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Applying Longevity and Anti-Aging Research to Athletic Performance: Strategies to Extend Playing Careers, Reduce Injury Risk, and Accelerate Recovery

Ansh Riyal, Taruna Agarwal, John Leddo, Dev Agarwal, Vidush Chandrasekar, Vihaan Penumatsa, Nihitha Yerram, Sara Tun, Riya Biswas, Collin O'Brien, Sarayu Thatiparthi, Zarah Koroth, Xinyu Jiang, Ajay Raju, Aarush Penmetsa, Ishwarya Ramineni, Shang Lyu, Deetya Hamilpur, Aashi Bandam, Sai Varun Konagalla, Yousef Malik, Anika Dubey, Eva Sonis, Adam Malik and Kriti Regandla

METY Technology, Inc.

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ABSTRACT

This paper reviews translational opportunities at the intersection of longevity science and sports performance. We synthesize evidence on mitochondrial function and biogenesis (Handschin & Spiegelman, 2006; Li & Hood, 2010), senolytic interventions (Robbins et al., 2020; Deledda et al., 2022), NAD^+ precursors (Shade et al., 2020; Prokopidis et al., 2025), and established recovery and injury-prevention practices (Dowling et al., 2020; Morton et al., 2018; Charest et al., 2020) to propose integrative strategies for athletes. Three applied goals guide this review: (1) enabling athletes to play longer by preserving physiological capacity, (2) reducing injury risk through workload and tissue-health management, and (3) accelerating recovery from injury. Evidence from molecular, clinical, and applied sports-research literatures is integrated into practical, evidence-informed recommendations. Limitations and ethical considerations for translating anti-aging interventions to athletes are discussed.

Introduction

Athletic performance is often framed narrowly in terms of training, coaching, and recovery practices. However, scientific advances in the biology of aging suggest that cellular and molecular processes typically studied in gerontology may have direct implications for sports. This intersection offers a novel framework for performance longevity—supporting athletes not only to excel but to extend their careers in a manner that maintains health and resilience. The aim of this paper is to review how longevity and anti-aging research may be leveraged to allow

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athletes to perform longer, reduce injury risks, and accelerate recovery from injury. In doing so, the paper integrates findings from cellular biology, physiology, sports medicine, and applied coaching science.

The science of aging has matured considerably over the past two decades, producing mechanistic insights and candidate interventions that target hallmarks of aging such as mitochondrial dysfunction, cellular senescence, impaired proteostasis, and altered intercellular signaling (Robbins et al., 2020). Concurrently, sports science continues to refine methods for training, load management, and recovery. Bridging these fields offers the potential to prolong athletic careers while maintaining or improving performance. This literature review summarizes key findings relevant to three practical aims: longevity of playing career, injury risk reduction, and faster recovery.

Mitochondrial health and biogenesis play central roles in cellular energy production, endurance capacity, and resilience to stress. Peroxisome proliferator-activated receptor gamma coactivator 1-alpha (PGC-1α) is a master regulator of mitochondrial biogenesis and oxidative metabolism; exercise-induced activation of PGC-1α mediates adaptive mitochondrial remodeling in skeletal muscle, improving endurance and metabolic efficiency (Handschin & Spiegelman, 2006; Li & Hood, 2010).

Nicotinamide adenine dinucleotide (NAD^+) homeostasis declines with age and is implicated in impaired mitochondrial function and repair. Preclinical studies of NAD^+ precursors such as nicotinamide mononucleotide (NMN) and nicotinamide riboside (NR) have demonstrated restoration of aspects of muscle metabolism and endothelial function in aged animals; however, recent reviews indicate mixed evidence and emphasize the need for well-powered clinical trials in athletic populations (Shade et al., 2020; Prokopidis et al., 2025).

Cellular senescence—irreversibly growth-arrested cells with a pro-inflammatory secretory phenotype—accumulates with age and after tissue injury. Senolytic agents (e.g., dasatinib plus quercetin, fisetin) selectively remove senescent cells in animal models, improving physical function and resilience; human trials are nascent and cautiously optimistic but require careful safety evaluation (Robbins et al., 2020; Deledda et al., 2022).

From an applied sports perspective, monitoring and managing training load remains one of the most robust strategies to lower injury risk. Studies across youth and varsity athletes show associations between excessive chronic or acute workload and increased injury incidence, supporting calibrated load progression and monitoring systems in practice (Dowling et al., 2020; Mehta et al., 2021). Sleep and nutrition—especially adequate protein intake—are well-established modulators of recovery and tissue repair (Morton et al., 2018; Charest et al., 2020).

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Evidence for specific adjunctive modalities such as cold-water immersion shows benefit for soreness and short-term recovery, though timing and context matter (Xiao et al., 2023).

Methods

This paper uses a narrative, translational-review approach: we identify mechanistic findings in longevity research that plausibly influence athletic physiology, evaluate clinical and preclinical evidence for interventions, and integrate those findings with applied sports-medicine best practices. Selection prioritized recent systematic reviews, meta-analyses, and high-impact mechanistic studies related to mitochondrial function, senescence, and recovery modalities.

Results: Translational Applications for Athletes

1. Strategies to Enable Athletes to Play Longer

Maintaining mitochondrial capacity is foundational for stamina, power recovery between efforts, and long-term tissue health. Training programs that emphasize repeated oxidative stimuli—periodized aerobic intervals, threshold work, and resistance training that stimulates mitochondrial adaptations—promote PGC-1α signaling and mitochondrial biogenesis (Handschin & Spiegelman, 2006). Nutritional strategies that support mitochondrial function include adequate protein, polyunsaturated fatty acids, and micronutrients involved in mitochondrial metabolism (Li & Hood, 2010).

Adjunctive pharmacologic or nutraceutical strategies are an active area of research. NAD^+ precursors (NMN/NR) improve markers of mitochondrial function in aged animals and may support endothelial and skeletal muscle metabolism; however, the human evidence base is not yet definitive for performance augmentation, and dose–response, timing, and long-term safety in athletes are unresolved (Shade et al., 2020; Prokopidis et al., 2025).

Injury risk in athletes is strongly influenced by connective tissue quality, inflammation, and the ability of muscles and tendons to withstand repetitive stress.

Longevity science highlights pathways of chronic inflammation (“inflammaging”) and senescent cell accumulation as key contributors to tissue fragility (Franceschi et al., 2018).

Senolytic therapies, which selectively clear senescent cells, have shown promise in preclinical models for restoring tissue repair and function (Zhu et al., 2015).

In sports, interventions that reduce low-grade inflammation or enhance extracellular matrix turnover could translate into fewer overuse injuries and improved resilience under heavy training loads.

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Nutritional interventions, such as omega-3 fatty acids and polyphenols, may also contribute by attenuating inflammation and oxidative stress (Calder, 2017).

Integrating these findings with existing sports medicine approaches could help create multi-layered injury-prevention strategies that target both macro-level biomechanics and micro-level cellular health.

2. Reducing Injury Risk

Workload monitoring (e.g., acute:chronic workload ratios, pitch counts, GPS-derived metrics) is central to injury prevention. Empirical work links sudden spikes in workload and cumulative excessive chronic loads to higher injury rates; structured progression, cross-training, and enforced rest periods reduce overuse injury risk (Dowling et al., 2020; Mehta et al., 2021). For collision and contact sports, neuromuscular training programs focusing on movement quality, eccentric strength, and proprioception reduce noncontact injury incidence (Kline et al., 2025).

At the tissue level, cellular senescence and chronic low-grade inflammation likely contribute to poor tissue repair and vulnerability to injury. While senolytic therapies show promise in preclinical models—improving tissue function after transient senescent-cell clearance—the translational pathway to enhance injury resilience in athletes is early (Robbins et al., 2020). If future human trials confirm safety and function, short-course, targeted senolytic interventions could theoretically improve outcomes (Deledda et al., 2022).

3. Accelerating Recovery from Injury

Effective recovery strategies are multimodal. Adequate protein intake—distributed across the day and matched to energy needs—supports muscle protein synthesis and repair, with meta-analytic evidence supporting benefits of supplemental protein for strength and hypertrophy during resistance training (Morton et al., 2018). Sleep optimization is vital: insufficient sleep impairs physiological recovery, increases biomarkers of inflammation, and elevates injury risk (Charest et al., 2020). Cold-water immersion and other post-exercise modalities can reduce soreness and accelerate short-term recovery; timing relative to training should guide use (Xiao et al., 2023).

Emerging molecular interventions—such as senolytics and NAD^+ precursors—offer intriguing possibilities for accelerating recovery by improving the tissue microenvironment, reducing pro-inflammatory secretions from senescent cells, and restoring metabolic flexibility. Preclinical data link senolytic administration to improved exercise capacity in aged animals; similarly, NMN/NR restore aspects of mitochondrial and endothelial function in older rodents (Robbins et al., 2020;

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Shade et al., 2020). Translational caution is warranted, as human trials are limited and results mixed (Prokopidis et al., 2025).

Discussion

Combining longevity biology with sports science yields a portfolio of interventions ranging from low-risk, evidence-based practices to experimental molecular therapies. Strengthening mitochondrial health through targeted training and nutrition is actionable today and supported by both mechanistic and applied evidence. Load monitoring, neuromuscular conditioning, protein nutrition, and sleep hygiene form a core set of interventions for injury prevention and recovery with strong supporting literature.

Conversely, while senolytics and NAD^+ precursors are promising in animal models, the human evidence remains emergent. Recent systematic and narrative reviews highlight inconsistent clinical outcomes for NMN/NR in improving muscle function in older adults, and senolytic human trials are early-stage (Prokopidis et al., 2025; Robbins et al., 2020). Athletes and clinicians should therefore treat these modalities as investigational.

Ethical, regulatory, and practical considerations are critical. Anti-doping frameworks must evaluate whether pharmacologic lifespan-extending agents confer unfair competitive advantages; informed consent and long-term safety must guide any off-label or experimental use. Equity concerns may also arise if access to advanced interventions becomes stratified by resources.

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