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The Tortoise and the Hare

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Distance running requires a high absolute oxygen consumption, while for a breath-hold diver the opposite is preferable. We compared physiological exercise parameters and mitochondrial function in a competitive triathlete with those seen in an accomplished breath-hold diver and notice some remarkable differences, possibly explaining why both have become successful.

"All this time the tortoise kept walking step by step by step. He never quit no matter how hot or tired he got. He just kept going".

[Aesop 620-564 BCE]

Some years ago, two colleagues in our group at Karolinska Institutet were working together in the laboratory on a project related to aerobic capacity, mitochondrial respiration, and tolerance to hypoxia [1–3]. It so happened that both are competing at a high level in sports that belong to the extreme ends when it comes to requirements for aerobic capacity. The first subject (hereafter named the Hare) is a triathlete who at the time was competing at the highest national level, while the second person (hereafter named the Tortoise) is a competitive breath-hold diver and currently the deepest active Swedish diver in the constant weight category. We decided to compare a number of physiological exercise-related parameters including mitochondrial function in these two individuals, hoping that the result could shed some light on why they have been successful in the sports they have chosen.

First, we measured basal metabolic rate (BMR) using indirect calorimetry and found a remarkable difference. BMR of the Hare was 122 kJ/kg/24 h which was more than 40% higher than the Tortoise (Figure 1A) and around 20% higher than a normal value for a male of this age [4]. With this result alone, it already seems intuitive that a low basal oxygen consumption should be advantageous in a sport like breath-hold diving. At the time, the two subjects had the same body weight (77 kg) which allowed us to make an interesting calculation. If the Hare spent all his days lying on the couch and their caloric intake was the same, then the Tortoise would have to run approximately 9 km every day not to gain weight compared with the Hare. Conversely, if their physical activity was the same the Tortoise would have to consume around 700 kcal less per day not to gain weight. This amount of calories is equivalent to a normal dinner. Next, we compared oxygen consumption during physical exercise for these individuals and not surprisingly the VO_{2max} of the Hare was superior to that of the Tortoise (Figure 1B). Obviously, a high VO_{2max} is a prerequisite to be able to compete at a high level as a triathlete. Now, we decided to see if the differences in whole body metabolism would be reflected also at the mitochondrial level. Fresh isolated mitochondria had been

Physiological parameters		
Basal metabolic rate (A)	High	Low
Maximum oxygen consumption		
- sea level (B)	High	Low
- high altitude (C)	Declines	Maintained
Blood oxygenation at high altitude (D)	Declines	Maintained

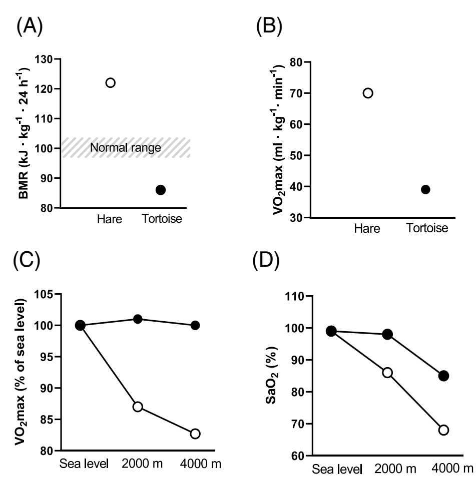

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Figure 1. Comparing the physiology of the Tortoise and the Hare. (A) Basal metabolic rate (BMR), (B,C) maximum oxygen uptake (VO_{2max}), and (D) blood oxygen saturation (SaO_2) at sea level and high altitudes, in a competitive triathlete (Hare) and a competitive breath-hold diver (Tortoise). The normal range for BMR (from [4]) is indicated in (A). These data have been extracted from [2,3].

harvested from muscle biopsies of vastus lateralis in both subjects [3]. A first observation had revealed that mitochondrial density was far greater in the Hare. Then, looking at the degree of proton leak, we found that it was lower in Tortoise's mitochondria [3] corroborating a more recent study showing a higher mitochondrial efficiency in breath-hold divers [5]. In other words, Tortoises' mitochondria consume less oxygen per ATP generated, thereby reflecting what we had noted for BMR on a whole body level. We have previously shown that mitochondrial oxygen affinity ($p50_{mito}$) is a major determinant of BMR in humans [3]. Indeed, when comparing $p50_{mito}$, it was higher in the Tortoise compared with the Hare. Given the vast differences in these mitochondrial parameters, it might be predicted that the Tortoise would perform relatively better when oxygen levels decrease such as when exercising at a high altitude [2]. Therefore, we finally compared both individuals during ergometric cycling when breathing room air or hypoxic air (13–16% oxygen) representing 2000–4000 m above sea level. Strikingly, Hare's VO_{2max} decreased considerably at lower oxygen levels while the Tortoise was able to maintain a level of VO_{2max} which was the same as that seen under normoxic testing (Figure 1C). Concomitantly, blood oxygen saturation fell considerably in the Hare upon exposure to hypoxia, while that of the Tortoise remained more stable (Figure 1D). These results are interesting considering that breath-hold diving is the ultimate form of hypoxia.

These experiments illustrate how normal mitochondrial function can vary profoundly between healthy individuals, explaining great differences in resting metabolic rate, exercise capacity, and tolerance to hypoxia. It is possible that an individual's intrinsic mitochondrial composition and function to some extent may determine how well a person will perform in sports requiring different handling of oxygen.

Declaration of interests

No interests are declared.

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