Effects of Dry-Land vs. Resisted- and Assisted-Sprint Exercises on Swimming Sprint Performances

Sébastien Girold, Didier Maurin, Benoit Dugué, Jean-Claude Chatard, and Grégoire Millet

ABSTRACT. Girold, S., D. Maurin, B. Dugué, J.-C. Chatard, and G. Millet. Effects of dry-land vs. resisted- and assisted-sprint exercises on swimming sprint performances. J. Strength Cond. Res. 21(2):599-605, 2007.—This study was undertaken to compare the effects of dry-land strength training with a combined in-water resisted- and assisted-sprint program in swimmer athletes. Twenty-one swimmers from regional to national level participated in this study. They were randomly assigned to 3 groups: the strength (S) group that was involved in a dry-land strength training program where barbells were used, the resisted- and assisted-sprint (RAS) group that got involved in a specific water training program where elastic tubes were used to generate resistance and assistance while swimming, and the control (C) group which was involved in an aerobic cycling program. During 12 weeks, the athletes performed 6 training sessions per week on separate days. All of them combined the same aerobic dominant work for their basic training in swimming and running with their specific training. Athletes were evaluated 3 times: before the training program started, after 6 weeks of training, and at the end of the training program. The outcome values were the strength of the elbow flexors and extensors evaluated using an isokinetic dynamometer, and the speed, stroke rate, stroke length, and stroke depth observed during a 50-meter sprint. No changes were observed after 6 weeks of training. At the end of the training period, we observed significant increases in swimming velocity, and strength of elbow flexors and extensors both in the S and RAS groups. However, stroke depth decreased both in the S and RAS groups. Stroke rate increased in the RAS but not in the S group. However, no significant differences in the swimming performances between the S and RAS groups were observed. No significant changes occurred in C. Altogether, programs combining swimming with dry-land strength or with in-water resisted- and assisted-sprint exercises led to a similar gain in sprint performance and are more efficient than traditional swimming training methods alone.

KEY WORDS. weight training, stroke technique, muscular strength

INTRODUCTION

Several conditioning training methods in swimming have been described to increase swimmers' physical abilities (18, 25). The efficiencies of the programs depend on the specificity of the event (5, 14, 23) and the intensity of the training sessions (2, 4, 17, 24). Two main strategies have been developed in training methods for swimmers: in-water and dry-land methods.

Maglischo et al. (13) have analyzed the effects of resisted- and assisted-sprint sessions on a swimmer's technique. Resisted sprint has been defined as an exercise realized against a resistance added to the natural resistance of the water. The swimmer was tethered with an elastic which increased the resistance during the swim. The assisted sprint corresponded to an exercise where the over-maximal speed was reached. The swimmer was pulled by an elastic during the swim. It has been shown that assisted sprint induced an increase in stroke rate without any decrease in stroke length, whereas resisted sprint led to a decrease in both stroke rate and stroke length. The authors suggested that the assisted-sprint method was more efficient than the resisted-sprint method for increasing swimmers' performances. Toussaint and Vervoorn (27) have also reported that resisted-sprint training for 10 weeks induced a significant increase in performance over 50, 100, and 200 meters by 2.0, 3.2, and 1.8%, respectively.

The positive effects of dry-land upper limbs strength training on sprint performances have also been reported extensively, and generally the gains in sprint performance are consistent: between 1.3 and 4.4% (5, 18, 24). For example, Strass (24) showed that press and draw exercises with barbells for 6 weeks led to a significant 4.4 and 2.1% increase in performance over 25 and 50 m, respectively. Several studies have demonstrated a strong relationship between upper body strength and sprint swimming performances over 25 yd and 50 m (10, 20, 22). However, 1 study (25) reported the absence of gain in performance after a dry-land strength training period. Nevertheless, the dry-land strength training program used in this study was a strength endurance training program (8 to 12 repetitions of each exercise), which is thought unlikely to improve swimming sprint. Tanaka and Swensen (26) questioned the specificity of the resistance training methods in swimmers and stated that combined swim and traditional dry-land resistance training did not enhance swimming performance, whereas combined swim and swim-specific in-water resistance training increased swimming velocity. These data suggested that specific in-water resistance training would be more efficient than dry-land training in swimmers. Surprisingly, although the efficiency of dry-land and resisted- and assisted-sprint (RAS) training methods on sprint performance are both widely documented, to our knowledge, no randomized comparative studies have been performed so far.

Therefore, the main purpose of our study was to compare the effects of combined dry-land strength with a swimming program with those of a combined RAS with the same swimming program. Due to the greater specificity of the in-water RAS method, this study tested the hypothesis that RAS induced some adaptations, leading...
to a greater short-term increase in sprint velocity in swimmers than dry-land strength training. Indeed, as reported by Tanaka and Swensen (26), Costill (5), and Stewart and Hopkins (23), the improvement of swimming performance depends on the specificity of the training methods. Nevertheless, in the present study, the dry-land strength training program was defined as specific as possible and was applied on specific muscle groups at a high intensity to improve sprint velocity.

**METHODS**

**Experimental Approach to the Problem**

The main purpose of this study was to investigate how the dry-land strength and resisted- and assisted-sprint training methods were able to enhance the performances of swimmers in the 50-meter sprint. It was thus decided to organize barbells and (specific) exercises such as pull-up in dry-land strength training conditions, and swimming exercises using specific elastics for resisted- and assisted-sprint training.

In dry-land strength training and in resisted- and assisted-sprint training, short and intensive sets were performed to increase maximal strength and anaerobic power respectively, and thus to improve sprint abilities over 50 meters during a 12-week training period.

**Subjects**

A group of 21 competitive swimmers, from regional to national level (10 men, 11 women) (mean ± SD, age: 16.5 ± 3.5 years, height: 170 ± 9 cm, weight: 62 ± 7 kg, arm span: 175 ± 11 cm) took part in this study. The swimmers or their parents, if the swimmers were minors, signed an informed consent form, and the subjects participated in the study on a voluntary basis. This study was approved by our University Committee on Human Research. Swimmers were randomly divided into 3 groups: (a) strength (S), (b) RAS, and (c) control (C) groups. Each group had the same aerobic dominant work session to counterbalance the 2 dry-land and resisted- and assisted-training sessions of 45 minutes per week, performed by S and RAS, respectively. Therefore, the training volume was exactly the same in all swimmers (Table 1).

No changes in the diet were requested. Swimmers were asked to follow their usual eating habits.

The training program lasted from January to March, and represented the second macrocycle of the season. Our athletes were preparing their national and regional championships that were to take place in April. During this macrocycle, there was no competition of importance, and the athletes' training program ended 2 weeks before the championships.

The strength training program for S concentrated on increasing first the muscular strength of the upper limbs, second the abdominal muscles, and third the lower limbs. The upper limbs were principally the biceps and triceps brachii, the back, and the pectoral and the deltoid muscles. The lower limbs were principally the quadriceps, gluteus muscles, and calf. The training sessions were 45 minutes long with a 10-minute warm-up using a skipping rope. In each strength session the program was the same. There were 3 exercises per muscle group with a rest of 2 minutes between each exercise. This program was repeated 3 times in a row per session. A maximum of 6 repetitions was realized in each exercise, except for the abdominal, for which 20 repetitions were realized. For the upper limbs, the exercises included press, pull-up, and draw with barbells. For the lower limbs, the exercises included different types of squat, and plyometric jumps. The load on the barbells was increased every exercise by 1.5 kg. The training volume lasted from January to March, and represented the second macrocycle of the season. Our athletes were preparing their national and regional championships that were to take place in April. During this macrocycle, there was no competition of importance, and the athletes' training program ended 2 weeks before the championships.

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The RAS training program was performed with elastic bands. The swimmers were tethered to the starting platform. They wore a belt around the pelvis which was attached to a 5.6-meter elastic surgical tube (Paul Factory, Saint-Etienne, France; inside and outside diameters were 8 and 12 cm, respectively). The other extremity of the tube was attached to the starting platform (Figure 1). The elastic tube imposed a length (Y; in meters) strength (X;
Swimmers' weight, height, and arm span were measured at W0, W6, and W12.

Statistical Analyses
Mean and standard deviation were calculated for all variables. Two-way repeated measures analyses of variance (groups [S, RAS, and C] × measures [W0, W6, and W12]) were used to compare the main characteristics: performances, muscular strength, stroke rate, stroke length, and stroke depth, of the 3 groups, before training began, at mid-training, and after training ended. A Tukey-Kramer post hoc test was used to localize the differences. Pearson correlation coefficients were calculated between the performance and the different measured parameters. For the whole group, stepwise regressions were calculated between the 50-meter front crawl velocity (independent variable) and the other variables (dependent variables).

Technical Parameters
All 50-m trials were video recorded with a digital camera (Sony miniDV) at a frequency of 25 Hz. The stroke rate, length, and depth were measured with picture digitizer software Pinnacle (Studio Pinnacle System, Inc, Mountain View, CA). A minimum of 3 complete stroke cycles were analyzed during each 50 meters, over a distance of 10 meters which corresponded to the field of the camera. The camera was placed 12.5 m from the edge of the pool, so the recording started 7.5 m after the departure until 17.5 m of each 25 m. The camera was placed in a Plexiglas waterproof box at a depth of 0.15 m. A ruler graduated every meter was placed in the field of the camera at a depth of 0.15 m in the swimmer's lane for calibration.

Muscle Strength Measurements
The flexion-extension peak torques (Nm) of the 2 forearms were measured with an isokinetic dynamometer (Cybex, Medimex Factory, Tassin la Demi Lune, France) at W0, W6, and W12. The forearm peak torque was retained because forearm forces account for a large part of total arm propulsion, as demonstrated by Shleiauf et al. (21). Before the measurements, a 5-minute standardized warm-up and familiarization period was performed with the apparatus at several submaximal velocities (60°·s⁻¹, 180°·s⁻¹) and in isometric condition. These different angular velocities were chosen because they seemed to be the most representative of a swimmer's movement speed (15, 16). The measurements took place at the end of each week, 24 hours after the last training session. Swimmers lay down and were strapped at the shoulders and pelvis. The arm was maintained parallel to the Cybex's arm lever. The spindle of the motor was positioned in line with the center of rotation of the elbow joint. Measures were performed on the right arm. The subjects were asked to perform 2 maximal efforts. The best performance was retained. A 30-second rest period separated each test. In isometric action, the effort lasted 5 seconds with a 2-minute rest period between repetitions; the elbow angle between the arm and forearm was set at 90°. Intraclass correlation coefficients of the physical strength measurements, assessed in 18 swimmers using the coefficient of variation of the difference between 2 measurements, were 2.7%.

Swimmers' weight, height, and arm span were measured at W0, W6, and W12.

Statistical Analyses
Mean and standard deviation were calculated for all variables. Two-way repeated measures analyses of variance (groups [S, RAS, and C] × measures [W0, W6, and W12]) were used to compare the main characteristics: performances, muscular strength, stroke rate, stroke length, and stroke depth, of the 3 groups, before training began, at mid-training, and after training ended. A Tukey-Kramer post hoc test was used to localize the differences. Pearson correlation coefficients were calculated between the performance and the different measured parameters. For the whole group, stepwise regressions were calculated between the 50-meter front crawl velocity (independent variable) and the other variables (dependent variables).
The effects of training on technical parameters are presented in Table 3. After 12 weeks of training, stroke depth was significantly (p < 0.05) decreased during the 50 meters in S and RAS, but not in C. Stroke rate was significantly increased (p < 0.05) in RAS and C, but not in S. There was no significant difference in technical parameters variation, expressed in percentage of baseline, between the 3 groups, over the 12-week training period.

**Effect of Training on Muscle Strength**

The effects of training on muscle strength are presented in Table 4. After 12 weeks of training, muscle strength was significantly (p < 0.05) increased in isometric condition for the elbow extensors in S and RAS, but not in C. Muscle strength was significantly (p < 0.05) increased in concentric condition for the elbow extensors at 60°·s⁻¹ in S and RAS, but not in C; and for the elbow flexors at 60°·s⁻¹ in RAS, but not in S and C. Muscle strength was significantly (p < 0.05) increased in concentric condition for the elbow extensors at 180°·s⁻¹ for the 3 groups. It is of interest to observe that most of the changes in muscle strength in S were significant only during the last 6 weeks of the training period (between W6 and W12).

Performance variations over the 12 weeks of training, expressed in percentage of baseline, were correlated with stroke depth (r = 0.94; p < 0.05) and stroke rate (r = 0.74; p < 0.05) variations in RAS, but this relationship did not occur in S and C; and also with muscle strength variations of the elbow extensors in concentric condition at 180°·s⁻¹ (r = 0.84; p < 0.05) in S, but not in RAS and C. None of the parameters was correlated with performance in C after 12 weeks of training.

**Training Effect: Comparison Between Strength, Technical, and Morphological Parameters**

In S, stepwise regression analysis between swimming performance and physical strength, technical, and morphologic parameters at W12 revealed that muscle

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**RESULTS**

Before training (W0) there was no significant difference in performance, technical, muscular strength, or morphologic parameters between the 3 groups (Table 2).

**Effect of Training on Swimming Performance**

The effects of training on swimming performance are presented in Figure 2. A significant improvement in performance (p < 0.05) at W12 was observed in S and RAS when comparing results with those obtained at W0. No changes in performance were observed in group C. The changes in performance were significantly different between S (2.8 ± 2.5%) or RAS (2.3 ± 1.3%), and C (0.9 ± 1.2%; p < 0.05) but not between S and RAS. It is worth noting this change in performance in S and RAS was significant only during the last 6 weeks of the training period (between W6 and W12).

**Figure 2.** Evolution of the performances over 50 m, over the 12-week training period; p < 0.05 (mean ± SD).
strength gain in concentric condition for the elbow extensors at 180°s⁻¹ (IS180E) was the most significant factor, while the arm span (AS) was the second most important factor. The effects of these 2 factors were additive; the effect of AS significantly increased the coefficient of correlation between performance and IS180E from 0.84 to 0.98 (p < 0.05), according to the equation:

\[ \text{Performance variation} = (0.078 \times IS180E) + (-4.027 \times AS) + 0.712 \]

Similarly, in RAS, the decrease in stroke depth (SD) was the most significant factor, while the increase in stroke rate (SR) was the second most important factor to explain sprint performance. The effects of these 2 factors were additive; the effect of SR significantly increased the coefficient of correlation between performance and SD from 0.94 to 0.98 (p < 0.05), according to the equation:

\[ \text{Performance variation} = (-1.128 \times SD) + (-0.75 \times SR) + 0.410 \]

In C, none of the factors was significantly correlated with the performance.

**Gender Effect**

There was a similar gender percentage in each group, and there were no significant differences in training effects between men and women in the 3 groups.

**DISCUSSION**

The main findings of the present study are:

1. The 2 methods combining swimming and dry-land strength or swimming and RAS were more efficient than the swimming program alone in increasing sprint performance, whereas no differences were observed between S and RAS. Muscle strength increased in S and RAS, whereas stroke rate increased only in RAS.

2. The muscle strength gain in concentric condition of the elbow extensors was a good predictor of the 50-m performance in S, while the stroke depth and the stroke rate variations were good predictors of the 50-meter performance in RAS.

After 12 weeks of training, no significant differences were observed between S and RAS on performance gain over 50 m (Figure 1). The 2.8% increase in 50-m performance in S is close to the 2.1% gain reported by Strass (24) over 50 m after a 6-week dry-land (strength) training period, and to the 3.6% gain reported by Sharp et al. (20) over 25 yd after an 8-week dry-land (swim bench) training period. The 2.3% increase in 50-m performance in RAS corroborated the results obtained by Delecluse et al. (6, 7) in athletics with similar methods, and the hypothesis of Maglischo et al. (13) on the efficiency of resisted and assisted training methods in swimming. Indeed, as they measured their impact on technical parameters, Maglischo et al. (13) speculated that these training methods would induce an increase in swimming performance. The S and RAS training methods were more efficient to increase sprint performance than swimming program alone. These results are in agreement with the study of Tanaka et al. (26), indicating that combining swim and in-land or in-water swim-specific resistance training was more effective than swim-alone training in improving swim performance. However, dry-land weight training does not seem to be the only way to overload functional muscles, and even if good results are obtained, the use of a sport-specific program may also be of importance. Nevertheless, further investigations are required to determine this aspect more precisely.

The strength group was more efficient than RAS to increase the muscle strength (Table 4). In S, the 45% increase in the isometric strength of elbow extensors is close to the 20 to 40% gain reported by Strass (24) and to the 20 to 75% gain reported by Faigenbaum (8) after 12 weeks of training. In RAS, the 32% increase in the concentric strength of elbow extensors at 60°s⁻¹ is in agreement with the results reported by Delecluse et al. (6, 7) in athletics, indicating that resisted- and assisted-sprint training enhance strength and power (strength x speed). In the 2 groups, the greatest gain in muscle strength concerned the elbow extensors, i.e., the triceps brachii. Birrer (3) has previously shown the importance of the triceps in the pushing phase for all strokes. Rouard et al. (19), and Schleihaufl et al. (21) have also reported that peak force occurs at the end of the aquatic phase of the stroke during forearm extension.

The strength training program realized by the S alternated dynamic phases in concentric conditions but also phases in isometric and eccentric conditions, developing, therefore, first the gain in muscle strength at low velocity. This could explain why the most significant strength gain in S was measured in isometric condition. Delecluse et al. (7) suggested that a high-resistance and a high-velocity sprint training enhances power and movement speed due to adaptive changes in the nervous system: high-resistance sprint first develops motor unit recruitment leading to a gain in movement velocity that may be limited by the time required for the motor units maximal recruitment to generate maximal strength. In complement, high-velocity sprint develops movement speed (in spite of the movement length), combined with a gain in power at high velocity. This could explain why the RAS group increased the concentric strength at 60°s⁻¹ and 180°s⁻¹ and increased the stroke rate. Resisted and assisted sprint represents a dynamic strength training method, developing first the gain in muscle strength at high velocity.

Muscle strength and technical parameters were found to be good predictors of 50-m swimming performance. In the present study, in S, the gain in 50-m performance was correlated to the gain in concentric strength of the elbow extensors at 180°s⁻¹. These data are in agreement with previous studies (9, 10, 16, 20), showing a strong relationship between the power of the upper limbs and the sprint swimming performance. In a 50-m sprint, stroke rate is a key factor and is higher than those observed in other swimming distances. Thus, to be efficient, the 50-m swimmer has to generate a maximal strength at high stroke rate. This may be the reason why the strength gain at the highest angular velocity (180°s⁻¹) was paramount in 50-m performance gain. These present data confirmed the results of Costill (5) and Stewart and Hopkins (23) regarding the importance of the specificity of the training methods, and those of Chatard and Mujika (4) and Mujika et al. (17) concerning the importance of the training intensity for improving swimming performance.

As reported by McCafferty and Horvath (14), the body adapts to adequately cope with the specific forms of exercise stress applied, and the adaptive process does not include any capacity that extends beyond the specific training stress. In the present study, principally due to the greater specificity of the in-water RAS method compared to in-land S, the hypothesis was that RAS should induce adaptations leading to a greater short-term in-
crease in sprint velocity in swimmers. However, no differences were observed between S and RAS, which is not in agreement with the previous study of Tanaka et al. (26) indicating that combined swim and swim-specific (in-water) resistance training improves performance more than combined swim and traditional (in-land) resistance training. Tanaka et al. (26) speculated that the strength gain induced by the dry-land program did not lead to increased swim performance to the same extent as the in-water resistance program, mainly because the swimming stroke is highly technical. In the present study, dry-land training was designed to be as specific as possible by the choice of the muscular groups and exercises (trajectory and speed).

Two technical parameters, stroke depth and stroke rate, were correlated to sprint performance, confirming the results of previous studies (1, 11, 12) on the importance of the technical parameters. In RAS, the correlation between the gain in performance and the changes in stroke depth and rate are in accordance with the observations of Maglischo et al. (13). Those authors observed a significant increase in stroke rate during assisted sprint, and a significant decrease in stroke rate during resisted sprint. They also observed that during assisted sprint swimmers tended to significantly decrease their stroke length while during resisted sprint swimmers tended to maintain it. Maglischo et al. (13) also suggested that assisted sprint would be the most efficient method to increase sprint performances, at the condition that after RAS training the effects on the technique are maintained without any assistance. In the present study, resisted- and assisted-sprint exercises were combined. After training, an increase in stroke frequency (p < 0.05) with no decrease in stroke length was observed. The combination of the resisted and assisted sprints led to a new technical adaptation. One may speculate, when comparing the present results with those of Maglischo et al. (13), that the increase in stroke rate was influenced by the assisted sprint and that stroke length was conserved by the resisted sprint. The gain in time during the stroke, that is necessary to increase the stroke rate without decreasing the stroke length, was made possible by the decrease in stroke depth. As the stroke rate increased for the same stroke length, the swimmer’s velocity was increased.

Both S and RAS groups significantly improved their performances with their specific training. However, we were not able to distinguish any significant differences in their swimming velocities at the end of the training program. The only significant difference concerned the gain in physical strength in isometric conditions at 0°-s⁻¹, which was more important in S. Nevertheless, isometric strength gain at 0°-s⁻¹ was not related to performance gain and, therefore, does not seem to be an important factor in sprint performance. However, it has to be remembered that both of our programs were specific concerning muscular groups, exercise trajectories and speeds. Though the improvement may stem from different signaling pathways, none of the programs was able to provide such a different stimulus that the outcome would differ. However, a longer period of training might lead to some different kinds of improvement. Further research is required to provide information on this aspect.

**Practical Applications**

The present study shows that methods combining swimming and dry-land strength or swimming and resisted and assisted sprint were more efficient than the swimming program alone in increasing sprint performance in

### Table 3. Evolution of technical parameters over the 12-week training period.*

<table>
<thead>
<tr>
<th></th>
<th>W0</th>
<th>W6</th>
<th>W12</th>
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<tbody>
<tr>
<td><strong>Stroke rate</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(cycle-min⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>48.9 (4.98)</td>
<td>49.8 (4.26)</td>
<td>50.7 (3.71)</td>
</tr>
<tr>
<td>S</td>
<td>48.9 (4.98)</td>
<td>49.8 (4.26)</td>
<td>50.7 (3.71)</td>
</tr>
<tr>
<td>S</td>
<td>48.9 (4.98)</td>
<td>49.8 (4.26)</td>
<td>50.7 (3.71)</td>
</tr>
<tr>
<td>RAS</td>
<td>48.2 (3.5)</td>
<td>48.8 (3.8)®</td>
<td>49.5 (3.4)®</td>
</tr>
<tr>
<td>C</td>
<td>47.8 (3.7)</td>
<td>47.8 (4.1)</td>
<td>48.7 (3.7)®</td>
</tr>
<tr>
<td><strong>Stroke depth</strong></td>
<td>0.86 (0.05)</td>
<td>0.84 (0.04)</td>
<td>0.83 (0.05)®</td>
</tr>
<tr>
<td><strong>Stroke length</strong></td>
<td>1.61 (0.11)</td>
<td>1.60 (0.10)</td>
<td>1.59 (0.09)</td>
</tr>
</tbody>
</table>

* Values are mean (SD); significant difference between W0 and W6; ® Significant difference between W6 and W12; § Significant difference between W0 and W12.

### Table 4. Strength variations in percentage of the baseline between the different measures.*

<table>
<thead>
<tr>
<th></th>
<th>Extensors</th>
<th>Flexors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Isometric 0°-s⁻¹</td>
<td>Concentric 60°-s⁻¹</td>
</tr>
<tr>
<td>W0 to W12</td>
<td>S</td>
<td>45.5 (38.7)®</td>
</tr>
<tr>
<td></td>
<td>RAS</td>
<td>12.4 (18.7)</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7.7 (16.1)</td>
</tr>
<tr>
<td>W0 to W6</td>
<td>S</td>
<td>20.7 (26.4)®</td>
</tr>
<tr>
<td></td>
<td>RAS</td>
<td>4.2 (26.9)</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>2.9 (10.3)</td>
</tr>
<tr>
<td>W6 to W12</td>
<td>S</td>
<td>20.6 (20.8)®</td>
</tr>
<tr>
<td></td>
<td>RAS</td>
<td>19.4 (17.4)</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>11.7 (17.6)</td>
</tr>
</tbody>
</table>

* Values are mean (SD); W0 = before training; W6 = after 6 weeks of training; W12 = after 12 weeks of training; S = strength group; RAS = resisted- and assisted-sprint group; C = control group.

† Significant at p < 0.05.
50-meter front crawl swimming. No differences were observed between dry-land strength training and in-water resisted- and assisted-sprint training methods.

These training methods can be used during the entire season. In a period of high training volume, resisted and assisted sprint can develop strength endurance in the water, the hydrodynamic position, and the stroke rate. In this period it must be realized with long sets at a moderate intensity with a short recovery time. In a period of competition, resisted and assisted sprint can be used to increase strength and power at a high velocity, and the stroke rate. In this period, it must be performed in short sets at maximal intensity with a long recovery time (at least equivalent to the working time).

The corresponding time of the swimming velocity gain over 50 m after the 12-week training period was: 

\[ 1.05 \pm 0.71 \text{ seconds in S} \quad 0.96 \pm 0.65 \text{ seconds in RAS} \quad 0.25 \pm 0.69 \text{ seconds in C} \]

Gains in muscle strength were more important in S than in RAS. However, the RAS training led to an increase in stroke rate while sprinting. The gain in performance was mainly explained by a gain in concentric strength and by an increase in stroke frequency. Further investigations are required to determine more precisely the effect of resisted and assisted sprint on stroke patterns.

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Acknowledgments

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