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HEART RATE VARIABILITY AND PARASYMPATHETIC TONE IN RESPONSE TO AEROBIC EXERCISE INTENSITY IN OLDER ATHLETES

Introduction

Older athletes remain an underrepresented group in exercise physiology despite their increasing participation in endurance sports such as running, triathlon, cycling, and Tai Chi. These activities, often sustained at 60–80% of maximal heart rate, provide opportunities to study how aerobic intensity influences autonomic regulation in aging athletes[1]. Unlike recreational exercisers, trained athletes aged 35–65 follow structured programs and display superior conditioning compared to sedentary peers, yet age-related declines in autonomic flexibility and recovery may impact both performance and long-term health[1].

The autonomic nervous system (ANS) governs cardiovascular response through sympathetic and parasympathetic balance. Heart rate variability (HRV), derived from ECG or validated wearables, quantifies beat-to-beat fluctuations and offers a window into vagal modulation, training adaptation, and recovery[2,3]. Indices such as RMSSD, LF/HF ratio, and SD1/SD2 provide insight into parasympathetic tone. Elevated values typically indicate stronger vagal activity, but it remains unclear whether older athletes experience the same autonomic advantages at varying intensities, given diminished vagal flexibility with age[1].

This review examines how HRV-derived parasympathetic tone responds to aerobic intensity in older athletes. It summarizes evidence from case studies, highlights methodological challenges, and considers implications for training and recovery.

Methodology

A targeted PubMed search identified peer-reviewed case studies (2015–2024) involving athletes aged 35+, HRV measurement, and aerobic interventions. Inclusion criteria required validated protocols (e.g., ECG, Polar, Kubios software) and HRV indices such as RMSSD, LF/HF ratio, or SD1/SD2. Exclusion criteria removed studies on sedentary or clinical populations, resistance-only training, or unvalidated devices.

Five case studies were included:

Road Runner (PMC33809818): female runner, 50, monitored RMSSD across base and interval training.

Tai Chi Master (PMC5140838): 65-year-old male, compared Tai Chi with cycling at matched intensity.

Ironman Triathlon (PMC7177248): 36-year-old ultra-endurance athlete tracked over 40 consecutive races.

Wheelchair Marathon (PMC6243632): 35-year-old male, HRV during and after a marathon.

Off-Road Triathlon (PMC8539484): 46-year-old elite triathlete, HRV and performance across intensities.

All studies employed validated HRV methods, though two disclosed conflicts of interest tied to proprietary HRV devices or software.

Results

HRV consistently declined during exercise, with greater suppression at higher intensities. RMSSD, the most frequently reported index, was highly sensitive to changes in training load and recovery status[4]. Frequency-domain measures like LF/HF ratio captured sympathetic dominance during intense sessions[2], while non-linear indices such as SD1/SD2 quantified both short- and long-term variability[1].

Case Study Summary

Case / Athlete	Age	Exercise Type & Intensity	HRV Measures Used	Key Findings
Road Runner (PMC33809818)	50	Base vs. interval training	RMSSD	Higher RMSSD in base training; sharp decline in interval weeks
Tai Chi Master (PMC5140838)	65	Tai Chi vs. cycling at matched intensity	RMSSD, HF power, LF/HF	Tai Chi increased parasympathetic activity (↑HF, ↓LF/HF)
Ironman Triathlon (PMC7177248)	36	40 consecutive Ironman races	RMSSD, SD1/SD2	HRV suppressed >48h post-race; prolonged vagal withdrawal
Wheelchair Marathon (PMC6243632)	35	Marathon	RMSSD, LF/HF	HRV reduced post-race; recovery over 24–36h
Off-Road Triathlon (PMC8539484)	46	High-altitude off-road triathlon	RMSSD, LF/HF, SD1/SD2	Extreme sympathetic dominance; vagal suppression sustained

Recovery duration varied by event. HRV remained suppressed for 24–48 hours after marathons and Ironman events[5,6]. Tai Chi enhanced parasympathetic activity compared to cycling, with HF power 12% higher and LF/HF ratios 15% lower[7]. The Road Runner case demonstrated higher RMSSD during moderate base training but sharp declines during interval training weeks[4].

These findings suggest that moderate-intensity aerobic activity supports vagal tone and recovery, while extreme endurance events prolong autonomic imbalance.

Discussion

HRV is a valuable tool for quantifying parasympathetic tone in older athletes. Evidence from case studies indicates that extreme endurance events such as Ironman triathlons and marathons lead to sustained vagal withdrawal, whereas moderate-intensity training and mind-body exercise such as Tai Chi promote stronger parasympathetic activity. This aligns with broader findings that increased vagal-related HRV metrics reflect positive adaptation, while reductions indicate training strain or insufficient recovery[3].

However, methodological issues limit generalizability. Each case tracked a single athlete, preventing statistical comparison. Devices like Elite HRV and Kubios use proprietary algorithms, creating potential conflicts of interest and complicating reproducibility. Differences in testing conditions—such as posture, breathing rate, and measurement timing—further reduce comparability across studies[8].

For older athletes, these limitations are particularly important. Age may amplify reductions in HRV and slow recovery, yet few studies directly compare responses across age groups. More longitudinal research is needed to evaluate training cycles, intensity shifts, and age-related changes in autonomic regulation.

Conclusion

HRV-derived metrics such as RMSSD and SD1/SD2 offer promising insights into parasympathetic tone in older athletes. Evidence indicates that moderate aerobic training enhances vagal function and supports recovery, while prolonged high-intensity efforts suppress HRV for extended periods. Nonetheless, current evidence is limited by methodological variability, small sample sizes, and conflicts of interest.

Future research should prioritize standardized HRV protocols, independent validation of devices, and larger age-stratified cohorts. Until then, HRV should be interpreted cautiously and alongside other performance and clinical markers.

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