

Conference Abstract

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A mobilization index for intermittent work: combining breathing frequency and heart rate for training intensity monitoringThomas M.Y. Lagoute ^{1*}, Eirik S. Jensen ¹, Leif R. Sollie ¹, Matthew Spencer ¹ and Stephen Seiler ¹

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1 Abstract**1.1 Background**

Heart rate (HR) remains the most widely used indicator for monitoring athletes' internal load during training sessions. However, limitations appear during short work-to-rest intervals. First, HR kinetic is inherently slow, with peak values occurring several seconds after the onset of exercise (Nicolò et al., 2020). Second, HR often reaches a ceiling effect: once athletes approach an average HR, further increases in exertion are no longer reflected in the HR signal (Dellal et al., 2012). Breathing frequency (BF), on the other hand, is

closely associated with rating of perceived exertion (RPE) (Nicolò et al., 2016) and is regulated by rapid mechanisms, including type III/IV muscle afferent feedback and central command, making it highly responsive (Nicolò & Sacchetti, 2023). These characteristics suggest that BF may be more sensitive than HR to the dynamic stress experienced during interval training. Combining information from HR and BF could therefore provide a more complete picture of the athlete's internal response (Seiler, 2024). The aim of this study was twofold: (1) to compare HR and BF responses during a high intensity interval session, and (2) to explore the potential of



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combining the two metrics into a single index — termed the mobilization index — to better reflect perceived training stress.

1.2 Methods

Thirteen male athletes (age = 31.8 ± 9.7 y, body mass = 77.5 ± 9.8 kg, height = 1.82 ± 0.06 m, $\text{VO}_{2\text{max}}$ = 56.2 ± 5.4 mL/min/kg, $\text{Power}_{\text{LT2}}$ = 3.8 ± 0.3 W/kg, training volume = 9.0 ± 2.8 hours/week) trained in cycling and running participated in the study, comprising four visits to the laboratory. During the first two visits, participants completed maximal incremental running and cycling tests in a same session. The first visit included a facemask for gas exchange measurement, whereas the second did not. Third and fourth visits consisted of sessions of a 5 minute warm up, followed by 40 minutes of low intensity work at 90% of the first ventilatory threshold (VT1), then a ramp protocol with one-minute steps to maximal exertion. Finally, participants performed two sets of ten 40-second work intervals interspersed with 20 seconds of passive recovery. A 5-minute recovery was observed between each part of the session. Throughout all sessions, HR was recorded via ECG and BF via a strain-measuring belt. Maximal heart rate was defined as the maximal value reached over any of the session, while maximal breathing frequency was defined as the highest 5-second rolling average of the 1Hz signal. Heart rate reserve (HRR) and breathing frequency reserve (BfR) were calculated using Karvonen's formula (Karvonen et al., 1957). A mobilization ratio was computed for each interval as BfR/HRR. To describe the kinetics of maximal BF and HR values reached

throughout the intervals, three models were tested: linear, exponential, and exponential with a drift constant. A linear mixed model was fitted to the mobilization ratio. The final value of the mobilization ratio in each set was tested using a one sided hypothesis t-test, aligned with the hypothesis that the ratio would exceed 1 at the end of the session.

1.3 Results

Maximal BF during the ramp did not differ significantly between running and cycling ($\Delta_{\text{cycling-running}} = 2$ bpm; $p = .43$) but did during submaximal effort ($\Delta_{\text{cycling-running}} = -10$ bpm; $p = .03$). None of the participants reached maximal BF during mask on trials. In contrast, eight athletes reached maximal HR during the masked ramp test. Linear models yielded the lowest Akaike Information Criteria for both HRR and BfR, suggesting that a linear description best captured their progression across intervals. The effects of interval number and set number were greater for BfR ($\beta_{\text{interval}} = 0.067$; $\beta_{\text{set}} = 0.028$) than for HRR ($\beta_{\text{interval}} = 0.010$; $\beta_{\text{set}} = 0.013$). In exponential models, asymptote was lower for HRR ($A_{\text{estimate}} = 92\%$) than for BfR ($A_{\text{estimate}} = 150\%$), and growth rates were higher for BfR. In the drift adjusted exponential model, the rate of increase was not significant when modelling BfR ($p = .58$). Modelling results suggest that both HR and BF tend to increase linearly throughout repeated high intensity intervals, yet BF displays a steeper and more variable increase than HR. While HR frequently plateaus, BF continues to rise, matching the progressive nature of rate of perceived exertion (RPE) during such sessions. This supports the interpretation

of BF as a sensitive marker of real time internal load. Across interval sessions, athletes exercised at approximately $139 \pm 5\%$ of power at VT2. No significant difference in blood lactate ($\mu_1 = 11.98$ mmol/L, $\mu_2 = 13.3$ mmol/L, $p = .91$) was observed between the two interval sets. Higher RPE values ($\mu_1 = 18.2$, $\mu_2 = 19.0$, $p = .04$) were reported in the second set. The mobilization ratio exceeded 1 at the end of the second set ($M = 1.05$, $p = .003$, $d = 1.26$), but not at the end of the first ($M = 0.90$, $p = .95$, $d = 0.61$), supporting the idea that the ratio could reflect the accumulated stress throughout the session.

1.4 Conclusions

Breathing related metrics are often examined to derive metabolic thresholds; however, BF also offers valuable insights into internal load monitoring, particularly during short intervals where HR may not fully reflect rapid changes in exertion. Practitioners should calibrate BF training zones separately for each modality (running vs. cycling), and these zones should be based on maximal BF values obtained without a mask, assuming a reliable BF monitor is used.

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