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Conference Abstract

Physiological Characteristics Associated with W′ and W′$_{bal}$ Used During Intermittent Exercise Task to Failure

Alexander J. Welburn[1], Stephen J. Bailey[1], Charles F. Pugh[2] Richard A. Ferguson[1],
[1] School of Sport, Exercise and Health Sciences, Loughborough University, Loughborough, LE11 3TU, UK
[2] Te Huataki Waiora School of Health, University of Waikato, Hamilton, 3240, New Zealand[2]

* Correspondence: (AW) a.j.welburb@lboro.ac.uk

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The critical power (CP) and W′ concept has become more integrated within applied cycling performance assessment. Both parameters can be tested for in the laboratory and field and have thus become a useful tool for coaches and athletes. The development of the W$_{bal}$ concept allows us to mathematically model the depletion and recovery of W′ (Skiba et al., 2012, Skiba and Clarke, 2021). When exercising above CP, there is a proposed linear utilisation of W′. When exercising below CP, W′ is reconstituted (W′$_{rec}$). When W′ has been fully utilised and W$_{bal}$ (the balance between utilisation and reconstitution) reaches 0, it is assumed exhaustion will occur.

Despite the attention given to the underpinning physiological determinants of CP which are well established (Poole et al., 2016; Mitchell et al., 2018 and Chorley et al., 2020) the physiological determinants of W′ are not as well understood. W′ correlates with muscle volume in elite track cyclists (Kordi et al., 2021) yet there are no correlations with the muscle fibre composition (Vanhatalo et al., 2016; Mitchell et al., 2018), muscle capillarity (Mitchell et al., 2018) or mitochondrial content and function (Rogers, Ferguson et al., unpublished). It has, however, been suggested that the so-called muscle typology influences W′$_{rec}$ following high intensity exercise (Lievens et al., 2020). Furthermore W′$_{rec}$ differs between intensity domains (Lievens et al., 2021) with Caen et al. (2021) concluding that W′$_{rec}$ following exhaustion is based on parameters of aerobic fitness due to the faster onset of $\dot{V}O_2$ kinetics, thus W′$_{rec}$ follows a two-phased exponential time course. Despite this, more work is needed to understand the factors influencing W′ and W′$_{rec}$ so we can have greater confidence in its use as a performance and training tool.

As part of a wider PhD research project the associations between physiological performance characteristics, W′ and W′$_{rec}$ were examined. The initial aim of the study was to assess the relationship between physiological performance characteristics and W′. The second aim was to then determine which characteristics were associated with the total amount of work done above CP (W′$_{total}$) during three different intermittent exercise protocols. Finally, W′$_{rec}$ parameters were modelled, using different Tau calculations to assess which model would predict a W$_{bal}$ of 0 at exhaustion.

Thirteen endurance trained cyclists (10 males, 3 females; age: 23[8] y, height; 177 [7] cm, body mass; 69.2 [8.3] kg, $\dot{V}O_{2max}$; 58.2 [8.9] mL·min^{-1}·kg^{-1}, MAP; 371 [70] W, P$_{MAX}$ 1214 [307] W, CP; 270 [49] W, W′ 20.5 [6.2] kJ, mean [SD]) were recruited for this laboratory-based investigation. Participants attended the laboratory on seven separate occasions for the determination of $\dot{V}O_{2max}$ and maximal aerobic power (MAP), lactate threshold (first LT [LT$_1$], baseline + 0.4 mMol.L^{-1}); second LT [LT$_2$, fixed blood lactate concentration of 4 mMol·L^{-1}), CP and W′ (3 and 12-minute method, Simpson and Kordi, 2017; peak lactate [Bla$^-$]$_{Peak}$ and lactate clearance rate [BLa$^-$]$_{CLR}$ and maximal sprint power ([P$_{max}$; peak 1s power). All performance tests were performed on the participants own racing bicycle attached to a Wahoo Kickr with self-selected power chosen for the CP trials and main trials completed in ERG mode. Three intermittent exercise trials were also completed. Intervals were performed at power output equivalent to the calculated 6-minute power (P6) + 50% of the difference between P6 and CP. Recovery power was 50% of LT_1. The three intermittent trial protocols involved: 3 x 60s efforts with 30s recovery proceeded by a sustained time to exhaustion (TTE); 3 x 20s with 10s recovery proceeded by a TTE; continued 20s efforts with 10s recovery until exhaustion, examining total work done above CP (W'_{total}). Different W'_{bal} Tau calculations were used (Skiba at al., 2012; Bartram et al., 2018 and Pugh et al., 2021 Rreg & Nat). Individualised Tau (Tau_{INDV}) using a single value to give W_{bal} 0 at the point of task failure were also assessed. To establish relationship between W′, W'_{total}, and Tau_{INDV}, Person's product-moment correlations were performed.

W′ was associated with P_{max} (r=.822 p=<0.001), MAP (r=.735, P=0.004), peak [BLa⁻] (r=.645, p= 0.017) and $\dot{V}O_{2max}$ (r=.581, p=0.037). W'_{total} was correlated with $CP{\cdot}kg^{-1}$ (r=.766, p=0.002), $LT_1{\cdot}kg^{-1}$ (r=.771, p=0.006) and $P_{Max}{\cdot}kg^{-1}$ (r=.792, p=0.001). W'_{bal} at the end of the 20:10 until exhaustion trial using the following Tau values were, Skiba -20.3 [12.6] kJ, Bartram 8 [3.5] kJ, Pugh Nat -3.8 [4.3] kJ and Charlie Reg -2.6 [4.7]. Tau_{INDV} was correlated with $CP{\cdot}kg^{-1}$ (r=0.696 p=0.012). $LT_1{\cdot}kg^{-1}$ (r=0.564, p=0.056) tended to correlate with Tau_{INDV}.

These data suggest that W′ has many contributing factors, with P_{max} and MAP being of particular importance, likely reflecting the extent of muscle mass usually associated with high absolute power outputs. We also demonstrate the importance of CP, LT_1 and P_{max} normalised to body mass are important factors for W'_{total} during severe intensity intermittent exercise, likely supported by associated metabolic adaptions such as large capillary networks enhancing oxygen extraction.

Implications for applied practitioners

Our findings confirm the possibilities to utilise the W′ and W'_{bal} concepts within applied cycling performance assessment. We suggest P_{max} should be part of the CP testing protocol.

Finally, we propose the use of Tau as a training metric, allowing the assessment of whether an individual is improving their rate of recovery, something not yet considered.

However, due to the large variances in the W'_{bal} remaining at the point of task failure it suggests that the current models need further improvement with a more standardised protocol to establish individualised Tau values.

References

Bartram, Jason C., Dominic Thewlis, David T. Martin, and Kevin I. Norton. 2018. 'Accuracy of W′ Recovery Kinetics in High Performance Cyclists-Modeling Intermittent Work Capacity'. *International Journal of Sports Physiology and Performance* 13(6):724–29. doi: 10.1123/IJSPP.2017-0034.

Caen, Kevin, Gil Bourgois, Charles Dauwe, Laura Blancquaert, Kobe Vermeire, Eline Lievens, J. O. Van Dorpe, Wim Derave, Jan G. Bourgois, Lauren Pringels, and Jan Boone. 2021. 'W ′ Recovery Kinetics after Exhaustion: A Two-Phase Exponential Process Influenced by Aerobic Fitness'. *Medicine and Science in Sports and Exercise* 53(9):1911–21. doi: 10.1249/MSS.0000000000002673.

Chorley, Alan, and Kevin L. Lamb. 2020. 'The Application of Critical Power, TheWork Capacity above Critical Power (W′), and Its Reconstitution: A Narrative Review of Current Evidence and Implications for Cycling Training Prescription'. *Sports* 8(9). doi: 10.3390/sports8090123.

Kordi, Mehdi, Campbell Menzies, and Len Parker Simpson. 2018. 'Relationship between Power–Duration Parameters and Mechanical and Anthropometric Properties of the Thigh in Elite Cyclists'. *European Journal of Applied Physiology* 118(3):637–45. doi: 10.1007/s00421-018-3807-1.

Lievens, Eline, Malgorzata Klass, Tine Bex, and Wim Derave. 2020. 'Muscle Fiber Typology Substantially Influences Time to Recover from Highintensity Exercise'. *Journal of Applied Physiology* 128(3):648–59. doi: 10.1152/japplphysiol.00636.2019.

Lievens, Maarten, Kevin Caen, Jan A. N. G. Bourgois, Kobe Vermeire, and J. A. N. Boone. 2021. 'W ′ Reconstitution Accelerates More with Decreasing Intensity in the Heavy- versus the Moderate-Intensity Domain'. *Medicine and Science in Sports and Exercise* 53(6):1276–84. doi: 10.1249/MSS.0000000000002574.

Mitchell, Emma A., Neil R. W. Martin, Stephen J. Bailey, and Richard A. Ferguson. 2018. 'Critical Power Is Positively Related to Skeletal Muscle Capillarity and Type i Muscle Fibers in Endurance-Trained Individuals'. *Journal of Applied Physiology* 125(3):737–45. doi: 10.1152/japplphysiol.01126.2017.

Poole, David C., Mark Burnley, Anni Vanhatalo, Harry B. Rossiter, and Andrew M. Jones. 2016. 'Critical Power: An Important Fatigue Threshold in Exercise Physiology'. *Medicine and Science in Sports and Exercise* 48(11):2320–34. doi: 10.1249/MSS.0000000000000939.

Pugh, Charles F., C. Martyn Beaven, Richard A. Ferguson, Matthew W. Driller, Craig D. Palmer, and Carl D. Paton. 2022. 'Critical Power, Work Capacity, and Recovery Characteristics of Team-Pursuit Cyclists'. *International Journal of Sports Physiology and Performance* 17(11):1606–13. doi: 10.1123/ijspp.2021-0478.

Simpson, Len Parker, and Mehdi Kordi. 2017. 'Comparison of Critical Power and W′ Derived from 2 or 3 Maximal Tests'. *International Journal of Sports Physiology and Performance* 12(6):825–30. doi: 10.1123/ijspp.2016-0371.

Skiba, Philip Friere, Weerapong Chidnok, Anni Vanhatalo, and Andrew M. Jones. 2012. 'Modeling the Expenditure and Reconstitution of Work Capacity above Critical Power'. *Medicine and Science in Sports and Exercise* 44(8):1526–32. doi: 10.1249/MSS.0b013e3182517a80.

Skiba, Philip Friere, and David C. Clarke. 2021. 'The W′ Balance Model: Mathematical and Methodological Considerations'. *International Journal of Sports Physiology and Performance* 16(11):1561–72.