

Individual training prescribed by heart rate variability, heart rate and well-being scores in experienced cyclists

Carla Alfonso^{1,2}, David C. Clarke³, Dr. Lluís Capdevila^{1,2}

1. Laboratory of Sport Psychology, Department of Basic Psychology, Universitat Autònoma de Barcelona (UAB), Barcelona, Spain.
2. Sport Research Institute, Universitat Autònoma de Barcelona (UAB), Barcelona, Spain.
3. Department of Biomedical Physiology and Kinesiology and Sports Analytics Group, Simon Fraser University, Burnaby, BC, Canada

Address for correspondence:

Carla Alfonso
Laboratory of Sport Psychology, Department of Basic Psychology
Universitat Autònoma de Barcelona (UAB)
Barcelona, Spain.
carla.alfonso@uab.cat

Guided-training programs

The training program used in the study was based on Kiviniemi et al. (2007) with some modifications, as detailed below.

For all programs, a 9-day baseline was established using HRV, RHR, and all subjective variables to calculate WB scores. Note that this study used RMSSD as the HRV values, instead of high-frequency power (HF). On the 10th day, the average data served as a dynamic reference point, updated daily thereafter. A rolling average is more useful for detecting situations of excess non-functional fatigue, compared to a single measurement (Le Meur et al., 2014; Plews et al., 2013).

For Program 1, HRV was used to guide training. For it, a daily reference value (defined as the “HRV Reference value”) was calculated by subtracting the standard deviation of the preceding 10-day HRV measurements from their 10-day average. This HRV Reference value was updated daily. A significant decrease in HRV was identified when the daily HRV reading fell below the reference threshold. If the HRV dropped significantly, low-intensity training was prescribed. If HRV increased or remained stable, high-intensity training was recommended. After two consecutive high-intensity sessions, low-intensity activity was mandated. The program also limited training to a maximum of nine consecutive days before enforcing a rest day. If HRV remained significantly depressed, rest was extended for up to two consecutive days, after which low-intensity activity resumed regardless of HRV readings. Overall, the concept of the program was to reduce training intensity when there was a decline in HRV. The primary goal was to minimize excessive training, ensure optimal recovery, and maintain fitness progression.

For Program 2, Well-being Scores (WB) were incorporated into the equations, so that training was recommended based on both HRV and WB. If the WB score of the day was lower than the average WB scores of the last 10 days minus the standard deviation of those 10 days (from now on defined as the “WB Reference value”), then the program modified the HRV-based recommendation: if HRV alone would have recommended to train “High” but the WB score was lower than the WB Reference value, then Program 2 advised to train “Low”; if HRV alone would have recommended to train “Low” but the WB score was lower than the WB Reference value, then Program 2 advised to “Rest”. The WB Reference value moved day by day, rolling the 10-day average, as did the HRV Reference values.

In Program 3, HRV, WB and resting heart rate (RHR) were used to recommend training. Specifically, the inverse of RHR ($1/\text{RHR}$) was used. The use of $1/\text{RHR}$ accounts for the non-linear, inverse relationship between R-R intervals and HR, mitigating both physiological and mathematical biases inherent in HRV calculations (Sacha et al., 2013). Since HRV is typically calculated using R-R intervals, incorporating $1/\text{RHR}$, rather than RHR directly, aligns with established HRV measurement methodologies (Sacha, 2014). Overall, normalizing HRV with RHR reduces the changes of HRV being skewed by variations in HR. So, to integrate it into Program 3, the first step was to convert RHR (in beats per minute) to milliseconds by dividing by 60 and multiplying by 1000. HRV was then normalized as: $\text{HRV}/(1/(\text{RHR} \times 1000/60))$, simplified as $\text{HRV} \times \text{RHR} \times 100/6$. This normalized value was used to guide training: if the resulting value of the day was lower than the average of the last 10 days minus the standard deviation of those 10 days (from now on defined as the “HRV-RHR Reference value”), then the program modified the training recommendations, depending on the training of the last 2 days, as defined for Program 1. Finally, the WB scores modified the recommendation from HRV and RHR in the same way as in Program 2.

The program defined “High”, “Low” and “Rest” as follows:

- “High” intensity consisted of either riding for 1h at $IF^{TM} > 0.76$, or less than 2h at IF^{TM} between 0.56-0.76 with effort above FTP^{TM} , or over 2h at IF^{TM} between 0.56-0.76.
- “Low” intensity was defined as 1h30 to 2h riding at Z2 (IF^{TM} between 0.56 and 0.76).
- “Rest” meant an active recovery (no bike) or riding at Z1 for 1h or less ($IF^{TM} < 0.56$).

The riders followed their own training plan, respecting “High”, “Low”, “Rest” recommendations. They were asked to include a warm-up and a cool-down to all their trainings. Warm-up consisted of 5min at $< 56\% FTP^{TM}$, 5' at 60% of $Vo2max$, three times 10sec all-out sprint with 1min30sec rest in between, and 5min at $< 56\% FTP^{TM}$. Cool-down was 10min at $< 56\% FTP^{TM}$.

References

- Kiviniemi, A. M., Hautala, A. J., Kinnunen, H., & Tulppo, M. P. (2007). Endurance training guided individually by daily heart rate variability measurements. *European Journal of Applied Physiology*, 101(6), 743–751. <https://doi.org/10.1007/s00421-007-0552-2>
- Le Meur, Y., Louis, J., Aubry, A., Guéron, J., Pichon, A., Schaal, K., Corcuff, J.-B., Hatem, S. N., Isnard, R., & Hausswirth, C. (2014). Maximal exercise limitation in functionally overreached triathletes: Role of cardiac adrenergic stimulation. *Journal of Applied Physiology (Bethesda, Md.: 1985)*, 117(3), 214–222. <https://doi.org/10.1152/jappphysiol.00191.2014>
- Plews, D. J., Laursen, P. B., Stanley, J., Kilding, A. E., & Buchheit, M. (2013). Training Adaptation and Heart Rate Variability in Elite Endurance Athletes: Opening the Door to Effective Monitoring. *Sports Medicine*, 43(9), 773–781. <https://doi.org/10.1007/s40279-013-0071-8>
- Sacha, J. (2014). Interaction between Heart Rate and Heart Rate Variability. *Annals of Noninvasive Electrocardiology*, 19(3), 207–216. <https://doi.org/10.1111/anec.12148>
- Sacha, J., Barabach, S., Statkiewicz-Barabach, G., Sacha, K., Müller, A., Piskorski, J., Barthel, P., & Schmidt, G. (2013). How to strengthen or weaken the HRV dependence on heart rate—Description of the method and its perspectives. *International Journal of Cardiology*, 168(2), 1660–1663. <https://doi.org/10.1016/j.ijcard.2013.03.038>