CROSSTALK

Rebuttal from David J. Bishop, Javier Botella and Cesare Granata

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In debating this CrossTalk it is important to keep in mind the original topic, which was: ‘Exercise training intensity is more important than volume to promote increases in human skeletal muscle mitochondrial content’. Despite this, our colleagues do not cite any articles that directly measured mitochondrial content in support of their position (MacInnis et al. 2019). While an argument can be made in favour of citrate synthase (CS) activity as a valid indirect marker of mitochondrial content in skeletal muscle (Larsen et al. 2012; Bishop et al. 2019), changes in mitochondrial respiration and intracellular signalling pathways are not. We have previously reported that training-induced changes in mitochondrial respiration and CS activity can be dissociated (Granata et al. 2016). More critically, exercise-induced cellular events often do not predict subsequent changes as a consequence of training (Miller et al. 2016). For example, we have reported no significant correlation between exercise-induced changes in PGC-1α mRNA and training-induced changes in CS activity (Granata et al. 2018), and a mismatch between the effects of exercise intensity on cellular events and changes in mitochondrial content (Granata et al. 2016, 2017). This is further supported by studies in well-controlled model systems (e.g. bacteria and yeast cells), where there is generally a poor correlation between global changes in mRNA and protein in response to various perturbations (De Godoy et al. 2008; Jayapal et al. 2008). Thus, arguments in support of exercise training intensity as the most important variable to increase mitochondrial content would be strengthened by referencing studies that contain valid measures of mitochondrial content.

We agree with our colleagues that higher-intensity exercise typically results in greater increases in CS activity per minute of exercise (at least initially). However, the topic of this CrossTalk is the effectiveness and not the time efficiency of high-intensity exercise; we would also add two important caveats. As noted by others (Hardcastle et al. 2014), while the time efficiency of high-intensity exercise is often justified based on total exercise time, it is, arguably, more important to consider the total session time (i.e. when the time for warm up, cool down, and recovery between intervals is included). In addition, if the argument is that a greater mitochondrial content is important (for either health or athletic performance), the discussion should be about the type of exercise that is more effective and not more time efficient. This is especially true for elite athletes who are typically not constrained by time. In summary, based on the weight of evidence (and not just isolated studies), it seems difficult to argue that exercise intensity is more important than training volume to mediate the greatest increases in mitochondrial content.

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References

Additional information

Competing interests
The authors declare no conflict of interest.

Author contributions
All authors have read and approved the final version of this manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All persons designated as authors qualify for authorship, and all those who qualify for authorship are listed.

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