

Physiological Mechanism and Application of Fish Exercise Training in Aquaculture

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Abstract

In farming conditions, fish had health problems, e.g., fatty livers, because they lacked the chances of movement. Previous studies have found that the training of cultured species has achieved significant results. This article mini-reviewed the physiological mechanism of fish movement training and its effects, changes in body composition, growth rate, disease resistance, drug residues and feed costs, etc., in the research on fish health and aquaculture products, and discussed the relevant problems encountered.

Keywords: Culturing fish; Exercise training; Physiological mechanisms; Body composition; Growth rate

Introduction

The function of fish movement is preying, avoiding predation, migration and reproduction, and is the primary factor to measure whether fish can adapt to the environment and survive. Thus, the movement of fish is a hot topic of physiology, ecology, and evolutionary biology, with the great theoretical and practical significance. In the 1960s, the vast majority of early studies of fish movement were on salmon trout and other cold-water fish, with two main purposes: 1) if exercise training is beneficial to improve the survival rate released to the wild and 2) if exercise training can improve growth and food conversion rates, thereby increasing business value [1]. In recent decades, the movement training of culturing fish for improving fish health and the quality aquaculture products have been carried out. A mini-review of physiological responses of culturing fish to exercise training is herein addressed, with the aim to assess the feasibility of technology extension of fish exercise training in aquaculture.

Physiological Metabolism of Fish Exercise Training

The scenarios of exercise training on fish can be roughly divided into aerobic exercise training and anaerobic exercise training. In general, studies on exercise training related to fish mainly focus on aerobic exercise training. Studies have shown that exercise training affected the experimental fish morphological structure, behavior, exercise capacity, feeding growth, biochemical composition, physiological metabolism, enzyme activity change and gene expression. Aerobic swimming training can improve the growth rates of fish and food conversion efficiencies [1], increase the maximum oxygen consumptions [2], promote hypertrophy of thick red muscles, increase muscle glycogens and metabolic activities, and increase muscle capillaries and mitochondrial densities [3].

Muscle fiber and growth rate

Some studies have found that increased exercise training to promote fish growth often accompanies the increase in white muscle fiber diameter or number [4,5]. In the training group of *Sparus aurata*, the cross-sectional areas of white muscle fibers in the skull after reanimation was significantly larger than those in the non-trained group, but there was no significant change in the fiber structure of the tail white muscle. The researchers considered that the increase of diameter of the white muscle fibers in the training group was the main reason [6].

Energy metabolism of fish

Many aquatic animals take proteins as the main sources for energy. Some scientists, however, believed that the energy supply of some fish species mainly comes from fats and carbohydrates during swimming with low or moderate intensity [7], and due to less protein production, protein breakdown occurs only after most of the fat and glycogen are utilized [8,9].

The effects of continuous aerobic training on the energy metabolism in fish of different feeding habits were different. Lauff and Weber [10] studied the effects of exercise training on energy metabolism of rainbow trout by measuring respiratory rate and total nitrogen excretion and found that fat was the most important energy source for rainbow trout in relatively short-term sustained exercise and the energy ratio of sugars and proteins changes with time. The omnivorous *Oreochromis niloticus* also uses fat for continuous exercise training, but more energy is maintained by increasing the utilization of sugars [11].

In anaerobic exercise training conditions, the energy in white muscle is mainly provided by PCr (phosphocreatine), ATP, other high-energy phosphate compounds, and muscle glycogens [12]. Among them, the main energy come from high-energy phosphate compounds in the early stages of exercise [13], but the whole process of movement was supported by anaerobic glycolysis-based energy [14].

Fish movement and hormone regulation

At present, the studies on hormone levels related to fish movement mainly focus on catecholamines and cortisones, and other hormones such as insulin, glucagon and thyroxine have not been extensively studied. Catecholamines in plasma are generally increased immediately after exercise training, but the duration is not long and after exercise they can quickly return to pre-exercise levels. Cortisol responded differently to exhaustive exercise and began to rise slowly 1-2 hours

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after exercise and lasted for several hours¹⁵. Both of these hormones are closely related to the metabolic regulation of carbohydrates, proteins, amino acids and lipids after exercise, and the mechanism of the regulation is related to the hormone receptors [15-17].

Application of Exercise Training in Aquaculture

Speed up growth

Studies have shown that within the controlled flow rate range, as the flow rate increases, the fish growth rate will increase, and the conversion efficiency of protein will increase [18-20]. The intensive aerobic training promotes the growth of salmon trout *Oncorhynchus mykiss*, and its specific growth rate is significantly increased at 0.9 BL/s [21]. *Salmo trutta* showed the highest rate of weight gain at a water flow rate of 1 BL/s [22]. In addition, some aerobic training also has a positive effect on the growth of non-salmon trout species such as *Sparus aurata*, *Piaractus mesopotamicus* and *Oreochromis niloticus* [23-25]. However, there are studies shown that aerobic exercise training has no significant or even negative effects on the growth of fish, such as *Oncorhynchus tshawytscha*, *Procypris rabaudi*, *Chondrostoma nasus*, *Paralichthys olivaceus*, *Xiphophorus montezumae* [26-30].

In addition, the effects of exercise training on fish growth may be related to the culture environment, seasons the sizes of the fish, and so on [31-34].

Changing body compositions

Some scholars have found that exercise training had a significant effect on lipid levels in fish muscle [35]. Song et al. found that lower flow rate training significantly promoted the growth of *Scylla serrata* and increased muscle protein content [36]. Zhu et al. found that in *Barbodes schwanenfeldi* in exercise groups, white and red muscle protein contents were increased while fat contents decreased [37]. However, some studies have found that there was no effect of aerobic exercise training on the composition of the nutritional composition of muscles. For an example, Felip et al. found that rainbow trout had no significant changes in the protein contents of white muscle and red muscles after exercising at a rate of 1.3 BL/s for 4 weeks [38].

Prevention of fatty liver

Fish have poor utilization of carbohydrates and persist hyperglycemia when fed on sugary sugars [39], causing fish to develop symptoms of slow growth and fatty liver, thereby inhibiting fish growth and immune function, leading to a decrease in disease resistance [40]. Studies have shown that fish were able to transport fat from stored tissues or other non-energy-consuming tissues to the energy-consuming tissues [41]. In addition, exercise training can reduce the conversion and accumulation of liver fat by reducing the deposition of hepatic glycogen in fish. After training for 4 weeks at 2.0 BL/s exercise intensity, Glycogen contents in *Barbodes schwanenfeldi* decreased significantly, and glycogen contents in *Spirurus aurata* at 1.5 BL/s exercise intensity for 3 weeks decreased significantly.

However, not all exercises have the same effects on all fish. The study found that persistent exercise had different effects on liver fat of different fish. Exercise training could reduce liver fat contents of rainbow trout⁴¹, but had no significant effect on liver fat contents of *Oreochromis niloticus* [42].

Reducing farming costs

For fish farming, feed costs often account for the vast majority of farming costs. In previous studies, feed costs were mostly reduced by

replacing cheap ingredients with cheaper ingredients. Such as the use of soybean meal instead of fishmeal [43], rapeseed oil instead of fish oil [44]. However, these simple alternatives often have a negative impact on the growth or quality of experimental fish. Mu et al. found that in training tilapia, the replacement of fish oil with sunflower oil not only reduced feed costs, but also significantly increased fish muscle protein contents [45]. Such studies show that training farmed fish to some extent can inhibit the negative impact of adding cheap raw materials.

Other aspects

Some studies have shown that exercise training also has a certain role in promoting the swimming ability of fish. Scarabello et al. [46] found that rainbow trout increased the swimming speed significantly after a high-speed exercise training. Li et al. [47] found that after training, the swimming speeds of experimental *Oreochromis niloticus* had been significantly enhanced.

The aerobic metabolism of fish is closely related to the function of the respiratory and circulatory system. The improvement of heart and gill function will be beneficial to the absorption and transport of oxygen by fish [48]. Therefore, the significant increase of heart and gill function was found in juvenile *Spinibarbus sinensis* after aerobic training [49]. This is similar to *Peltebagrus vachelli* after exercise training [50].

In addition, Song et al. [51] found that in the exercise training of juvenile *Barbodes schwanenfeldi*, the content of norfloxacin hydrochloride in the fish in the flow rate group was significantly decreased as compared with the control group ($P < 0.05$), indicating that appropriate exercise can promote fish metabolism and speed up the elimination of drug residues.

Conclusion

Early studies on fish training mainly focused on the field of physiology and ecology. Recently, its main purpose was to explore the healthy development of fish farming.

Studies have shown that the increase of fish muscle white muscle fiber diameter or number can increase the growth rate of fish; and the researches of fish energy metabolism found that exercise training can effectively reduce the incidence of fatty liver. However, in actual research and production, some species cannot be improved by exercise training. Therefore, which fish species should be benefited by training and what methods to get the improvement effect are the future research target. The current study on hormones in trained fish focused on catecholamines and cortisones, but other hormones such as insulin, glucagon, thyroxine are neglected and need for more extensive research.

In addition, due to the current large-scale use of various types of aquatic drugs, the problem of drug residues for aquatic products is also being paid more and more attention. A few reports have already confirmed that through the exercise training, the metabolism of drugs in the fish can be accelerated and the drug residue can be rapidly reduced. However, the mechanism and scope of application of this method still need to be studied and verified.

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