THE EFFECTS OF ACCELERATION AND EXPERIENCE ON HIGH VELOCITY SWIM PERFORMANCE IN JUVENILE RAINBOW TROUT

Wendy J. McFarlane
Department of Biology
McMaster University
1280 Main Street West, Hamilton, Ontario Canada L8S 4K1
ph: (905) 525-9140 x23170/fax: (905) 522-6066
E-mail: mcfarlwj@mcmaster.ca

Gordon McDonald
Department of Biology, McMaster University
ph: (905) 525-9140 x24266/fax: (905) 522-6066
E-mail: mcdonald@mcmaster.ca

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Introduction

Swimming performance assessment of fish has focussed mainly on two measures; the maximum achievable or "burst" velocity and the maximum sustainable velocity. The former is usually an invoked startle response and is typically <20 sec in duration, while the latter is the result of a gradual stepwise acceleration to a speed at which the fish fatigues or, specifically, is unable to maintain position in current. The time weighted average of the final two velocities is calculated and referred to as the critical velocity (U_{crit}), which is generally sustainable for at least 200 min (Brett, 1964). These two extremes have been very well characterized (for recent reviews see Hammer, 1995, Domenici and Blake, 1997), yet the intermediate region of swimming performance has received relatively less attention and is arguably where most of the swimming behaviour of stream dwelling fish lies.

Recently, McDonald et al. (1998) developed the fixed velocity sprint test as a tool for assessing intermediate swimming performance in fish. In their study the authors measured the fixed velocity sprint performance of three species of stream dwelling salmonids, and showed that fatigue time scaled with body size (Length^4-L^5) and was reproducible in repeat trials. Moreover, they showed that when fish were rapidly accelerated to U_{crit} velocities (approx. 6-7 body lengths $\cdot s^{-1}$ for fish of fingerling size) they would exhaust much more rapidly than if slowly accelerated to the same speed.

Although previous studies have shown that the rate of acceleration affects the outcome of a U_{crit} test (Farlinger and Beamish, 1977), effects of acceleration on sprint performance are not well established. Also not well established is the role of experience in modifying swim performance. In a recent review Davison (1997) concluded that in general, training effects appear modest. However, this may simply be because the training regimes were different from the testing regimes. Therefore, the purpose of this study was to further characterize the effects of acceleration on sprint performance in the rainbow trout and to examine the specific effects of repeated sprint exercise and of other training regimes on sprint performance.

Methods

We used relatively small rainbow trout (1-5 g) of hatchery origin where, because of their age (< 5 months) and the nature of rearing conditions they would have little or no high speed swimming experience. Fish were fed a 4% ration of commercial trout feed, and held in circular 40 L tanks with temperature varying seasonally from 7-18ºC. Fish were exercised in groups (typically 10 fish per trial) in an open, recirculating swim flume (102 L volume). Two types of swimming procedures were used in this study: i) a maximum sustainable swimming speed (U_{crit}) test and ii) a sprint test. In both protocols, fish were sequentially removed from the flume as they fatigued, with fatigue time (FT) in minutes used either to calculate U_{crit}, or to provide a measure of performance in the sprint test. The main difference between the U_{crit} and sprint tests is the rate of acceleration to the final velocity (~7 $BL\cdot s^{-1}$), as the fatigue endpoint was identical in both cases.

Results

Effects of acceleration

U_{crit} was 38 ± 0.8 cm·s^{-1} or 6.8 ± 0.1 BL·s^{-1} (N=20). In this measurement, acceleration to the final velocity (41 ± 0.8 cm·s^{-1}, i.e. higher than the critical velocity) took 3.3 ± 0.1 h from the initial orientation speed of 1 BL·s^{-1} and the average duration at the final velocity was 8.9 ± 1.5 min. In contrast, fish sprinted to ~U_{crit} velocity over 2 min fatigued in an average time of 3.3 ± 0.5 min. Lengthening the time for acceleration from 2 to 60 min progressively increased fatigue time, so that a 60 min acceleration period led to a 10 fold increase in FT to an average of 36 ± 5.0 min.

Effects of training

Sprint training had a number of effects. Firstly, fish oriented to current more rapidly and exhibited a lower incidence of burst and coast swimming during the acceleration period, a swimming behaviour usually noted just prior to fatigue. Secondly, there was an incremental improvement in mean FT over successive daily trials. The amplitude of the increase was as much as 8 fold in as little as 5 days and there was no indication that the performance improvement was reaching a plateau by the end of the training period. However, some fish in each trial failed to show any improvement throughout the training period. Finally, improvements in performance were fairly persistent. When fish were re-tested after 7 days of rest, there was no significant reduction in performance.

Fish that were repeatedly accelerated to sprint velocity, but not fatigued, exhibited a similar magnitude of performance improvement. In contrast, fish manually chased to exhaustion (a more stressful exercise endpoint) or continuously swum at 1 BL·s^{-1} (strictly aerobic, low stress exercise) showed no improvement in sprint performance.

Conclusions

Therefore, we conclude that acceleration rate is the most important determinant of sprint endurance in rainbow trout, a finding that suggests that U_{crit} is not a very ecologically relevant measure of swim performance especially in those circumstances where trout are negotiating passage through high velocity environments. Secondly, we find that experience (i.e. learning and/or training) has a quite profound effect on swimming endurance. This finding is particularly relevant to the comparison of wild to hatchery reared salmonids, as the former is more likely to gain experience of periodic high speed swimming especially if it is a stream resident.

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