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LETTER

Investigating the effect of exercise duration on functional and biochemical perturbations in the human heart: total work or 'isoeffort' matching?

Intensity and duration of exercise are the two fundamental components of an acute bout of exercise. Understanding the effect of intensity and duration of exercise on physiological responses is of paramount importance for exercise prescription. In a recent paper by Stewart *et al.* (2016) published in *The Journal of Physiology* the authors investigated the effect of exercise duration on functional and biochemical perturbations in the human heart. Stewart *et al.* compared a 90-min trial at 110% of the gas exchange threshold (GET) with a 120-min trial at 80% of GET, matching total external mechanical work between trials. Overall cardiac stress was found to be considerably higher during and following the 90-min trial. This led the authors to conclude that the GET demarcates a threshold for exercise-induced cardiac functional stress and for the release of cardiac biomarkers. While we recognise the value of this investigation, we believe that the methodology used by the authors may have biased their results. Specifically, we are concerned that physical stress (and more precisely effort) was not appropriately matched by balancing total mechanical work. This matching method presents a confounding factor that potentially explains *per se* the between-trial differences in cardiac stress that Stewart *et al.* (2016) instead attribute to exercising at an intensity higher than GET.

The practice of matching total work for different exercise durations has been widely used in exercise physiology, but it is now recognised that this method is not appropriate as it results in between-trial differences in the participants' overall effort (Seiler *et al.* 2013; Nicolò *et al.* 2014). This is important because participants' effort rather than work done is likely to be more indicative of the stress experienced during exercise. To overcome this limitation, an 'isoeffort' approach can be used, which is based on the exercise prescription method commonly used by athletes (Seiler *et al.* 2013; Nicolò *et al.* 2014). An 'isoeffort' matching approach can be achieved for constant workload trials if exercise is prescribed by means of the highly predictable curvilinear relationship between exercise intensity and duration. This relationship between exercise intensity and duration is described by a power-law curve when effort is constant. This relationship has been found to hold true across different species and exercise modalities (Kennelly, 1906; Morton & Hodgson, 1996). Consequently, the relationship between the total work done and exercise duration should be described by a linear function, i.e. a longer exercise duration is matched to a higher (not the same) total work done. Thus as in the study of Stewart *et al.* where the increased exercise duration is not matched by an increase in total work, the effort exerted for the whole exercise bout will be decreased. The situation is analogous to asking a runner to cover exactly the same distance (a proxy for total work when running) in 90 min or 120 min. In this example it is clear that the effort and cardiac stress of the 120-min trial would be notably lower even though total work was the same. The fact that one trial was performed above GET and the other below may be seen only as a contributing factor, not necessarily the reason for the lower cardiac stress.

The most practical way to measure effort during exercise is by means of the rating of perceived exertion (RPE). Trials with different duration are matched for effort if no between-trial differences in RPE are observed when values are normalised to relative exercise duration (Nicolò *et al.* 2016). Yet, when RPE is normalised in this way it is seen that the total work increases with exercise duration (Nicolò *et al.* 2016). A physiological correlate of effort is respiratory frequency (f_R) (Nicolò *et al.* 2014, 2016). Similar to RPE, 'isoeffort' trials differing in exercise duration do not show differences in f_R when values are normalised to relative exercise duration (Nicolò *et al.* 2016). Whilst f_R appears to be a very robust correlate of RPE (Nicolò *et al.* 2014, 2016), there is also evidence suggesting that perceived exertion and f_R are linked by a common regulation mechanism, i.e. central command (Nicolò *et al.* 2015, 2016). Therefore, physiologically, effort can be defined as the degree of motor effort (i.e. the magnitude of central command).

Given the important role of central command in cardiovascular control during exercise (Williamson *et al.* 2006; Green & Paterson, 2008), it is plausible that the lower cardiac strain observed by Stewart *et al.* (2016) in the 120-min trial was influenced by the lower central command. An amendment to the experimental design by Stewart *et al.* (2016) could experimentally help verify whether the observed responses were determined by a lower effort (our interpretation) or by the fact that the subjects were exercising below the cardiac stress intensity threshold (authors' interpretation). This would be determined by including an extra 120-min bout of exercise at an exercise intensity identified to require the same effort as the 90-min trial (i.e. somewhere between 110% of GET and 80% of GET). Note too that the exact required power output could be predicted in advance from the power–duration relationship for each individual. Using the power–duration relationship for exercise prescription is straightforward, and can be adopted to prescribe both maximal and submaximal exercise. During the trials valuable insight into effort levels could be obtained by measuring RPE and f_R. The proposed addition to the experimental design of Stewart *et al.* (2016) would further our understanding of the dose–response relationship between endurance exercise and acute cardiac stress/injury. At present, we are concerned that the findings of Stewart *et al.* (2016) do not necessarily support their conclusion that the GET demarcates a threshold for cardiac stress, because, together with exercise duration, effort was altered too. Further studies are needed to address this issue and inform exercise prescription.

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Additional information

Competing interests

None declared.