Swimming Performance After Passive and Active Recovery of Various Durations

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Purpose: To examine the effects of active and passive recovery of various durations after a 100-m swimming test performed at maximal effort. Methods: Eleven competitive swimmers (5 males, 6 females, age: 17.3 ± 0.6 y) completed two 100-m tests with a 15-min interval at a maximum swimming effort under three experimental conditions. The recovery between tests was 15 min passive (PAS), 5 min active, and 10 min passive (5ACT) or 10 min active and 5 min passive (10ACT). Self-selected active recovery started immediately after the first test, corresponding to 60 ± 5% of the 100-m time. Blood samples were taken at rest, 5, 10, and 15 min after the first as well as 5 min after the second 100-m test for blood lactate determination. Heart rate was also recorded during the corresponding periods. Results: Performance time of the first 100 m was not different between conditions (P > .05). The second 100-m test after the 5ACT (64.49 ± 3.85 s) condition was faster than 10ACT (65.49 ± 4.63 s) and PAS (65.89 ± 4.55 s) conditions (P < .05). Blood lactate during the 15-min recovery period between the 100-m efforts was lower in both active recovery conditions compared with passive recovery (P < .05). Heart rate was higher during the 5ACT and 10ACT conditions compared with PAS during the 15-min recovery period (P < .05). Conclusion: Five minutes of active recovery during a 15-min interval period is adequate to facilitate blood lactate removal and enhance performance in swimmers. Passive recovery and/or 10 min of active recovery is not recommended.

Keywords: recovery, competitive performance, fatigue, lactate

During training or competition, swimmers are asked to participate in multiple events or repetitions of maximum effort. Muscle and blood homeostasis may dramatically change under these conditions.1,2 When the recovery time is short, a subsequent effort cannot be effectively applied unless an adequate restoration of homeostasis occurs. Apparently, any practice that will enhance recovery will help swimmers to perform better in a subsequent event, since inadequate restoration of homeostasis deteriorates performance.2,3 Active recovery (slow swimming between swimming events or repetitions in training) that aims to enhance restoration of performance, is commonly suggested...
by coaches. This practice decreases blood lactate concentration faster than passive recovery\(^4,5\) and affects performance, of a subsequent swimming effort, either positively\(^6,7\) or negatively.\(^8,9\) The total time of recovery, the duration of active recovery, and the swimming effort (intensity and duration) seem to be important parameters for a conclusive decision concerning the effectiveness of active recovery. For example, 2.5 minutes of passive and 3.5 minutes of active recovery (6 minutes of total recovery time) had no effect on sprint performance (~27 s; 50 m) compared with 6 minutes of passive recovery.\(^8,9\) In contrast, when Felix et al\(^6\) applied a longer active recovery period of 14 minutes, including 10 minutes of active recovery, they found an improvement on performance of a 200-yard test (139 s; 183 m). Consequently, the duration of active recovery in combination with the total interval time may be important for the outcome of a subsequent performance.

At international competitive level, the swimmers avoid competing in successive races and normally have plenty of time to cool down and prepare for the next race. On the other hand, participation in successive events and inadequate recovery time may be seen in local or qualifying trial competitions for age group or club swimmers. In this case, swimmers need time to get ready from one race to another. Thus, it is important to have information on the most effective time of active recovery that may improve performance during the next event.

During a 100-m swimming distance (~1 minute in duration), an increase in glycolytic activity, a decrease in phosphocreatine (PCr) levels, and an accumulation of metabolic by-products are evident.\(^10,12\) During a 15-minute interval between two 100-m events, a complete recovery of PCr is expected,\(^3\) while other metabolic agents, that interfere with the muscular function (H\(^+\), Pi), are still present in the cell.\(^3,13\) For these reasons, a 15-minute recovery time was selected in the current study to simulate competitive or training conditions and avoid complete metabolic recovery. Extended recovery time allows a complete restoration of acid-base balance and PCr in the cell,\(^3,13\) masking any effect of active recovery. The rate of recovery of the accumulated fatigue agents may differ during passive and active recovery using short or long duration and this may affect performance.

The purpose of the current study was to compare the effects of 15 minutes of passive recovery with a 5 or 10 minutes of active recovery followed by 10 and 5 minutes of passive recovery between 100-m maximum efforts.

**Methods**

**Subjects**

Eleven competitive swimmers (5 males, age: 17.8 ± 2.5 years; body mass: 73.4 ± 11.9 kg; height: 1.82 ± 0.07 m, and 6 females, age: 16.9 ± 1.4 years; body mass: 60.1 ± 3.8 kg; height: 1.75 ± 0.05 m) participated in the study. Three swimmers competed at the senior level and the rest were age-group swimmers. All swimmers had at least 6 years of competitive experience and trained daily covering 40,000 to 45,000 m per week during the testing period. Their performance time of 100-m front crawl, recorded in official competitions 2 to 3 weeks before testing, was 61.9
± 5.9 s (males: 57.18 ± 3.48 s, females: 65.82 ± 4.33 s). This performance corresponds to 614 ± 116 and 563 ± 94 points assessed by the International Point Score (IPS—Fédération International Natation Amateur). All procedures had the approval of the departmental review board and were conducted according to the Helsinki declaration. The swimmers or their parents signed an informed consent form. All testing procedures were completed during the preparatory training phase, when aerobic training sessions were mainly performed. All procedures were completed within a period of 2 to 3 weeks for each swimmer.

**Experimental Procedure**

Each swimmer performed two 100-m maximal tests separated by a 15-minute interval, under three experimental conditions: passive recovery of 15 minutes (PAS); combined 5-minute active and 10-minute passive recovery (5ACT) and combined 10-minute active and 5-minute passive recovery (10ACT) in a counterbalanced order, 4 to 6 days apart. Active recovery, at a self-selected pace started within 10 s after the first 100-m test using the front-crawl style. No attempt was made to control the pace of active recovery, since swimmers are able to select their own pace, that was recorded and repeated accurately on the next active recovery trial. During the interval period of passive recovery, the swimmers dried themselves, covered their body with a towel and rested seated on a chair. The first 100-m test in each condition started 10 minutes after a warm-up of 1200 m that included 400-m swim, 4 × 50-m leg kick, 4 × 50-m swimming drills, 4 × 50-m progressively increasing speed, 25-m sprint, and 100 to 150 m of easy swimming. The repetitions of 100-m tests started just as in an official competition using the front-crawl swimming style.

Time was recorded simultaneously by two experienced timekeepers using a digital chronograph (Casio HS-30W-1V Professional Lap Memory Stopwatch; Casio Computer, Ltd, Tokyo, Japan) and the mean value was used for analysis. The time to complete three stroke cycles (T3) was recorded in the middle of each 50-m split and used to calculate the stroke rate (SR = 180/T3). Stroke length (SL) was calculated from SR and swimming velocity (V) using the equation SL = V/SR. The mean stroke rate and stroke length of each 100-m test was calculated from the first and second 50-m split values.

Heart rate was recorded continuously during the experimental conditions. A set of straps (stays lace) was securely attached to the male swimmers’ shoulders to ensure good contact of the HR transmitting unit and to avoid the displacement of the unit during swimming. Heart rate data before, immediately after, as well as 5, 10, and 15 minutes after the first 100-m test; and 5 minutes after the second 100-m test were used for the analysis (POLAR S810i; Polar Electro, Kampele, Finland). A capillary blood sample (10 μL) for the determination of blood lactate (microphotometer Dr Lange, M8; Germany) was drawn from a finger tip 2 minutes before the start and 5, 10, 15 minutes during recovery after the first 100-m test, as well as 5 minutes after the second 100-m test. A short break (30–40 s) for blood sampling was used at the fifth minute of active recovery during the 10ACT condition. All experimental conditions were conducted in a 50-m indoor swimming pool, with the water temperature at 25º to 26ºC, during the same time of day.
Two days before each experimental condition, swimmers followed a similar diet and similar low intensity aerobic training. The experimental conditions of the study are shown in Figure 1.

**Statistical Analysis**

Normal distribution of the data were tested using the Kolmogorov–Smirnov test. Analysis of variance for repeated measures on two factors (conditions × repetitions) was used to treat the data and the Tukey post hoc test was applied to locate any differences between means. The relationship between variables was examined using the Pearson product–moment correlation coefficient. The results are presented as mean ± SD and the accepted level of significance was set at $P < .05$.

**Results**

**Performance Time**

Swimming performance time of the first 100-m test, corresponded to $95\pm5\%$ of the current best time and was not different between conditions (PAS: $65.24 \pm$
4.11; 5ACT: 65.34 ± 4.07; 10ACT: 65.43 ± 4.26 s; \( P > .05 \)). The performance time of the second 100-m test was 1.0 ± 1.2% and 0.1 ± 1.8% slower and 1.3 ± 1.2% faster than the first 100-m test for PAS, 10ACT and 5ACT conditions respectively (\( P > .05 \)). During the 5ACT condition, however, performance time was better compared with PAS and 10ACT conditions after the second 100-m test (64.49 ± 3.87, 65.89 ± 4.55, 65.49 ± 4.63 s respectively; \( P < .05 \); Figure 2). During active recovery, swimming velocity corresponded to 63 ± 5% of the first 100-m velocity and to 60 ± 5% of the best recent competitive 100-m velocity. This pace was not different between the 5ACT and 10ACT conditions (\( P > .05 \)). The swimmers covered a distance of 289 ± 29 and 525 ± 39 m during the 5ACT and 10ACT conditions.

**Blood Lactate Concentration**

Lactate removal during the interval period was faster after the 5ACT and 10ACT conditions as compared with the PAS condition (\( P < .05 \)). Five minutes after the second 100-m test, no differences were observed on lactate concentration between conditions (PAS: 12.26 ± 5.14, 5ACT: 11.67 ± 4.38, 10ACT: 10.82 ± 4.14 mmol/L; \( P > .05 \); Figure 3). The difference of blood lactate concentration from 5 to 10 (\( \Delta \text{-la}_{5 \text{to} \text{10}} \)) and 10 to 15 minutes (\( \Delta \text{-la}_{10 \text{to} \text{15}} \)) intervals was not different between conditions (\( \Delta \text{-la}_{5 \text{to} \text{10}} \): PAS: 1.03 ± 1.69, 5ACT: 1.48 ± 1.81, 10ACT: 2.53 ± 2.58 mmol/L; \( \Delta \text{-la}_{10 \text{to} \text{15}} \): PAS: 1.12 ± 1.04, 5ACT: 1.37 ± 0.74, 10ACT: 1.28 ± 1.57 mmol/L; \( P > .05 \)). A significant correlation was observed between swimming time of the first 50 m obtained during the second 100-m test and blood lactate concentration at the end of the interval period (15 minutes) in all conditions (PAS: \( r = -0.60 \), 5ACT: \( r = -0.67 \), 10ACT: \( r = -0.63 \); \( P < .05 \)). No significant relationship was observed between blood lactate concentration at the end of the interval period

![Figure 2](image-url) — Performance time changes of the 100-m freestyle tests during the experimental conditions. *\( P < .05 \), 5ACT compared with PAS and 10ACT.
and the swimming performance time of the second 100-m test (PAS: $r = -0.53$, 5ACT: $r = -0.45$, 10ACT: $r = -0.48$, $P > .05$).

### Heart Rate

Heart rate (HR) after the first 100-m test was not different between the three experimental conditions ($P > .05$). During the fifth minute of recovery after the first 100-m test, HR was higher for the 5ACT and 10ACT than PAS condition and remained higher in the 10ACT ($125 \pm 21$ bpm) compared with PAS and 5ACT conditions after 10 minutes of recovery ($P < .05$, Figure 4). During the first 5 minutes of active recovery, no difference was observed between the 5ACT and the 10ACT conditions (5ACT: $138 \pm 20$ and 10ACT $130 \pm 18$ bpm; $P > .05$). At the start of the second 100-m test, HR was not different between conditions ($P > .05$).

### Stroke Rate and Stroke Length

A significant reduction of stroke rate (SR) and an increase of stroke length (SL) were observed during the second 100-m test as compared with the first ($P < .05$). During the second 100-m test, the SR was lower and the SL was higher in the 5ACT as compared with PAS condition ($P < .05$, Table 1). Swimming performance time was related to stroke rate during the second 100-m test in the PAS condition ($r = -0.7; P < .05$) and to stroke length in the 5ACT condition only ($r = -0.61; P < .05$).
Discussion

The main finding of the current study indicates that a 5-minute active recovery followed by 10 minutes of passive recovery (5ACT condition) was more effective and improved performance, compared with 15 minutes of passive recovery (PAS condition) and/or to 10 minutes of active recovery followed by 5 minutes of passive recovery (10ACT condition). The short duration of active recovery

![Figure 4 — Heart rate changes during the experimental conditions. *P < .05 5ACT and 10ACT compared with PAS, #P < .05 10ACT compared with 5ACT and PAS. The shaded bars indicate the 100-m tests.](image)

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Stroke rate (cycles/min)</th>
<th>Stroke length (m/cycle)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>first 100 m</td>
<td>second 100 m</td>
</tr>
<tr>
<td>PAS</td>
<td>45.2 ± 3.3</td>
<td>44.8 ± 2.8</td>
</tr>
<tr>
<td>5ACT</td>
<td>44.2 ± 2.5</td>
<td>43.8 ± 2.2*</td>
</tr>
<tr>
<td>10ACT</td>
<td>44.6 ± 2.9</td>
<td>44.1 ± 3.1</td>
</tr>
<tr>
<td>Mean of all conditions</td>
<td>44.7 ± 2.8</td>
<td>44.3 ± 2.6</td>
</tr>
</tbody>
</table>

*P < .05, 5ACT compared with PAS.

*P < .05, between 1st and 2nd 100 m independent of conditions.
(5 minutes, ~300 m) was equally helpful with the 10-minute active recovery (525 m) for blood lactate removal. The combination of 10 minutes of passive rest, after 5 minutes of active recovery, probably induces a favorable metabolic response.

The swimming time of the second 100-m test was faster in the 5ACT condition, compared with the corresponding test in the PAS and the 10ACT conditions ($P < .05$). This difference may prove significant for the final ranking in a competitive event. It is important to note that all swimmers were faster in the second 100-m test compared with the first when they followed a 5-minute active and a 10-minute passive recovery (5ACT condition). The procedures before the second test may create an optimal condition for warm-up. For example, a medium intensity warm-up, such as the one used in the current study, followed by a 100-m maximum effort, a 5-minute active recovery (~300 m) and a 10-minute rest, may help to maintain the elevated body temperature and allow the restoration of high-energy phosphates.14

It could be argued that swimmers did not apply maximal effort on the first 100-m test because they knew that a second effort would follow. This would have an impact on performance of the second 100-m test in all three conditions. However, performance improved only in the 5ACT condition. Furthermore, during the preparatory training period and despite an increased training volume, swimmers were able to reach 95% of their recent competitive performance. Elite swimmers normally attain performance time reaching 93% to 96% of their personal best time during testing.15 Nevertheless, the 95% of the current best 100-m time achieved in the current study is comparable to the intensity reported previously during testing (ie, 92% and 96%).6,7 Additionally, the blood lactate level at the fifth minute of recovery after the first 100 m was similar to that reported previously on swimmers of a similar age and level after a competition.10 Based on the above, the first 100-m test in the current study was performed at a maximal effort.

Several experimental protocols were applied to examine the effects of active recovery on cycling performance. These protocols used a variety of recovery modes, exercise durations and intensities, and showed improvement of performance after active recovery.16–18 The above mentioned studies, applied active recovery for the total duration of the interval period. For practical reasons (ie, blood sampling), in studies examining the effects of active recovery on swimming performance the interval duration was divided in segments of passive and active recovery.6,8,9,19 For example, the 200-yard performance time, was improved after 14 minutes of recovery including a period of 10 minutes of active recovery (2 minutes passive, 10 minutes active, 2 minutes passive).6 However, Toubekis et al8 found that 3.5 minutes of active recovery within a 6-minute interval period had no negative or positive effect on performance of a 50-m test compared with passive recovery. Similar findings were reported by Peyrebrune et al, during repeated 50-yard swimming tests, when 3 minutes of active recovery was applied within a 5-minute interval period.19 The passive recovery duration used for blood sampling in studies with swimmers may be an important parameter for the outcome of performance. In the current study, performance improved when 5 minutes of active recovery was followed by 10 minutes of passive recovery. The significance of the duration of active or passive recovery in swimming performance may not be the same for all distances (50/100/200 m) because of differences in energy demand and energy system contribution on each distance.1 The energy system contribution
of each competitive distance may dictate the importance of the proper choice of
duration of active or passive recovery. For a positive effect on performance of
short distances (50–100 m), the duration of passive recovery may be long enough
to allow resynthesis of PCr$^3$, which is important for energy supply during the short
duration distances. The duration of active recovery may be short but sufficient to
restore pH and remove muscle lactate$^{20,21}$ to facilitate glycolysis, which is impor-
tant for energy supply during 100- and 200-m swimming.$^1,11$ Enhanced rate of
muscle pH restoration occurs during the first 5 minutes of a 10-minute recovery
after intense exercise, and possibly presents minimal effects after this period.$^{20}$
Consequently, the shorter active recovery period in the 5ACT may have removed
a significant portion of H$^+$ into the blood stream,$^{20,21}$ leaving enough time for the
PCr resynthesis during the 10 minutes of passive recovery. According to this
hypothesis, the second 100-m test was performed under a more favorable environ-
ment, created in the muscle within the first 5 minutes of active recovery and this
may be reflected to an increased stroke length and faster performance time in the
5ACT condition. In this case, the duration of recovery (active or passive) is of
prime importance, while another significant factor, such as the intensity of active
recovery, becomes a secondary variable.

The intensity applied during active recovery in the current study (60% of the
100-m velocity), is similar to the intensity applied in swimming$^{4,5,6,8,9,19}$ and well
below the lactate threshold of competitive swimmers.$^8$ The intensity change of
active recovery may have altered the performance outcome on the second 100-m
test. In fact, a 10-minute active recovery corresponding to the lactate threshold
velocity (86% of the 200-yard velocity) improved performance at a subsequent
200-yard performance more than active recovery at a lower velocity.$^7$ This recent
finding is in contrast to those reported for repeated sprints,$^{8,9,19}$ meaning that both,
intensity and duration of active recovery, may show different effects in perfor-
mance of each swimming distance (100 m present study, 183 m$^6,7$). For example,
this may imply that lower active recovery intensity may be optimal for short dis-
tances (50–100 m) as compared with longer distances (200 m). Nevertheless,
these issues need further examination.

Apart from an improved function of the metabolic pathways, improved per-
formance during the 5ACT condition could also be attributed to altered mechani-
cal factors (spatial or temporal) or a combination of these two factors. Stroke
length increased in the 5ACT compared with PAS and 10ACT conditions and this
temporal parameter may have also been affected by the force production,$^{22}$ which
is related to muscle function and energy status of the cell. A loss of force observed
when swimmers are fatigued, may also decrease SR.$^{23,24}$ A significant relationship
of SR with swimming performance time of the second 100-m test during the PAS
trial may be attributed to the swimmers’ effort to compensate for loss of force and
possibly the decreased propelling efficiency.$^{23}$ Similarly, the correlation of swim-
manship performance time during the same test with SL in the 5ACT condition, may
reflect a better muscle function and maintenance of efficient stroke mechanics.
Indeed, a connection between metabolic and temporal parameters has been report-
ed.$^{24}$ A correlation (higher in the 5ACT compared with PAS and 10ACT condi-
tion) between blood lactate concentration at the end of the 15-minute recovery
with the swimming time of the first 50 m on the second 100-m test indicates that
increased blood lactate does not affect swimming speed, but may be related to
reduced hand speed. The last observation is in agreement with the slower SR and increased SL in the 5ACT condition, and lead to enhanced performance in the current study.

Differences in performance of the second 100-m test between conditions may also be attributed to altered metabolic contribution. During a 100-m test, anaerobic glycolysis (20 to 25%), aerobic metabolism (~60%), and PCr (15 to 20%) contribute to the ATP resynthesis. The procedures followed before the second 100-m test may be important for energy availability and performance during this test. Therefore, any change in the rate of activation of the metabolic pathways may cause changes in performance. An increased oxygen kinetics and aerobic contribution, which may spare some PCr for later use, has been observed on a bout following high intensity exercise. The faster activation of the aerobic metabolism may increase performance during intermittent exercise.

We should expect an equally positive outcome on performance time after the 10ACT condition. However, no benefits on performance or stroke mechanics were observed when a 10-minutes active recovery was applied (10ACT condition). The PCr resynthesis may be reduced during active recovery, while several minutes of recovery may be needed for a complete restoration of the depleted PCr stores. The double time duration of active recovery and the short passive recovery period during the 10ACT condition may have increased the total energy cost for swimming and lactate metabolism and have possibly reduced the available oxygen for the muscle cell. Oxygen availability is a crucial factor for PCr resynthesis. Inadequate PCr restoration may impair performance of the second 100-m test in the 10ACT condition. During the 10ACT condition, the heart rate increased for two-thirds of the 15-minute interval period, indicating an increased metabolic rate. In addition, the 10 minutes of active recovery (10ACT condition) may have also reduced glycogen resynthesis, mainly on type I muscle fibers. Even though decreased muscle glycogen content is not crucial for a maximum effort of short duration (ie, 30 s), it may have affected performance on a longer duration effort such as the 100-m test (ie, 65 s).

Despite the different duration of active recovery, the blood lactate concentration 10 minutes after the 100-m test was similar in the 5ACT and 10ACT conditions. A faster blood lactate removal probably occurs during the first minutes of recovery, possibly because of an increased muscle to blood gradient. However, the ion exchange between muscle and blood is a complicated procedure that depends on several factors (ie, blood to muscle gradient, blood flow, exercise intensity, buffering capacity). Similar lactate concentration after 5 or 10 minutes of active recovery is not easy to explain based on blood lactate values. Furthermore, blood lactate concentration at the start of the effort may have minimal impact on performance time of the second 100-m test, since it is not related to performance time on a maximum swimming effort.

In conclusion, the application of active recovery for 5 minutes (the first third of the total interval time) is adequate to reduce blood lactate concentration and positively affect subsequent performance of a 100-m test in competitive swimmers of club or national level. The improvement of performance is possibly attributed to the effective restoration of muscle pH and PCr, both related to an optimal combination of active and passive recovery duration. Further increase of the duration of active recovery (to the two-thirds of the total interval time) does not offer
any further benefit on lactate removal and performance. Even though the present results may not be relevant to elite swimmers, coaches should advise their swimmers to start cooling down or apply active recovery as soon as possible after a race. Based on the results of the current study, it is not necessary to extend the duration of active recovery more than 5 minutes (i.e., 300 m) when a second competitive event follows after a period of 15 minutes.

References

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