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Heritable variation in swimming performance in Nile tilapia

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Critical swimming speed in Nile tilapia is heritable and can be used to predict growth performance

This study evaluated heritable variation in swimming performance in Nile tilapia (*Oreochromis niloticus*) and determined that critical swimming speed in this species is heritable and can be used to predict growth performance. Photo by Darryl Jory.

The heredity of athletic performance has received considerable research attention in dogs, horses and humans. There are few genetic parameter estimates for swimming performance in fish, but available research suggests that swimming performance has a heritable component.

Nile tilapia (*Oreochromis niloticus*) is often produced in smallholder tilapia ponds without aeration. In non-aerated ponds, dissolved oxygen (DO) drops below critical level (3 mg per liter) during the night, negatively affecting fish growth. It may be expected, therefore, that Nile tilapia with high oxygen uptake efficiency may grow better under these conditions than tilapia with low oxygen uptake efficiency. As critical swimming speed (Ucrit) may reflect the oxygen uptake efficiency, our research described here addressed the possibility that fish with high Ucrit will grow better under conditions where oxygen is limiting.

A high throughput method to assess the individual variation in oxygen uptake efficiency subjects fish to exhaustive exercise in a critical swimming challenge test where swimming speeds are incrementally increased at prescribed intervals until fish stop swimming and fatigue. Individual fish fatigue when swimming at a specific speed interval for a certain period, from which the Ucrit can be determined. We have recently developed and applied such tests for gilthead sea bream (*Sparus aurata*) and Atlantic salmon (*Salmo salar*).

Fish that are able to consume more oxygen can swim faster, or the reverse case for the connection that we are interested in: faster swimming fish have higher oxygen uptake efficiency. Particularly for tilapia, the link between Ucrit and maximal oxygen consumption may be strong because tilapia has a high Ucrit (and a very high maximum metabolic rate). Hence, Ucrit could be a good indicator of oxygen uptake efficiency of individual tilapia.

This article – adapted and summarized from the **original publication** [Mengistu, S.B. et al. 2021. Heritable variation in swimming performance in Nile tilapia (*Oreochromis niloticus*) and negative genetic correlations with growth and harvest weight. *Sci Rep* 11, 11018 (2021)] – discusses a study to estimate swimming performance in Nile tilapia to assess the genetic correlation between Ucrit and fish size early in life, and to determine the genetic correlations between Ucrit early in life and harvest weight (HW) and daily growth coefficient (DGC) later in life.

Study setup

Our research used phenotypic [observable characteristics] data collected as part of the **GIFT** (Genetically Improved Farmed Tilapia) selective breeding program managed by **WorldFish** at the Aquaculture Extension Centre of the Malaysian Department of Fisheries at Jitra, Kedah State, Malaysia. Nile tilapia of the GIFT strain from generation 18 was used in this experiment. The 60 families were produced using 31 males and 58 females, of which two females were used twice with different males. Each full-sib [sharing the same parents] family was reared separately in a hapa (fine mesh net enclosure) set up in an earthen pond.

For detailed information on the experimental setup and fish husbandry; swim test; calculation of critical swimming performance and surface area; and statistical analyses, refer to the original publication.

Results and discussion

Our results demonstrate for the first time with a large-scale experiment that swimming performance is heritable in Nile tilapia, and that the genetic correlation with harvest weight is strongly negative, even when corrected for body size at testing. The heritabilities, genetic correlations, methodology and the practical application of a swimming performance test in breeding programs are discussed in the original publication.

The data shows the existence of heritable variation in critical swimming performance with a moderate heritability [a measure of how well differences in genes account for differences in traits] of 0.41 to 0.48. Our heritability estimate for Ucrit early in life is in the same range as reported previously for other species and for similar traits. Of the four studies that estimated genetic parameters for swimming performance in fish, only the study that assessed the burst swimming performance trait is not comparable with Ucrit in our study. Our heritability estimate for relative Ucrit (0.15) was not significantly different from zero, which is different from the heritability of 0.55 for relative maximum swimming speed in European sea bass. The difference in heritability of relative Ucrit might be due to a species-specific difference, particularly reflecting the high or long body shape of tilapia and sea bass, respectively.

Species specific differences also exist in the relation between Ucrit and body size. Absolute Ucrit was genetically strongly correlated with body weight at swim testing, at a higher value than the estimated genetic correlation reported by other authors between swimming stamina and body weight in Atlantic salmon. The genetic correlation between absolute Ucrit and standard length (0.83) was also different from the estimated number between swimming stamina and fork length in Atlantic salmon. And the strong genetic correlations between absolute Ucrit and tilapia length and weight at testing early in life show that larger fish swim faster in absolute terms.

Fish with high Ucrit at testing had lower daily growth rate (DGC) and harvest weight (HW) later in life. These negative genetic correlations do not support our hypothesis that Nile tilapia with higher Ucrit, reflecting higher oxygen uptake efficiency, are those that perform better in terms of weight increase in non-aerated ponds where hypoxia is frequent. Instead, the negative genetic correlation shows that fish with higher Ucrit early in life produce less body weight increase later in life. These data do not provide insight on fish body shape and composition at slaughter size. For example, it may be that fish with higher Ucrit are the leaner fish later as compared to fish with lower Ucrit. Fish with lower Ucrit may be heavier but not necessarily have more fillet mass. Results by other researchers with gilthead sea bream, also a high bodied fish, suggested that fast swimmers build lower fillet mass later in life.

A plausible explanation for our results may be the existence of a juvenile trade-off between swimming and growth performance where fish with high Ucrit early in life show slower growth later. Young juveniles may choose to either swim fast or grow fast, which may represent, for instance, two anti-predator strategies: to be able to escape predators or to become too large to be eaten rapidly.

Studies have shown that a trade-off between growth rate and locomotor performance can exist, for instance during accelerated growth, which can negatively influence fish muscles and development. For example, fast-growing growth hormone (GH) transgenic carp had lower critical swimming performance than non-transgenic controls. Fast-growing GH transgenic salmon had similar critical swimming speeds than non-transgenic controls but were also able to consume considerably more oxygen and may thus have compensated for lower critical swimming performance.

In our study, 1,493 fish were used to estimate genetic parameters. Previous studies that estimated genetic parameters used a much lower number of fish (range 96 to 129) as compared to our study and estimated broad sense heritability using full-sib families. Our much larger sample size gave a much higher precision of estimates of specific heritabilities.

The negative genetic correlation between absolute Ucrit and HW, and between Ucrit and DGC, clearly indicates that selection for high harvest weight will favor faster-growing animals with lower Ucrit. Whether this is desirable needs to be determined. One can speculate that under conditions of hypoxia, as frequently encountered in non-aerated ponds or ponds with algal blooms, smaller, more active fish will have a higher chance of survival. In optimal management conditions, however, growth rate can be further increased by including Ucrit at testing as a breeding objective, next to harvest weight.

Fish with higher Ucrit may also be more resilient: swimming exercise improves physiological fitness; cardiovascular and respiratory performance and increases mitochondrial densities and muscle tissue capillarization. Also, the immune system capacity appears to be linked to swimming performance, as other researchers have reported finding 21 virus-responsive genes in phenotypically poor swimmers as compared to good swimmers in Atlantic salmon.

Perspectives

Our results suggest a juvenile trade-off between swimming and growth performance where fish with high critical swimming speed, Ucrit, early in life show slower growth later under conditions of limited oxygen availability; Ucrit in Nile tilapia is heritable and can be used to predict growth performance.

Including absolute Ucrit as a breeding objective in addition to harvest weight (HW) and daily growth coefficient (DGC) could be beneficial if the aim is to select for fitter fish, especially in environments where oxygen is limiting. Absolute Ucrit can be measured at an early stage on the selection candidates themselves with high throughput and non-invasively, although the size of the tested fish may be restricted due to difficulty in reaching sufficiently high flow speed.

However, selection on Ucrit with 10 percent selection intensity for the highest values of Ucrit could lead to a 19 percent reduction in mean harvest weight of the offspring, compared to direct selection on harvest weight. In practice, we recommend a two-stage selection scheme, where selection in the first stage is on retaining 90 percent of the fittest fish in terms of Ucrit, followed by a second stage selection on harvest weight.

This study showed for the first time the existence of significant additive genetic variance for critical swimming speed in Nile tilapia. We found favorable genetic correlations between Ucrit and various traits early in life. The main finding of our research demonstrated a negative genetic correlation between Ucrit and harvest weight later in life, and between Ucrit and daily growth coefficient later in life. Overall, including Ucrit as a breeding goal may help improve resilience of Nile tilapia.

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