16 The Burden of Locomotion in Water: Could the Aquatic Ape Have Overcome It?

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SUMMARY
Special adaptations for buoyancy, locomotion, and thermoregulation are typical of any aquatic mammal. A hypothetical aquatic human ancestor must have lost such qualities in later stages of our phylogeny for present-day humans are poor survivors in water. Protagonists of the Aquatic Ape Theory assume the cradle of mankind to have been located in a warm climate on an African coast. The humans least subjected to ecological pressures, and hence most resembling those ancestors, would be those living nowadays in that area: black Africans. However, though their exercise capacity appears to equal that of other humans, their swimming performance is relatively poor. Their buoyancy is less, they are less streamlined and their thin subcutaneous adipose layer is less suitable for insulating the body. Of all the diverse present-day humans, black Africans seem the least well suited for an aquatic way of life.

INTRODUCTION

Among the factors on which survival in water depends, buoyancy and locomotion are undoubtedly of great importance, as would be thermoregulation in a colder environment.

All aquatic mammals have to emerge from the water to breathe. So buoyancy is one feature that would be advantageous to an ape adapting itself to an aqueous environment. Of all terrestrial mammals, humans are among the poorest survivors in water. If man did indeed descend from an aquatic ape, one must assume that at some later stage of human phylogeny our ancestors lost the ability, present in most animals, to survive longer in water than the average human does (Wind, 1976, and chapter 17 of this volume).

It is generally accepted that the cradle of mankind must have been situated in a warm, if not hot, climate: according to protagonists of the Aquatic Ape Theory, this would have been on the East African coast (Ellis, 1987; LaLumiere, this volume, chapter 3). Evolutionary pressure for change should have been stronger the farther our ancestors moved from this cradle. Of all the diverse humans running around on the earth's surface, which one resembles most the shape and body composition of an aquatic animal? Indeed, if the Aquatic Ape Theory is correct, the answer

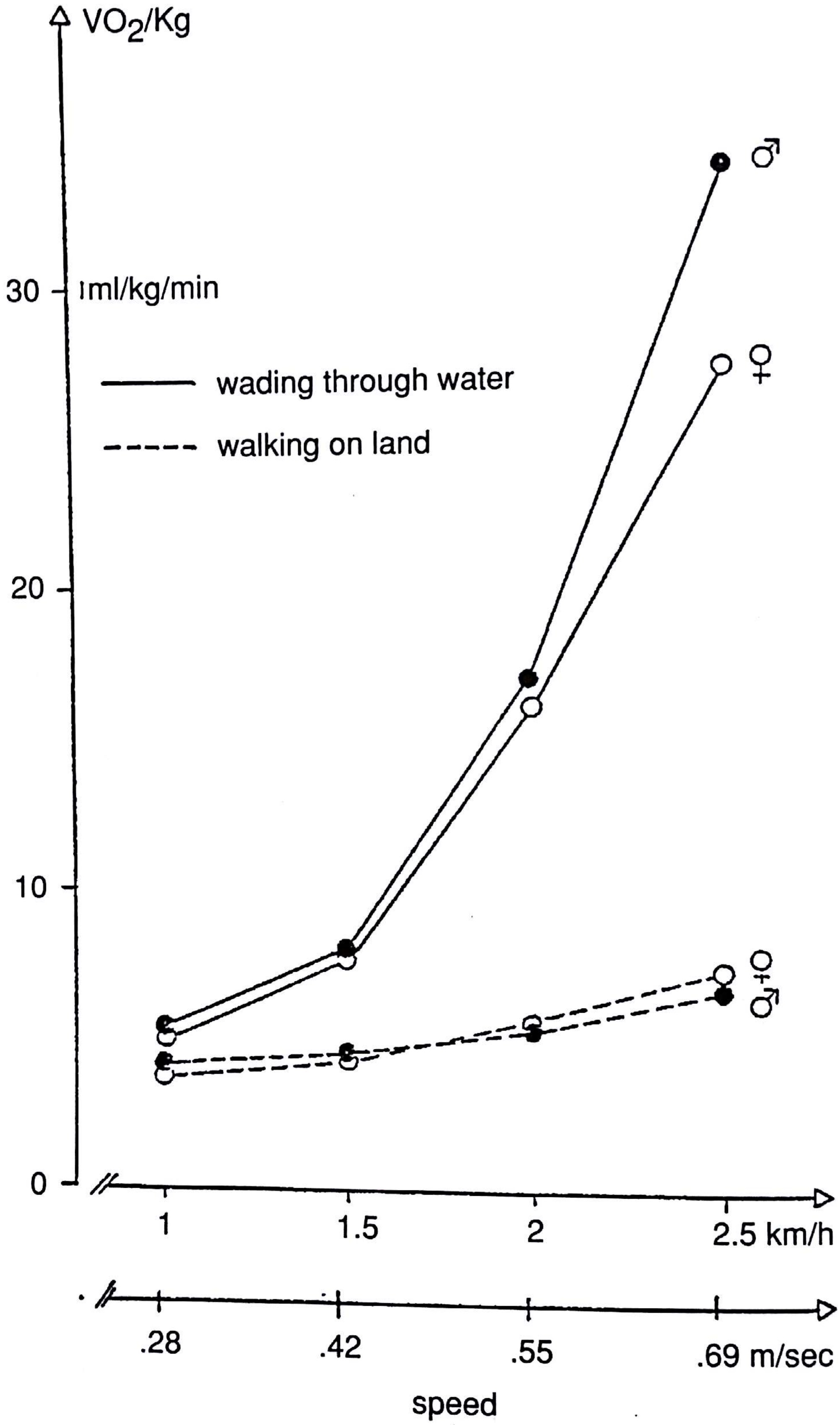

Figure 16.1 Net oxygen uptake in ml per kg body weight at speeds 1 to 2.5 km per hour in 6 women and 6 men (19 to 22 years old) on dry land and wading through water up to their armpits.

should be the humans living around the area where mankind originated, and where the selection pressure for evolutionary change was least. This leads straight to the black African.

WADING IN WATER

A successful hunter–gatherer has to move about to catch his prey. So locomotion is indeed very important. Aquatic mammals move mainly horizontally through the water. This is obviously the most economic solution, since wading in an upright position requires extremely thin legs to overcome the water resistance, as storks and kiwis demonstrate. Walking on sturdy legs in water will provoke such strong turbulence and drag that the energy requirements of displacement in the upright position, at even slightly increased speed, will become prohibitive.

Figure 16.1 shows the difference in net oxygen uptake in humans (six men and six women, about twenty years old) between walking on dry land and wading through water (submerged to the armpits) at speeds of 1 to 2.5 km per hour (unpublished data from our laboratory). It is obvious that wading through water can only be maintained at affordable levels of energy expenditure at a very low speed, at least for present-day man. Figure 16.2 shows that, at speeds of 0.8 m per second or more, wading through water becomes by far the most expensive mode of locomotion.

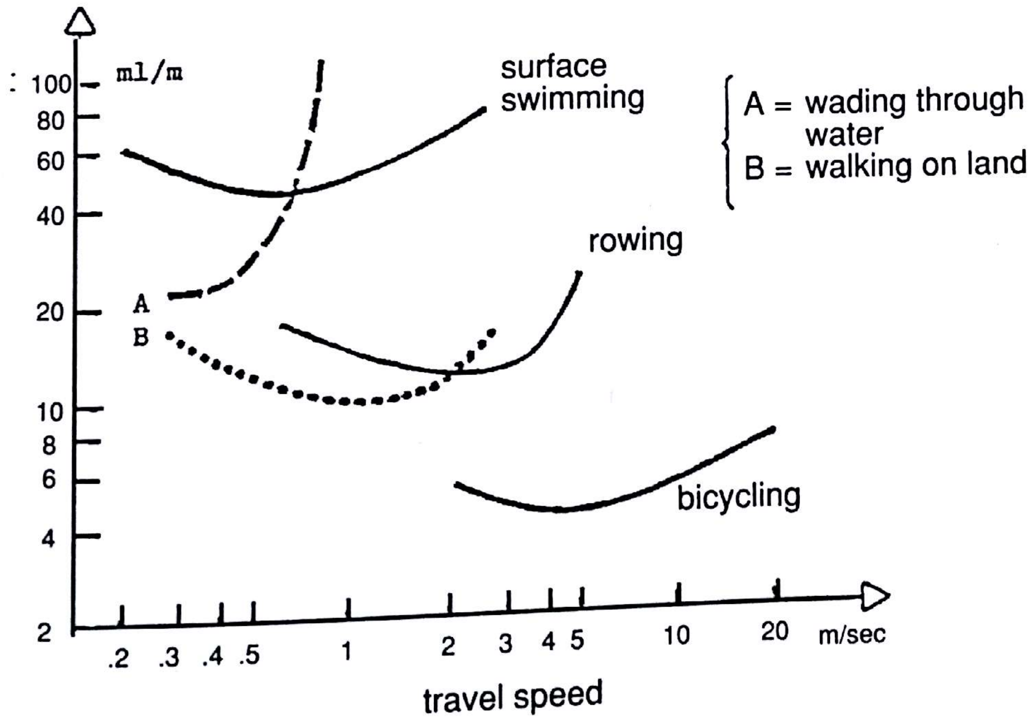

Figure 16.2 Oxygen consumption per unit travel range versus speed for various on-land and in-water activities (adapted from Baz, 1979; curves A and B are based on own data).

SWIMMING

We therefore can safely say that the vertical wading position was not the usual means of locomotion in the aquatic ape, and that it is more likely to have been horizontal locomotion by swimming. Obviously, the energy-yielding capability of the individual must have been very important. With regard to differences in energetic power between different human populations, there is no reason to doubt that the exercise capacity of blacks is as good as that of whites. This has been proved in many sporting events, where their achievements are equal, if not better – but with one exception: swimming. The absence of African swimmers, or swimmers of African origin, from the world sports elite is indeed conspicuous. To be sure, sociocultural background no doubt influences an individual's choice of sport; also (though it is no longer the case), for a long time access to some sports may have been denied to blacks. Hence, one could argue that biological predispostion is, at present, a more important determinant in the individual's choice of sport. Might it be that in swimming blacks have a certain handicap to start with? Are their body shape and composition less suited for swimming?

Leaving energy, motivation and culture aside, swimming, at least in the early learning stage, will be affected by:

(1) buoyancy in water;
(2) shape and morphology of the body; and
(3) the ability of the body to thermoregulate its core.

Buoyancy, if less of a problem to a top short-distance swimmer, is indeed an important feature with regard to locomotion in water over long distances or periods, and hence for the survival of aquatic species. As stated by Wind (1976), the survival time in water of man's air-breathing ancestors can be considered to have been positively correlated with buoyancy. Champion swimmers practise in heated pools, mainly to avoid the extra energy expenditure of keeping their bodies warm. Long distance swimmers and professional divers (Channel swimmers, for example, and Ama divers), who practise or work in cold water, do develop a subcutaneous fat layer which helps to protect them from the cold environment. This subcutaneous fat layer, it has to be stated, is to a large extent an acquired property (Clark and Edholm, 1985).

Patrick (this volume, chapter 14) points out that to stay at the surface, the density of the body has to be less than that of the surrounding water, and this difference has to be great enough to keep the airway-opening above the water surface, or at least to bring it there at regular intervals. If the density of the body is equal to or greater than that of the water, extra energy will be needed to keep the airway at the surface or to bring it above it. The colder and saltier the water, the greater its density – and hence the easier for a given subject to float. If early hominids went through an aquatic phase in tropical fresh waters, they would have required considerable buoyancy – greater than modern man's. But they would have required less buoyancy if they were living in tropical seas, and still less in cold sea water.

Buoyancy in water is determined by three main components:

(1) the lean body mass, which is heavier than water;
(2) the body fat, lighter than water; and
(3) the amount of air in the lungs.

Table 16.1 shows the average values for these components in the bodies of standard, 'constructed' black and white models. Of these three factors, the lean body mass is the site of most of the metabolic activity. A decrease in lean body mass, while increasing buoyancy, will at the same time reduce the energy-yielding capacity of the subject. Since we accept that the exercise capacities of blacks and whites are at par, in constructing our models in Table 16.1 we attribute an equally lean body mass to both.

Table 16.1 Buoyancy in 'constructed' black and white models

	Black	*White*
Lean body mass		
– weight (kg)	50	50
– density	1.08	1.08
– volume (l)	46.3	46.3
Adipose tissue		
– weight (kg)	5	10
– density	0.95	0.95
– volume (l)	5.26	10.53
Lung volume		
– FRC (l)	2.2	3.0
TOTAL		
– volume (l)	53.76	59.83
– weight (kg)	55.0	60.0
Buoyancy (kg)	- 1.24	- 0.17

FRC = functional residual capacity

An increase in the amount of body fat is obviously a handicap in terrestrial locomotion, where it behaves as dead weight. But in water it may offer advantages – by increasing buoyancy, by providing thermal insulation, and possibly by streamlining the body. Young blacks, particularly male Africans, tend to be slimmer than Europeans, or Americans of European origin (Tanner, 1964; Eveleth and Tanner, 1976). Their thin subcutaneous fat layer is obviously not simply due to the supposed prevalence of undernutrition. It is also observed among adequately fed Africans (Ghesquiere and Eeckels, 1984). One could hardly imagine that world cross-country champions are in an under-nourished state year after year. Yet the Ethiopian, Kenyan and Tanzanian athletes who perform these feats look very thin, as indeed they are.

Finally, a larger air volume in the lungs will increase buoyancy. On the other hand, a smaller lung volume leads to an increased respiratory frequency in order to provide the same effective ventilation. This, of course, adds to the work of breathing, which is less efficient and requires considerably more energy in water than in the air. On the other hand, lung volume is not in itself a limiting factor with regard to exercise capacity, as even at the highest rate of exercise a top athlete rarely uses more than 60 per cent of his ventilatory capacity.

That the lung volumes of Africans differ markedly from those of Europeans has been well documented (Damon, 1966; Johannsen and Erasmus, 1968; Dedoyard and Ghesquiere, 1980). The African has, in relation to his body size, a total lung capacity (TLC) and functional residual capacity (FRC) that is approximately 20 per cent smaller than the European's. FRC gives an approximate measure of the amount of air in the lung when swimming, and may thus influence buoyancy.

The effects of the differences in the amount of body fat and in the lung volumes can easily be calculated, as shown in Table 16.1, which shows a difference between black and white of 1.07 kg. The negative buoyancy of the white, -0.17 kg, can be overcome with little extra energy, while the -1.24 kg buoyancy of the black will require more. Again, this may be of little importance to the top swimmer, but it can be a handicap for black boys and girls learning to swim. Likewise, this inferior buoyancy will be an extra burden for any human having to spend long periods in water.

As for body shape, aquatic mammals, without exception, have superbly streamlined bodies. With top human swimmers, we should bear in mind that their performance lasts only one or more minutes, and that the ability to produce maximal pull with the relatively small muscle mass of the arms and shoulders is crucial. There has been a strong tendency towards greater stature among top swimmers in recent years: indeed, if body shape and composition are similar, the muscle power increases to the second power of stature, giving the taller individual an advantage.

That his body mass, and hence weight, will at the same time increase to the third power of his stature is irrelevant, since his body will float. (Compared to their land-dwelling cousins, aquatic mammals invariably have a large body mass – some extremely large.) Variety of body shape in modern man is rather limited. We can single out, though, the more angular and longer-lined body type of the black: the width of shoulders as compared to hips, and the ratio of arm or leg length to total body length, are both greater in the black than in the white (Hiernaux, 1985; Hauspie *et al.*, 1985). Comparatively broad shoulders, small hips, proportionally long legs and, in addition, a thin subcutaneous fat layer – all these factors will make the body less streamlined, and add drag and turbulence to a human frame moving through water (Clarys, 1978).

CONCLUSION

We must conclude that present-day humans are poorly suited for dwelling in water, be it for a short or for a long period. Of all humans, the one who has remained closest to the presumed cradle of mankind, where the aquatic hominid may have lived, and who has thus been least exposed to genetic pressure for change – the black African – seems to be the least suited for such an aquatic way of life.

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