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Review paper

Myosatellite Cells: The Architects of Muscle Regeneration and Repair

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ABSTRACT

Myosatellite cells, also referred to as satellite cells, are muscle-specific stem cells that play a crucial role in skeletal muscle regeneration, growth, and repair. These cells sit nestled between the basal lamina and sarcolemma of muscle fibers, and upon activation, they proliferate and differentiate into new myofibers. This monograph gives an overview of the biology, function, and therapeutic potential of myosatellite cells, with integration of recent scientific advances. Their effects in muscle homeostasis, the molecular mechanisms regulating their activation, and the regenerative medicine potential are discussed. Future directions for research and clinical applications conclude the review.

1. Introduction

Skeletal muscle is an excellent active tissue and can properly regenerate after injury. This power of regeneration is said to be due to resident stem cells known as myosatellite cells (Mauro, 1961). First recognized by Alexander Mauro in 1961, these cells have been acknowledged to play a pivotal role in muscle postnatal growth, maintenance, and repair. Myosatellite cells are quiescent under normal conditions but are rapidly activated when muscle damage occurs, giving rise to a cascade of events that lead to muscle regeneration.

Recent advances in molecular biology and single-cell technologies have provided fundamentally new views into the heterogeneity, regulation, and therapeutic opportunities for myosatellite cells. That is to say, this review seeks to integrate contemporary knowledge concerning myosatellite cells, focusing on their roles in muscle biology and applications in regenerative medicine.

2. Biology of Myosatellite Cells

2.1 Origin and Localization

Myosatellite cells, originating from the embryonic mesoderm, are closely associated with the skeletalmuscle fibers. They localize in a niche situated between the basal lamina and sarcolemma of muscle fibers; such a niche has been reported to provide a unique microenvironment, properly regulating the maintenance and function of these cells (Kuang et al., 2008). Such a niche is a critical regulator of the quiescence, activation, and differentiation of satellite cells.

2.2 Heterogeneity and Subpopulations

Emerging evidence has shown that myosatellite cells are a heterogeneous population with several groups, each having different capacities for regeneration (Pawlikowski et al., 2015). For example, some satellite cells have a high propensity for self-renewal, while others are committed to differentiation. This heterogeneity is regulated by intrinsic factors, such as transcription factors and epigenetic changes, as well as by extrinsic signals coming from the niche.

3. Molecular Mechanisms of Myosatellite Cell Activation

3.1 Quiescence and Activation

Under normal conditions, myosatellite cells are quiescent, low in metabolic activity, and express specific markers such as Pax7 (Relaix & Zammit, 2012). In response to muscle injury, these cells are activated by signals from the damaged microenvironment that include inflammatory cytokines, growth factors, and mechanical stress.

3.2 Key Signaling Pathways

Several signaling pathways regulate the activation and differentiation of myosatellite cells and involve:

3.2.1 Notch Signaling

It promotes the proliferation and maintains the stem cell pool (Bjornson et al., 2012).

3.2.2 -Wnt Signaling

It drives myogenic differentiation (Brack et al., 2008).

3.2.3 mTOR Pathway

The mechanism of mTOR plays an essential role in regulation of growth-metabolism signaling in response to nutrient availability (Rodgers et al., 2014).

4. Role in Muscle Regeneration and Repair

4.1 Myogenesis

Myosatellite cells become active and undergo proliferation and differentiation into myoblasts, which subsequently fuse either to form new myofibers or to repair the damaged fibers, in a process known as myogenesis, which is important for muscle regeneration (Yin et al., 2013).

4.2 Contribution to Muscle Homeostasis

Besides being an active agent in the restoration of injury, these cells also maintain muscle homeostasis by replacing damaged or aged myonuclei. This function is particularly salient in aging muscles, in which the capacity of satellite cells for regeneration declines (Sousa-Victor et al., 2014).

5. Therapeutic Potential of Myosatellite Cells

5.1 Regenerative Medicine

Myosatellite cells are potentially important candidates for the treatment of muscle-related disorders, including muscular dystrophies and age-related sarcopenia. Advancements in cell therapy and tissue engineering have allowed for the isolation, expansion, and transplantation of satellite cells to facilitate muscle regeneration (Bentzinger et al., 2013).

5.2 Challenges and Future Directions

The challenges encountered are numerous which need to be addressed through avenues that include more successful cell delivery, the production of long-term engraftments, and measures to stop the functional decline in myosatellite cells as we age (Blau et al., 2015).

6. Conclusion

Myosatellite cells' imperative need in skeletal muscle regeneration and repair thus makes them significatory for muscle biologists. Their distinct nature of quelling to activation change gives them the edge in muscle biology. Further insights into their molecular regulation and therapeutic potentials have opened new avenues for treating muscle diseases. Future research should strive to alleviate these limitations and move on toward translating these findings into clinical applications.

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