear} program, because the pyramid program, fluctuated between power and strength (50 to 70 percentage of a personal MDC); conversely, the linear program comprised limited stimuli to power and apparently only to strength (70 percentage of a personal MDC).

A limitation of this study was the lack of access to study adaptations that followed the period of intervention. Where the effects of overcompensation could have reacted differently of each program, into the period of transformation of strength-power to a specific speed of competition. [13]

**CONCLUSION**

The results of this study suggest that: the specific training of swimming tethered to external loads organized in pyramidal set program; is more efficient than linear set program of training. Besides, the demands of specific strength swimming training; can variate in a wave form; decreasing before reach strength or power improvements; with low improvement effects of swim performance.

**References**


