## Reoxygenation kinetics operational definitions

* Manually set start position (time = 0).
* Manually set max reoxygenation time window.
  + 300 sec after maximal exercise.
  + Or to start of subsequent work bout.
  + Or including some period of the subsequent work bout to include accessory muscle delayed kinetics.
    - Including subsequent work bout will be influenced by muscle pump.
* Option to filter NIRS signal
  + Empirically select an appropriate moving average, Butterworth low-pass filter, or smoothing spline depending on sample rate, signal-to-noise ratio, and other contextual considerations (e.g. movement effects, interfering periodicity, etc).
  + (Rodriguez et al. 2018)
* Option to normalise NIRS signal within window to 0-100%.
* Understand direction of kinetics (up or down).
  + If down (e.g. HHb), then “peaks” must become “nadirs”, etc.
* Calculate end-work mean value (last 15 or 30 sec of work).
  + Omit 5 sec around t = 0 for imprecise end-work position,
  + Or to omit anticipatory/movement effects.
* Find peak value (no subsequent peaks within 15 or 30 sec).
  + Include post-peak window (15 or 30 sec).
  + If no peak, take end value of manual reoxygenation window.
* Parameterising reoxy kinetics with amplitudes or slopes is dependent on absolute NIRS values and will differ more between individuals, and between NIRS devices.
* Parameterising reoxy kinetics as time in seconds is independent of absolute NIRS values and will have less variability.

## Parametric reoxygenation models

* Fit with monoexponential & logistic models:
* *Yt* is the fitted model NIRS value at time *t* (in seconds)
* *YA* is the end-work starting value of the response.
  + ? Clamped to the end-work 15/30 sec mean, or free to optimise for least sum of squares?
* *YB* is the peak NIRS value observed during the recovery interval.
* The difference between *YB* and *YA* is the total reoxygenation amplitude.
* *TD* is the time delay (in seconds) between the end of work (t = 0) and the start of the systematic exponential curve.
* *Tau* is the time constant (in seconds) of the exponential curve.
  + *Tau* represents the time of the exponential curve.
  + *K* = 1/*Tau* and is the rate constant, representing the rate or speed of the exponential curve.
* Mean response time (*MRT*) is calculated as the sum of *TD + Tau.*
  + *MRT* is a more reliable estimate of the reoxygenation kinetics than either *TD* or *Tau* alone.
  + *MRT* captures net of mechanical and metabolic components which can contribute unpredictably to *TD* & *Tau.*
* *Xmid* is the time (in seconds) at the inflection point of the logistic curve.
  + *Xmid* represents the timing of the mismatch between O2 delivery > O2 uptake during recovery, resulting in reoxygenation.
  + *Xmid* is analogous to *MRT* and is an estimate of the reoxygenation kinetics.
* *scale* is a scaling factor (growth rate) of the logistic curve.
  + *scale* represents the magnitude of the mismatch between O2 delivery > O2 uptake during recovery.
  + A [5-parameter logistic model](https://www.r-bloggers.com/2019/11/five-parameters-logistic-regression/) with an additional asymmetry parameter, or a modified case of the generalised logistic function (e.g. Gompertz curve) may improve fit, or may overfit the data.
  + (Bopp et al. 2011)
* Satisfactory model fit criteria include:
  + Pseudo-R2 or adjusted R2 > 0.85 (de Groote et al. 1996, Efron 1978, Van Hooff et al. 2022)
    - However, do not use R2 to compare or select between non-linear model fits.
  + *TD* may be negative, but *MRT* should not be negative.
  + *MRT* and *Tau* should not be greater than the time to peak reoxygenation value.
  + *Xmid* should not be negative, nor should it be greater than the time to peak reoxygenation value.
    - These indicate that the responses do not adhere to a monoexponential or logistic curve and should be quantified non-parametrically (e.g. with *HRT*).
* Selection of best fitting model can be done with:
  + *RMSE*: root mean squared error.
  + *RSS*: residual sum of squares value. (Bopp et al. 2011)
  + *AIC*: Akaike information criterion.
  + *BIC*: Bayesian information criterion.
    - *AIC* & *BIC* may only be appropriate to compare nested models, I’m not sure.
  + There are probably other ways to compare model fits.

## Non-parametric reoxygenation models

* Half Recovery Time (*HRT*) can be calculated manually as the time to recover half of the NIRS reoxygenation amplitude. (Chance et al. 1992)
  + *HRT* is analogous to both *MRT* and *Xmid* and represents the time of reoxygenation kinetics.
* Peak reoxygenation slope can be calculated manually from e.g. the peak of a 10-second rolling slope calculation.
  + Peak reoxy slope is analogous to *scale* and represents the magnitude of the mismatch between O2 delivery > O2 uptake during recovery.
  + The time of occurrence of the peak reoxy slope is analogous to *Xmid* and represents the timing of the mismatch between O2 delivery > O2 uptake during recovery.
  + Research using vascular occlusion testing look at the slope immediately after cuff release, which corresponds to the peak slope (McLay et al. 2016, Rosenberry & Nelson 2020). However, after exercise the peak slope does not occur immediately.
* Net reoxygenation slope can be calculated from the amplitude and time between the end of work (t = 0) and the peak reoxygenation value. This does not consider the shape of the reoxygenation kinetics.

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