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Commentary

Cellular Proliferation and Skeletal Muscle Fiber Formation in Cultured Fish

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DESCRIPTION

Fish skeletal muscle is mainly composed of white muscle, red muscle, and intermediate fibers. White muscle generally contributes to short-duration, high-intensity swimming, while red muscle supports sustained activity. The proportion and organization of these muscle types differ among species and are influenced by body size, swimming behavior, temperature, oxygen availability, and life stage. Myocyte hyperplasia is particularly relevant during early development, when the number of muscle fibers increases rapidly. Later growth can involve both the enlargement of existing fibers, known as hypertrophy, and the production of additional fibers.

The development of new muscle cells begins with populations of muscle precursor cells. These cells become activated in response to developmental signals and environmental stimuli. They proliferate, differentiate, and contribute to the formation of new muscle fibers. In fish, satellite cells are an important population involved in postnatal muscle growth and tissue repair. Their activity can vary according to species, age, nutritional condition, temperature, exercise level, and tissue requirements.

During embryonic and larval development, muscle formation follows coordinated cellular stages. Myogenic precursor cells proliferate and subsequently differentiate into muscle-forming cells. These cells combine to establish developing muscle fibers. As the fish grows, additional precursor cells can participate in the formation of new fibers. The rate of this process is not constant throughout life. Young fish generally exhibit greater cellular proliferation than mature individuals, although continued muscle fiber production can occur in many species.

Nutrition has a direct influence on muscle cell development. Dietary protein supplies amino acids required for the formation of cellular proteins, enzymes, structural components, and contractile proteins. Amino acid availability can influence both the formation of new muscle cells and the growth of existing fibers. Essential amino acids such as lysine, methionine, leucine, and other amino acids contribute to protein synthesis and tissue development. The balance between amino acid supply and energy availability can therefore influence muscle growth in aquaculture systems.

Feed quality is particularly important during juvenile stages because fish have high tissue growth requirements. Diets that provide adequate protein and energy can support cellular proliferation and muscle protein deposition. In contrast, prolonged nutritional restriction can reduce cell proliferation and alter the activity of molecular pathways involved in muscle development. Excessive dietary energy without suitable protein availability may also affect the distribution of nutrients between muscle growth and other physiological processes.

Several molecular regulators participate in myocyte proliferation and differentiation. Myogenic regulatory factors, including MyoD (Myogenic Differentiation) and myogenin, are associated with the progression of precursor cells toward differentiated muscle cells. MyoD is commonly linked with early myogenic commitment, while myogenin contributes to later differentiation. Other regulatory systems involving insulin-like growth factor signaling, mechanistic target of rapamycin activity, and growth-related transcription factors influence muscle protein synthesis and cellular development. The relative contribution of these pathways can differ between fish species and developmental stages.

Temperature is another important factor affecting myocyte hyperplasia. Fish are ectothermic animals, meaning that body temperature is closely associated with environmental temperature. Changes in temperature can alter metabolic activity, enzyme function, cellular proliferation, and growth rate. Within a suitable thermal range, increased temperature may accelerate developmental processes in some species. However, temperatures outside the species-specific preferred range can reduce feeding, alter metabolism, and affect muscle development. Consequently, temperature management in hatcheries and grow-out facilities can influence the cellular basis of growth.

Swimming activity can also affect skeletal muscle development. Regular movement creates mechanical demands on muscle tissue and can modify cellular signaling related to muscle maintenance

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and growth. Fish maintained in systems with water movement may experience different muscle-development patterns compared with fish kept under relatively static conditions. Exercise can affect muscle fiber size, metabolic characteristics, mitochondrial activity, and the recruitment of precursor cells. The response depends on exercise intensity, duration, species, developmental stage, and environmental conditions.

Water quality has an indirect but important association with muscle growth. Dissolved oxygen, ammonia, nitrite, salinity, pH, and temperature influence physiological performance and energy allocation. Poor water conditions can increase physiological stress and alter feeding behavior. When substantial energy is directed toward maintaining internal balance, fewer resources may be available for tissue production. Maintaining suitable water conditions can therefore support normal cellular growth and muscle development.

CONCLUSION

Myocyte hyperplasia is therefore an important biological process in fish growth. It represents the addition of new muscle fibers and works together with hypertrophy to determine overall muscle development. Its rate is influenced by developmental stage, genetics, nutrition, temperature, physical activity, and environmental quality. A clearer understanding of these factors can help aquaculture researchers evaluate growth differences between species and production systems. Such knowledge can also support improved feeding strategies, breeding programs, husbandry practices, and assessment of flesh quality while maintaining suitable physiological conditions for cultured fish.