News & Comment / Training & Performance

The Fifth International Conference on Altitude/Hypoxia Training at the Beijing Sport University

Will G Hopkins

This biennial conference consisted of lectures by seven invited speakers translated on-the-fly for the Chinese audience. Peter Wagner explained the physiological basis of limitations to endurance performance that altitude training has to overcome. Will Hopkins explained how to make inferences about the effects of altitude. Yannis Pitsiladis spoke of the as yet unrealized promise of genomics technologies for personalizing altitude training. Rob Aughey focused on the need to get the training itself right. Martin Burtscher provided evidence of the health benefits of adapting to hypoxia, especially the intermittent variety. Chris Gore presented a strong case for altitude enhancing performance via an increase in hemoglobin mass, offset by low iron status, illness, and negative energy balance. Carsten Lundby asserted that altitude training had no benefit for top endurance athletes with high hemoglobin mass, but a small temporary benefit for some such athletes seems more likely. KEYWORDS: athlete, endurance, genomics, intermittent, live high, performance, train high, train low.

Reprint pdf · Reprint docx

I was fortunate to be one of the seven invited speakers at this fifth biennial conference on altitude and hypoxia training at the Beijing Sport University, May 12-15. It is an impressive campus: rose gardens, colonnades of trees, sculptures, a sense of tradition, seriously physically active staff, and state-of-the-art sport-science facilities. Most of the ~16,000 students live on site, so there was a feeling of youthful energy in the air all week, especially in the evenings.

The conference opened with the theme music from the Magnificent Seven, and we turned out to be the only speakers. Our talks were translated sentence by sentence for the attendees, who came from all over China. I found the format surprisingly enjoyable: as a member of the audience I had more time to understand each point the speaker was making, and as a speaker I had more time to gather my thoughts for the next point I was about to make. The lesson from this experience: try to reduce the rate of delivery of information when speaking at a regular conference, especially in Europe.

A major factor in the success of the conference was our host Bing Yan and his team. Bing was responsible for the logistics and did most of the translating. He spent time with us before our talks to make sure he understood and translated concepts, not just words. BSU students with a good command of English were our chaperones for meals and tours, all provided generously by the vice president of BSU, Professor Yang Hu. The highest point for me, aside from the truly Great Wall, was some impromptu sessions with students and staff to discuss research.

The speakers, in temporal order, were Martin Burtscher, (University of Innsbruck), Peter Wagner (University of California San Diego), Chris Gore (Australian Institute of Sport), Yannis Pitsiladis (University of Brighton), Carsten Lundby (University of Zurich), Rob Aughey (Victoria University), and Will Hopkins (also Victoria University, part-time). I will present a synopsis of each presenter's talk in a thematic sequence under a heading that I think best summarizes their point of view.

Peter Wagner: The systems approach

Chris Gore and Carsten Lundby were due to talk about physiological adaptations to hypoxia, especially an increase in oxygen carrying capacity of the blood via an increase in hemoglobin mass. Peter demonstrated with classic

physiological principles that cardiac output, oxygen-carrying capacity, and oxygen diffusion in the muscles all interact to limit oxygen consumption, but an increase in hemoglobin concentration would lead to an increase in maximum oxygen consumption and therefore endurance performance, other things being equal.

Peter also presented his study of a small sample of Tibetans and Han Chinese, in whom there was reasonably clear evidence that higher oxygen-carrying capacity (higher hemoglobin concentration) was associated with moderately *lower* maximum oxygen consumption, and that the Tibetans had hemoglobin concentrations typical of lowlanders. Presumably other things are *not* equal when you adapt to altitude either in the short term (the Han) or over many generations (the Tibetans). An intriguing study, but I don't think there are any implications here for athletes using altitude training to enhance performance.

Will Hopkins: Estimate the effect magnitude

I gave my IOC talk on inferences about magnitudes of effects, modified to make most of the examples relevant to studies of altitude training. The smallest important change in performance for an endurance runner would be ~0.3%; it follows that a claim of "no effect" of altitude on performance would require a sample size in excess of 100 for magnitude-based inference and in excess of 300 for a null-hypothesis test.

I included two slides about the critique of magnitude-based inference published this year in Medicine and Science in Sports and Exercise and about the manuscript Alan Batterham and I have submitted to that journal in response. The slideshow is available here.

Yannis Pitsiladis: Omics still only promising

Although Yannis was billed to talk about the use of -omics technologies to personalize altitude training, it became apparent from his presentation that the genome and its downstream transcriptome, proteome and metabolome are too complex to deliver a practical altitude-ome anytime soon. Yannis spent much of his talk describing the brutal altitude training in the highlands of Kenya, leaving us uncertain about whether the superiority of the Kenyans is down to genes, hard training, altitude exposure, or all of the above. He also promoted the Sub2 project, a collaboration aimed at directly contributing to progression to a marathon time of less than two hours by 2020. This record seems likely to be achieved by an East African in the next 10 years, if not the next five.

Rob Aughey: Training, the neglected modifier

Rob's original title suggested he was going to focus on individual responses to altitude, but following Chris's treatment thereof he gave us a lecture on the importance of the training component of altitude training. His main message: get the training right first, then monitor it before, during and after the period of altitude exposure using measures of external load (GPS, accelerometry) and internal load (physiological indices, perceived effort). Without the more detailed examination of training, it will remain difficult to ascertain if altitude training is truly beneficial.

Martin Burtscher: Hypoxia for health

Martin and his colleagues have been responsible for much of the research on the potential health benefits of exposure to hypoxia, especially the intermittent variety (typically 5 min on, 5 min off, 1 h per day for several weeks). He provided convincing evidence of benefit in animal models and patients with cardiorespiratory and metabolic diseases. Preconditioning also reduces the incidence of sudden cardiac death in skiers, reduces the risk and severity of high-altitude sickness, and improves exercise performance at altitude. See Martin's publications on hypoxia in Google Scholar. Benefits to performance of athletes at sea level were less clear.

Chris Gore: Altitude works via hemoglobin

Chris pulled together a large number of studies to conclude that there is an increase in hemoglobin mass of 1.0% per 100 h per 2000 m of total exposure of either live-high train-high or live-high train-low altitude, with diminishing returns after ~4 weeks of exposure. He also presented evidence on factors accounting for failure of individual athletes to respond to altitude: low iron status, illness, and negative energy balance. But does an increase in hemoglobin mass translate into enhanced endurance performance? In cross-sectional studies of various athlete and non-athlete populations, a 1% difference in hemoglobin mass is associated with a 1% difference in VO_2max, although for highly trained endurance athletes the difference in VO_2max might be closer to 0.5%. In altitude-training studies, a 1% increase in hemoglobin mass is associated on average with a 0.5% increase in maximum oxygen uptake (Saunders et

al., 2013), which Peter Wagner was happy with.

But what about actual endurance performance? Chris showed the graph from the meta-analysis I did in 2009 with one of my PhD students, in which the percent changes in VO2max translated on average into similar percent changes in endurance power output (Bonetti and Hopkins, 2009). It's a bit worrying that he didn't present more convincing data from studies completed since then. Another concern is the duration of the increase in hemoglobin mass on return to sea level. A meta-analysis showed gains of ~3% had fallen to ~1.5% by 3-5 wk after live-high train-low and practically 0% by 4 wk after live-high train-high (Gore et al., 2013).

Carsten Lundby: Altitude–not for top athletes?

Having been persuaded by Chris Gore that altitude training was worthwhile, we had to accommodate Carsten's skepticism, based on his own study that showed no benefit of altitude training in highly trained endurance athletes with an already high hemoglobin mass (Siebenmann et al., 2012). In this double-blind study, 10 athletes lived high in normobaric hypoxia and trained low, while six control athletes lived low and trained low. There were no significant differences between the groups in the changes in hemoglobin mass, VO2max or time trial performance throughout the study.

So what's the answer? I think it is wrong to dismiss altitude training for top athletes on the basis of no significant effects in a grossly underpowered study, however well designed and executed it may have been in every other respect. Presenting outcomes with confidence intervals would show that Carsten's study did not exclude the possibility of a true beneficial (or harmful) effect. It was clear from the data Carsten and Chris presented that in some studies even athletes with the highest initial hemoglobin mass gained on average 2-3% hemoglobin mass and 1-2% VO2max from the usual altitude exposure (Robach and Lundby, 2012; Saunders et al., 2013), and these changes would translate on average into a 0.5-1.0% improvement in performance. For whatever reason– undiagnosed illness, other unknown confounding factors, or simply a Type II (false-negative) error–the athletes in Carsten's study did not experience an increase in hemoglobin mass, and hence their performance did not improve.

Carsten convincingly demolished claims of performance enhancement with intermittent hypoxia, and he was persuasive in dismissing the claim of superiority of live-high train-low over live-high train-high in the classic study of Levine and Stray-Gundersen (1997). He also presented data showing that a ~5% increase in hemoglobin mass that occurs in untrained subjects after 3-4 wk at altitude is down to ~1.5% by 2 wk after return to sea level. But he also showed data from a recent study of nine top skiers who experienced an increase in hemoglobin mass of ~3 ± 4 % (mean ± SD) when they lived at altitude and trained at even higher altitude (Lundby and Robach, in press; the article has not yet appeared on line).

Did Chris and Carsten reach a consensus about the benefits of altitude training for top athletes? Unfortunately Carsten opted to miss Chris's presentation in favor of a guided tour, and Chris had to return to the AIS before Carsten's presentation, so I have revisited some of the key studies to reach my own conclusions. It seems reasonably clear that some (most?) competitive endurance athletes will get a useful gain in performance from altitude exposure, but the gain will last only as long as the increase in hemoglobin mass. With live-high train-high, the gains are probably lost by 3-4 wk after exposure, but a substantial gain in hemoglobin mass might still be present 5 wk after live-high train-low. More research could be done to determine whether the right kind of training in the weeks following the exposure can slow the loss of hemoglobin and of the enhancement of performance. Identifying the subject characteristics (genotype or phenotype) of any positive responders, non-responders and negative responders is also worth pursuing.

Bonetti DL, Hopkins WG (2009). Sea-level exercise performance following adaptation to hypoxia: a meta-analysis. Sports Medicine 39, 107-127

Gore CJ, Sharpe K, Garvican-Lewis LA, Saunders PU, Humberstone CE, Robertson EY, Wachsmuth NB, Clark SA, McLean BD, Friedmann-Bette B (2013). Altitude training and haemoglobin mass from the optimised carbon monoxide rebreathing method determined by a meta-analysis. British Journal of Sports Medicine 47, i31-i39

Levine BD, Stray-Gundersen J (1997). "Living high-training low": effect of moderate-altitude acclimatization with low-altitude training on

performance. Journal of Applied Physiology 83, 102-112

Robach P, Lundby C (2012). Is live high–train low altitude training relevant for elite athletes with already high total hemoglobin mass? Scandinavian Journal of Medicine & Science in Sports 22, 303-305

Saunders PU, Garvican-Lewis LA, Schmidt WF, Gore CJ (2013). Relationship between changes in haemoglobin mass and maximal oxygen uptake after hypoxic exposure. British Journal of Sports Medicine 47, i26-i30

Siebenmann C, Robach P, Jacobs RA, Rasmussen P, Nordsborg N, Diaz V, Christ A, Olsen NV, Maggiorini M, Lundby C (2012). "Live high–train low" using normobaric hypoxia: a double-blinded, placebo-controlled study. Journal of Applied Physiology 112, 106-117