FROM ARBOREAL LOCOMOTION OF TERRESTRIAL TETRAPODS TO ROCK CLIMBING IN HUMANS

Legreneur, P.[1], Neumann, U.[2]

[1] Laboratoire Interdisciplinaire de la Biologie de la Motricité, University of Lyon, Villeurbanne, France. pierre.legreneur@univ-lyon1.fr

[2] Thurnerstr. 64a, D-51069 Köln, Germany. udinimedia@googlemail.com. http://www.udini.com

Abstract

The purpose of this paper is to highlight the interest of comparative locomotion for coaches and researchers, to understand the current locomotion in rock climbing, and the future evolutions of climbing performance. Human is a specie whose ancestors were arboreal. Thus, Human musculo-skeletal system is designed for biped hand-assisted running, climbing and jumping in the trees. These modes of locomotion are similar to those of other modern arboreal species. Thus, studying these species in their environment makes it possible to understand the optimal coordinations necessary for the realization of arboreal locomotion, and thus rock climbing performance, since they result from millions of years of evolution.

Keywords: Comparative locomotion, evolution, biomechanics

Résumé

L'objectif de cet article est de mettre en évidence l'intérêt de la locomotion comparée pour les entraîneurs et les chercheurs pour comprendre la locomotion actuelle en escalade et les évolutions futures de la performance. L'Homme est une espèce dont les ancêtres étaient arboricoles. Ainsi, le système musculo-squelettique de l'Homme est conçu pour la marche arboricole bipède avec l'aide des bras, l'escalade et le saut dans les arbres. Ces formes de locomotion sont similaires à celles des autres espèces arboricoles modernes. Ainsi, l'étude de ces espèces dans leur environnement permet de comprendre les coordinations optimales nécessaires à la réalisation de la locomotion arboricole, et donc à la performance en escalade, car elles résultent de millions d'années d'évolution.

Mots clés : Locomotion comparée, évolution, biomécanique

Introduction

The classical approach for analysing sport performance is to consider the athlete in *in situ* conditions (training or competitive environment) or in laboratory-standardized conditions. These approaches allow characterising the physiological, biological, and all other factors of performance at a given instant. However it doesn't permit understanding the relations between the whole organism and performance as a result of an adaptation of individuals to the environment.

From a biological point of view, the performance of individual is directly related with its ability to survive, reproduce and disseminate. Thus, the performance of an athlete is not only the result of a social construction that imposes rules and a performance framework. It is also and mainly the result of about 380 My of evolution since the first tetrapod fish (with 4 limbs) left the water to conquer the dry land. This transition was very gradual (Laurin, 2010). In addition to the fins that have become limbs, many adaptations have been necessary, *i.e.* to release the mobility of the head, to breathe in the open air, to reproduce in a non-aqueous environment, etc. These adaptations allowed vertebrates to occupy new, unexplored habitats throughout their history on land. In the great diversity of terrestrial habitats, the one that interests us is the arboreal environment. This ecospace is particularly important as it provides new food resources and protection from large ground-dwelling predators. *Suminia getmanovi* (Figure 1) was one of the first vertebrate to live in trees, 260 My ago (Fröbisch & Reisz, 2009).

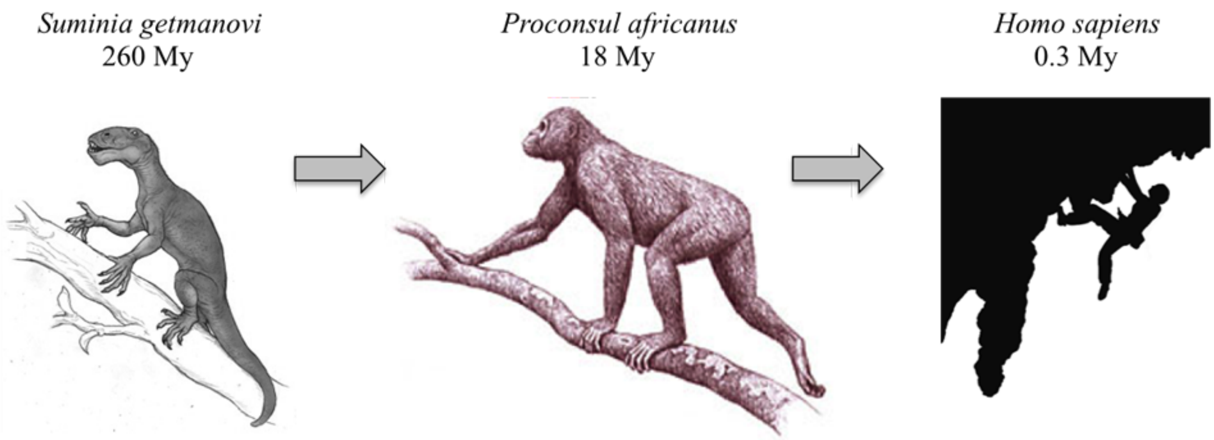

Figure 1. Some arboreal species along the evolution: *Suminia getmanovi* Ivachnenko 1994, *Proconsul africanus* Hopwood 1933, *Homo sapiens* Linnaeus 1758.

Today, many vertebrate species are arboreal, *e.g.* lizards, frogs, birds, mammals. They present all similar phenotypic traits, *i.e.* elongate limbs, long hands, opposable thumbs, etc. The term "phenotypic trait" gathers all the observable and measurable characteristics of an individual. Concerning the hands, differentiation between grasping and clinging morphotypes has been observed, the former displaying elongated proximal phalanges and the latter showing an elongation of the penultimate phalanges. These phenotypic similarities between species that everything separates (phylogeny, geography) results from the evolutionary convergence mechanism that leads the species, constrained by the same environments, to adopt several physiological, morphological and sometimes behavioural traits, often to adapt to ecological niches with common points (Legreneur *et al.*, 2013).

From trees to rock climbing

The arboreal environment imposes modes of locomotion to which the morphologies of the individuals are adapted. Three main locomotion's can be distinguee: (*i*) walking and running on branches, (*ii*) climbing on trunk and (*iii*) and jumping between branches and trees. These locomotions allow intra-specific interactions between congeners and inter-specific or predator-prey interactions. For example, it may be necessary to jump to other branches to escape a predator. For this, arboreal species are equipped to jump upwards or downwards with a maximum angle of 30 ° (long jump take-off angle in humans). These angles, found in so-called generalist leapers like lizards (Legreneur *et al.*, 2012), squirrel (Essner, 2002), lemurians (Crompton & Sellers, 2007) or humans, could be viewed as a trade-off between the reduction of vulnerability to predators and the energy expenditure.

In addition to these forms of locomotion, living in trees has led the great apes, and latter *Homo* species to stand up on their lower limbs. From quadruped, the common crown hominoid ancestor (the ancestor of living apes) became biped (Thorpe *et al.*, 2007). Indeed, hand-assisted bipedalism in the canopy allows the most arboreal great apes, like modern orangutan, to move on flexible supports that are otherwise too small to access.

Thus, modern Humans, which ancestors were arboreal, have a musculo-skeletal that is optimized for displacing and living in vertical environment, with specific forms of locomotion that are (i) hand-assisted biped walking and running, (ii) jumping with take-off angles lower than 30° and climbing with holds like branches (grasping) or trees (compression). An idea of this locomotion is given by gibbon displacement in trees. Indeed, their musculo-skeletal system is very closed with the one of humans, especially in term of tendon *vs*. muscle belly length ratio (Payne *et al.*, 2006). On the other hand, certain major forms of locomotion found in rock climbing require specific adaptations, *i.e.* upwards propulsion with the upper limbs alone since the propulsion function is provided by the hind (or lower) limbs in tetrapods vertebrates, or vertical jumping (dyno) for which the best performances (at most 0.55 m) are obtained in sprinters or volleyball players.

Conclusion

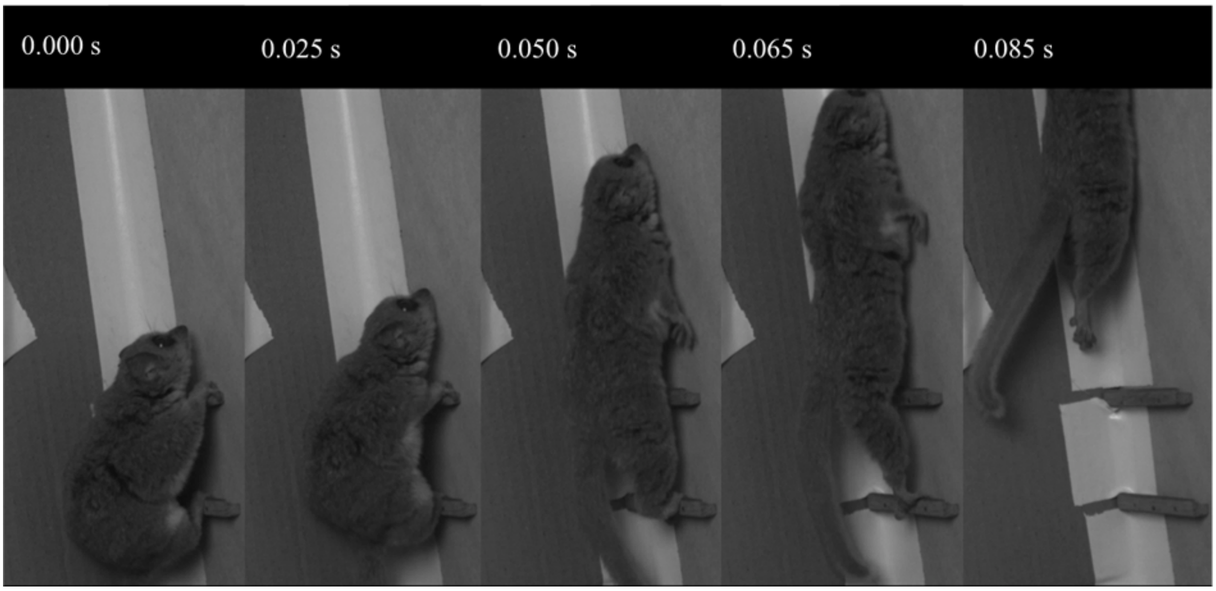

Figure 2. Dyno in *Microcebus murinus* (Snout-Vent length = 127 mm; Mass = 89 g) on an adapted campus board (unpublished results, Legreneur P., 2010).

Throughout the history of species evolution, despite changes in shape, structure, and motor control, physical laws applying to individual locomotion have remained immutable (Lauder, 1991). Thus, for sport trainers and searchers, the evolutionary history of species is like a gigantic experiment that lasted hundreds of millions of years and which resulted in modern human locomotion in general, and rock climbing in particular. The robust solutions that emerged during this long evolution have a very high probability of being nearly optimal in terms of energy use.

This original approach is called "comparative locomotion". The idea is to analyse performance in regards to evolution history of species, and particularly of species that live in similar environment with similar constraints. For example, analysing the leap of a lemur (*Microcebus murinus* Miller 1777) on an adapted campus board shows the optimal coordinations to succeed a dyno in rock climbing (Figure 2). The status of super predator has led to the establishment of nerve inhibitions in Humans that must be raised by training to re-find this original arboreal locomotion: climbing, running and jumping. Maybe will it be the future of top level rock climbing? Current developments suggest it.

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