The Reliability of Repeated Measures of the Time Constant for Post-Exercise Phosphocreatine Recovery Using a Weighted Intraclass Correlation Coefficient

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Background:

The time constant (tau) of post-exercise phosphocreatine (PCr) recovery is directly related to oxidative metabolism. Despite its frequent use, relatively little information is known about the reliability of the PCr recovery time constant (tau-PCr). The reliability of tau-PCr may be related to the magnitude of exercise as a result of either measurement difficulties or physiologic intersample fluctuations. One method for improving the reliability of tau-PCr may be to perform repeated measures during a single session. [1, 2]

Protocols currently used to calculate tau-PCr, fatigue muscle by maximally depleting PCr and then collect PCr values repeatedly until it has recovered. Using these high-intensity exercise protocols, PCr concentrations change over a large range of values thus allowing for a good fit of the recovery curve. However, due to the exhaustive nature of the protocol, repeated measures during the same session is not feasible. Low-intensity exercise protocols, in which the muscle is not fatigued, can be repeated within the same session. However, with a low-intensity exercise protocol PCr concentrations change over a small range of values and thus may yield a less good fit of the recovery curve compared to a high-intensity exercise protocol.

We theorize that tau-PCr calculated from repeated low-intensity exercise protocols will be more reliable than tau-PCr calculated from a single low-intensity exercise protocol. Additionally, it will have equal or greater reliability than tau-PCr calculated from a single high-intensity exercise protocol. The goal of this pilot study is to assess the point estimates of the reliability of tau-PCr for these different exercise protocols.

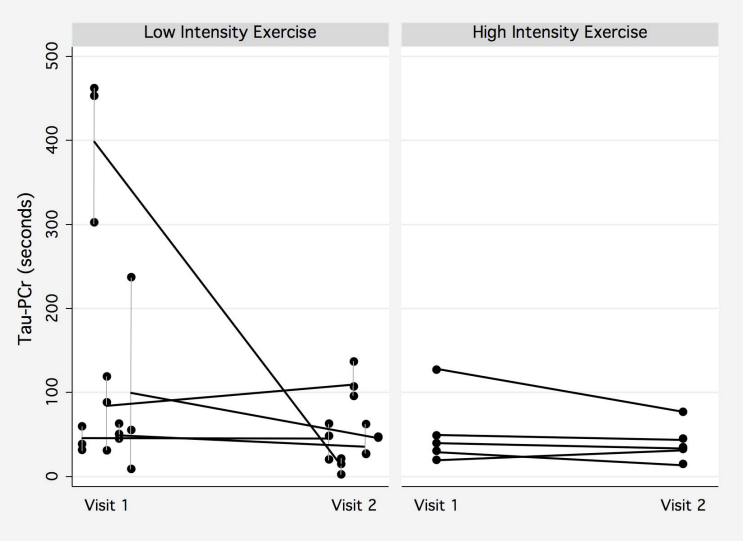
Methods:

Five healthy volunteer subjects performed the same procedure twice approximately 1 week apart. It consisted of three sequential low-intensity exercise protocols followed by a high-intensity exercise protocol of isokinetic plantar flexion while laying supine in a 3T clinical magnet. ^{31}P spectra of the posterior calf muscles were acquired every 10 seconds before and during the 8-minute recovery period of each exercise protocol using a pulse-and-acquire free induction decay (FID) sequence. The PCr fraction, PCr/(PCr + Pi), was normalized and fit to a monoexponential curve. We calculated the intraclass correlation coefficients (ICC) using linear mixed-effects models that incorporated weights (inverse variance) for the tau-PCr estimates. Weighting the tau-PCr estimates by their precision allows for a more accurate measure of reliability.

Results:

The average decrease in PCr values from baseline to end-exercise for the low-intensity exercise protocol for visit 1 and visit 2 were 13% ± 5% and 13% ± 4% respectively. The average decrease in PCr values from baseline to end-exercise for the high-intensity exercise protocol for visit 1 and visit 2 were 89% ± 4% and 83% ± 15% respectively. Paired plots of tau-PCr for visit 1 and visit 2 are shown in the figure below.

The low-intensity ICCs are listed in the table below. The ICC for tau-PCr derived from the three low-intensity exercise protocols was 0.89 within the first visit and 0.82 within the second visit.



Weighted Intraclass Correlation Coefficients for Tau-PCr

Protocol	ICC
Single low-intensity exercise protocol per visit without fixed-effect time (visit) in the model*	0.27
Single low-intensity exercise protocol per visit with fixed-effect time (visit) in the model*	0.39
All three low-intensity exercise protocols per visit without fixed-effect time (visit) in the model	0.92
All three low-intensity exercise protocols per visit with fixed-effect time (visit) in the model	0.92
Single high-intensity exercise protocol per visit without fixed-effect time (visit) in the model	0.86
Single high-intensity exercise protocol per visit with fixed-effect time (visit) in the model	0.88

* Calculated as the average of all nine possible permutations of a single low-intensity exercise per visit.

Discussion:

The reliability estimate of tau-PCr is poor (0.27) when it is derived from a single low-intensity exercise protocol for each subject on each of the two visits. We then added time into the linear mixed-effects model to account for the fact that measurements of tau-PCr one week apart could be different and less correlated than those within a single visit. However, adding time to the model does not dramatically change the ICC (0.39).

The reliability of tau-PCr increases to excellent (0.92) when we utilize all three tau-PCr measures from both visits. When time is added to this model, the ICC remains unchanged (0.92). This supports our hypothesis that repeating measures during each visit increases the reliability of tau-PCr.

The reliability estimate of tau-PCr is good (0.86) when it is derived from a single high-intensity exercise protocol. This point estimate of reliability also remains unchanged (0.88) when we add time to the linear mixed-effects model. The reliability of tau-PCr derived from repeated low-intensity exercise protocols on each visit is similar to the reliability of tau-PCr derived from a single high-intensity exercise protocol on each visit.

Literature:

1. Forbes SC, Paganini AT, Slade JM, Towse TF, Meyer RA. Phosphocreatine recovery kinetics following low- and high-intensity exercise in human triceps surae and rat posterior hindlimb muscles. Am J Physiol Regul Integr Comp Physiol. Jan 2009;296(1):R161-170.
2. Layec G, Bringard A, Le Fur Y, et al. Reproducibility assessment of metabolic variables characterizing muscle energetics in vivo: A 31P-MRS study. Magn Reson Med. Oct 2009;62(4):840-854.