

Editorial

Durability: Redefining Performance in Endurance Sports

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Endurance sports demand exceptional physical and mental resilience, particularly the ability to sustain performance under fatigue. This capacity, termed durability, is the ability to minimize performance decline after prolonged or intense efforts, a critical factor in determining competitive success. In marathon running, the final kilometres often separate elite from sub-elite athletes, just as rowers rely on sustained stroke power in a 2000-meter race's closing stages. This editorial explores the current state of durability research, its role as a performance metric, its application in talent identification, and future research directions. By examining durability's impact, we aim to bridge scientific inquiry with practical strategies to enhance performance across endurance sports.

The State of Durability Research - Durability has emerged as a cornerstone in sports science, defined as the capacity to maintain maximal mean power (MMP) [1]. Field-based studies demonstrate its reliability, with standard errors of measurement (SEM) below 5% and intra-class correlation coefficients (ICC) above

0.90 for MMP decline in professional cyclists, suggesting durability's robustness as a performance indicator [2]. This precision allows coaches and scientists to track subtle performance changes, distinguishing elite athletes in sports where fatigue resistance is paramount [3].

The influence of exercise intensity is central to durability. Efforts above CP or threshold significantly impair performance compared to sub-threshold work, as high-intensity efforts above CP reduce MMP across various durations, while lower-intensity efforts have minimal impact [1,4]. For instance, elite marathon runners maintain pace in the final stages, and rowers preserve stroke power late in races, reflecting superior durability [5]. Comparative studies across competitive levels show that higher-tier athletes exhibit less performance decline post-fatigue, a trend observed in cycling and likely applicable to running, swimming, and triathlon [2,6]. This positions durability as a universal marker of excellence, warranting broader investigation across endurance disciplines.



Durability as a Performance Metric -

Durability's significance lies in its alignment with the dynamic demands of endurance sports, which feature stochastic challenges—intermittent high-intensity efforts amidst sustained workloads [7]. Unlike static metrics like VO₂max or lactate threshold, durability captures real-world performance under fatigue, providing a holistic view of athletic capability [8]. In triathlon, for example, effective running after swimming and cycling hinges on durability beyond aerobic capacity [9]. This makes durability a vital tool for assessing an athlete's ability to perform when fatigued, a hallmark of competitive success.

Quantifying durability through metrics like MMP decline or pace stability enhances performance analysis. Elite athletes exhibit smaller output reductions post-fatigue, reflecting advanced physiological adaptations [2,6]. Coaches leverage this by incorporating high-intensity interval training above threshold to mimic race conditions, thereby improving durability [10]. The metric's repeatability supports longitudinal monitoring, enabling precise evaluation of training interventions [3]. Durability also informs tactical decisions, such as pacing strategies, allowing athletes to optimize performance in critical race phases, like a final sprint in a distance run or a decisive surge in a cycling stage [5,7]. By integrating physiological and strategic elements, durability offers a comprehensive framework for performance optimization.

Durability in Talent Identification

Durability's reliability extends to talent identification, particularly in young athletes. A study of junior endurance athletes found

that international-level (ILG) athletes exhibited less MMP decline after high-intensity efforts compared to national-level (NLG) peers, indicating superior durability [11]. In running, ILG athletes-maintained pace over repeated intervals, a predictor of elite potential [12]. This discriminatory power underscores durability's role in identifying athletes suited for endurance demands.

Normative data, such as percentage decay in output post-fatigue (e.g., <10% in elites vs. >25% in sub-elites), provide objective benchmarks for talent scouting [11]. Durability's variability—explaining significant interindividual differences—complements metrics like CP or VO₂max, offering a nuanced profile of potential [13]. Its field-based assessment aligns with resource constraints in youth programs, making it accessible for federations and grassroots initiatives [3]. Targeted training, such as high-intensity intervals above CP, can enhance durability in young athletes, accelerating their progression to elite levels [10]. By identifying and nurturing durable athletes early, coaches can build a pipeline for future success.

Future Directions - Despite its advancements, durability research faces gaps. Sex differences are underexplored; some studies suggest women may exhibit greater fatigue resistance in ultra-endurance events, yet controlled settings show larger short-term output declines compared to men [14,15]. Experimental studies are needed to clarify physiological and hormonal influences, informing sex-specific training protocols. Environmental factors—nutrition, hydration, and temperature—also

affect durability but lack systematic investigation [16]. Longitudinal studies could reveal how these factors modulate fatigue resistance, enhancing training precision.

Technological advancements offer opportunities to refine durability measurement. Wearables and real-time analytics can capture granular data during competition, improving assessment accuracy [17]. Machine learning could identify patterns distinguishing elite performers, enhancing predictive models [11]. Extending durability metrics to sports like rowing and swimming could unify insights into fatigue resistance, fostering cross-disciplinary collaboration [18]. Such efforts would broaden durability's applicability, advancing sports science and practice.

References

1. Mateo-March M, Leo P, Muriel X, Javaloyes A, Mujika I, Barranco-Gil D, et al. Is all work the same? Performance after accumulated work of differing intensities in male professional cyclists. *J Sci Med Sport*. 2024;27(6):430-4. doi:10.1016/j.jsams.2024.03.005
2. Leo P, Mateo-March M, Giorgi A, Muriel X, Javaloyes A, Barranco-Gil D, et al. The influence of high-intensity work on the record power profile of Under-23, Pro Team, and World Tour cyclists. *Int J Sports Physiol Perform*. 2024;19(6):545-9. doi:10.1123/ijsp.2023-0451
3. Pallarés JG, Valenzuela PL, Mateo-March M, Muriel X, Lucia A. Validity and reliability of critical power and W' obtained in competitive cycling events. *J Strength Cond Res*. 2023;37(10):1999-2006. doi:10.1519/JSC.0000000000004420
4. Brownstein CG, Mira J, Murias JM, Millet GY. Power output manipulation from below to above the gas exchange threshold results in exacerbated performance fatigability. *Med Sci Sports Exerc*. 2022;54(11):1947-60. doi:10.1249/MSS.0000000000002976
5. Seiler S, Tønnessen E. Intervals, thresholds, and long slow distance: the role of intensity and duration in endurance training. *Sportscience*. 2009;13:32-53.
6. Muriel X, Hernández-Belmonte A, Mateo-March M, Valenzuela PL, Zabala M, Barranco-Gil D, et al. Is the record power profile repeatable? A practical analysis and interpretation in professional cyclists. *J Strength Cond Res*. 2023;37(5):1131-4. doi:10.1519/JSC.0000000000004419
7. Abbiss CR, Laursen PB. Models to explain fatigue during prolonged endurance cycling. *Sports Med*. 2005;35(10):865-98. doi:10.2165/00007256-200535100-00004
8. Maunder E, Seiler S, Mildenhall MJ, Kilding AE, Plews DJ. The importance of 'durability' in the physiological profiling of endurance athletes. *Sports Med*. 2021;51(8):1619-28. doi:10.1007/s40279-021-01459-0
9. Bentley DJ, Millet GP, Vleck VE, McNaughton LR. Specific aspects of contemporary triathlon: implications for physiological analysis and performance.

- Sports Med. 2002;32(6):345-59. doi:10.2165/00007256-200232060-00001
10. Hawley JA, Myburgh KH, Noakes TD, Dennis SC. Training techniques to improve fatigue resistance and enhance endurance performance. *J Sports Sci.* 1997;15(3):325-33. doi:10.1080/026404197367326
 11. Mateo-March M, Sánchez-Jiménez JL, Peña-González I, Moya-Ramón M, Javaloyes A. High-intensity durability and physiological profiles in junior cyclists: a comparison above critical power for talent identification. [Manuscript in preparation]. 2024.
 12. Billat VL, Sirvent P, Py G, Koralsztein JP, Mercier J. The concept of maximal lactate steady state: a bridge between biochemistry, physiology and sport science. *Sports Med.* 2003;33(6):407-26. doi:10.2165/00007256-200333060-00003
 13. Spragg J, Leo P, Swart J. The relationship between training characteristics and durability in professional cyclists across a competitive season. *Eur J Sport Sci.* 2023;23(6):1050-9. doi:10.1080/17461391.2022.2049886
 14. Tiller NB, Elliott-Sale KJ, Knechtle B, Wilson PB, Roberts JD, Millet GY. Do sex differences in physiology confer a female advantage in ultra-endurance sport? *Sports Med.* 2021;51(7):1401-13. doi:10.1007/s40279-020-01417-2
 15. Baumgartner S, Sousa CV, Nikolaidis PT, Knechtle B. Can the performance gap between women and men be reduced in ultra-cycling? *Int J Environ Res Public Health.* 2020;17(7):2521. doi:10.3390/ijerph17072521
 16. Valenzuela PL, Mateo-March M, Muriel X, Zabala M, Lucia A, Barranco-Gil D, et al. Ambient temperature and field-based cycling performance: insights from male and female professional cyclists. *Int J Sports Physiol Perform.* 2022;17(11):1710-4. doi:10.1123/ijsp.2022-0145
 17. Halson SL. Monitoring training load to understand fatigue in athletes. *Sports Med.* 2014;44(Suppl 2):S139-47. doi:10.1007/s40279-014-0253-z
 18. Mujika I, Padilla S. Scientific bases for precompetition tapering strategies. *Med Sci Sports Exerc.* 2003;35(7):1182-7. doi:10.1249/01.MSS.0000074448.73931.11