Rebuttal by Lars Nybo and Carsten Lundby

Nybo, Lars; Lundby, Carsten

DOI: https://doi.org/10.1113/JP271668

Posted at the Zurich Open Repository and Archive, University of Zurich
ZORA URL: https://doi.org/10.5167/uzh-122947

Originally published at:
DOI: https://doi.org/10.1113/JP271668
CrossTalk opposing view: Heat acclimatization does not improve exercise performance in a cool condition

Lars Nybo1 and Carsten Lundby2
1Department of Nutrition, Exercise and Sport Sciences, Section for Integrative Human Physiology, University of Copenhagen, Copenhagen, Denmark
2Zürich Center for Integrative Human Physiology, Institute of Physiology, University of Zürich, Zürich, Switzerland

Email: nybo@nexs.ku.dk

It is clear that heat acclimatization markedly improves endurance performance in hot environments (Sawka et al. 1985; Nielsen et al. 1993; Racinais et al. 2015), but the idea that physiological adaptations achieved via heat acclimatization will also transfer to improved performance in cooler environments is questionable. Except from studies suffering from the lack of a matched control group, only one recent study, by Lorenzo et al. (2010), provides evidence for a transfer effect, as the authors report remarkable improvements in maximal oxygen consumption and ergometer time trial performance in both hot and cool conditions following 10 days of heat acclimation training. In that study acclimation was achieved through 90 min of additional training per day conducted in climatic heat chambers combined with maintenance of the participants’ habitual training (volume or intensity not reported or quantified). In contrast we observe no change in outdoor bicycle or laboratory ergometer time trial performance, peak power output during incremental indoor cycling, or maximal oxygen consumption when endurance trained cyclists are tested in cool conditions following either 10 days of indoor heat acclimation (Keiser et al. 2015), i.e. similar to the approach used by Lorenzo et al. (2010), or after 14 days of outdoor natural dry heat acclimatization (Karlsen et al. 2015). However, both regimes did facilitate improvements in time trial performance when conducted in the heat and were fully compatible with those reported to occur in the heat by Lorenzo et al. (2010). Furthermore, the sudomotor and cardiovascular adaptations were similar to the physiological heat acclimatization effects reported in studies of similar duration (Nielsen, 1998; Racinais et al. 2012; Taylor, 2014).

The premise for concluding that heat acclimatization improves aerobic performance in athletes exercising in cool conditions requires that there is a truly additional effect achieved from acclimatization that will translate into performance gains, and that the observations are not just a normal training effect or influence by the participation in a scientific study, which indeed may influence performance if the participating athletes do not have an optimized and stable training period prior to the intervention (Levine & Stray-Gundersen, 1997). Several studies with no control group report that completing a training camp in the heat may elevate the participants’ physiological performance capacity (Hue et al. 2007; Buchheit et al. 2011; Racinais et al. 2014), but so may a period with improved training quality in cool conditions (Laursen et al. 2002; Iaia et al. 2008). Therefore, it is essential to secure that pre-tests represent the highest level that the subjects will achieve from optimized training in cool conditions and, if applicable, the scientific gold-standard design of blinded, placebo-controlled, cross-over trials should be utilized (Lundby et al. 2012; Siebenmann et al. 2012). For obvious reasons blinding is not possible in heat acclimatization studies and it may also be discussed how training should be matched across conditions as heat stress will elevate the relative intensity if similar work load is utilized, whereas a higher work load may be endured in cool conditions if heart rate is used to match the exercise intensity across conditions. However, both when matched for heart rate during indoor control vs. heat acclimation training (Keiser et al. 2015) or allowing heat stress to influence the relative exercise intensity during natural outdoor training (Karlsen et al. 2015), we observe that heat acclimatization does not transfer to improved performance in cool or moderate temperature conditions for competitive cyclists who have been training for several years with inclusion of high intensity intervals in their habitual training.

Our opponents propose that the mechanism for heat training to improve exercise performance in a cool environment is linked to concomitant increase in plasma volume (Lorenzo et al. 2010), although this is not supported by experimental evidence. However, this is controversial as Kanstrup & Ekblom (1982), for example, reported no effect of acute plasma volume expansion on \( V_{O_2 \text{max}} \) in well-trained endurance athletes and in our recent studies neither acute plasma volume (PV) expansion nor the increase in PV associated with heat acclimation or acclimatization training facilitated time trial performance or improved the participants’ maximal aerobic power (Karlsen et al. 2013; Keiser et al. 2015; see also Fig. 1). In contrast, acute PV expansion may have a moderate effect on \( V_{O_2 \text{max}} \) in untrained men (Coyle et al. 1990) and the differences across observations may relate to training status of the subjects and their habitual training. Thus heat acclimation has been reported to increase \( V_{O_2 \text{max}} \) in untrained subjects

Lars Nybo is Doctor of Science and Professor at the Department of Nutrition, Exercise and Sport Sciences at Copenhagen University. His main research focus is hyperthermia-induced fatigue and issues related to central fatigue during prolonged exercise. The research includes very invasive mechanistic studies on cerebral and muscular parameters of importance for fatigue as well as field studies conducted in the heat. He has authored several reviews focusing on physiological factors limiting exercise performance in hot environments. Carsten Lundby is professor at the University of Zürich. He obtained his PhD degree at the Copenhagen Muscle Research Centre in Denmark under the guidance of Bengt Saltin, and today he leads a small research group focusing on integrative human physiology at the University of Zürich. His research interest includes adaptations to exercise training, high altitude and heat exposure.
(Nadel et al. 1974; Shvartz et al. 1977; Sawatzki et al. 1985), whereas in trained subjects only Lorenzo et al. (2010) report an improvement, while we (Karlsen et al. 2015; Keiser et al. 2015) and others (Shvartz et al. 1977; Kirby & Convertino, 1986; Houmard et al. 1990; Gore et al. 1997; Chen et al. 2013) observe no change in $\dot{V}_{O_2,\text{max}}$ after heat acclimation or outdoor training in the heat. It should be emphasized however that only a few of the cited studies included a control group (Lorenzo et al. 2010; Karlsen et al. 2015; Keiser et al. 2015) while the remaining studies were designed with other aims as the primary purpose and were not focused on comparing performance effects across environmental conditions. Another factor that may influence the opposing observations across studies could relate to the magnitude of the PV expansion evoked by acclimatization. As proposed by Coyle et al. (1990), untrained humans may benefit from a moderate PV expansion, while the induced haemodilution and lower oxygen carrying capacity associated with an acute large PV expansion will outweigh the effects of the augmented stroke volume and cardiac output. For endurance trained subjects with high plasma volumes, it is therefore expected and verified with our recent study (Keiser et al. 2015) that further haemodilution will not benefit arterial oxygen delivery.

Improved exercise efficiency is another proposed physiological adaptation from heat acclimation that potentially could benefit exercise performance in cool conditions (Sawka et al. 1983). However, exercise economy is indeed a factor that may be affected by familiarization with the experimental set-up, and results from studies that include training on the same equipment used for testing should be interpreted with great caution. For a trained group of cyclists, we observed no change in delta or gross cycling efficiency following heat acclimatization (Karlsen et al. 2015).

Hence, for endurance trained subjects the energy cost of exercise appears to be robust to heat acclimatization and since plasma volume expansion fails to elevate maximal oxygen uptake in this group of subjects, we conclude that there is no additional effects of training in the heat in terms of improving exercise performance in cool environments. In this context we emphasize that cool condition refer to the range of environmental conditions where performance is not influenced by hyperthermia (Nybo et al. 2014) and in this perspective the exercise mode needs to be considered as that will affect the combined exercise and environmental heat stress (Nybo, 2010; Corbett et al. 2014). We also emphasize that training in the heat does not preclude that subjects may benefit from training or that well-trained subjects can maintain their performance capacity in cool conditions concomitantly with adapting to exercise in the heat. However, there is no evidence supporting superior effects of training in the heat as compared to training in cool climates in terms of improving exercise performance in a cool environment.

Figure 1. Changes in physiological performance capacity versus change in plasma volume

Changes in physiological performance capacity evaluated in cool conditions (triangles representing average power output during time trials (TT) and squares representing peak aerobic power during incremental exercise testing) versus the percentage change in plasma volume following acute plasma volume expansion (filled symbols; albumin infusion) or 2 weeks of natural outdoor heat acclimatization (open symbols). The symbols represent individual values from Karlsen et al. (2015) and Keiser et al. (2015) with the delta changes calculated as the percentage increase from control.

Call for comments

Readers are invited to give their views on this and the accompanying CrossTalk articles in this issue by submitting a brief (250 word) comment. Comments may be submitted up to 6 weeks after publication of the article, at which point the discussion will close and the CrossTalk authors will be invited to submit a ‘Last Word’. Please email your comment, including a title and a declaration of interest, to jphysiol@physoc.org. Comments will be moderated and accepted comments will be published online only as ‘supporting information’ to the original debate articles once discussion has closed.

References


