Early life mammalian biology and later life physical performance: maximising physiological adaptation

Andres E Carrillo,[1] Yiannis Koutedakis,[2,3] Andreas D Flouris[1,4]

[1]FAME Laboratory, Institute of Human Performance and Rehabilitation, Centre for Research and Technology – Thessaly, Trikala, Greece
[2]School of Sports, Performing Arts and Leisure, University of Wolverhampton, Wolverhampton, UK
[3]Department of Exercise Sciences, University of Thessaly, Trikala, Greece
[4]Department of Research and Technology Development, Biomnic Ltd., Trikala, Greece

Correspondence to
Dr Andreas D Flouris, Institute of Human Performance and Rehabilitation, Centre for Research and Technology – Thessaly, Trikala 42100 Greece; aflouris@cereteth.gr

Accepted 26 June 2011
Published Online First 27 July 2011

ABSTRACT
The malleability of mammalian biology during early life, which carries considerable weight throughout the course of the lifespan, may contribute to the creation of a human phenotype ideal for prime physical performance. In this article, the authors consider the East African cohort of exceptional athletes that dominate marathon performance. Since entering international marathon competition in 1960, East Africans have competed at the front of the pack and now hold the top 10 men's marathon times. The authors present lines of evidence supporting that exposure to factors such as altitude and early metabolic adjustments that are inherent in East African early life exert a strong influence in later life physical performance and may collide with a genetic advantage to induce biological changes that allow for a more robust biological response to training in later life.

The malleability of mammalian biology during early life carries considerable weight throughout the course of the lifespan.[1] Factors like socioeconomic status and early mental stimulation are associated with later life cognitive function. But influential circumstances during critical periods of early development are not limited to the cognitive milieu. The nascent notion that potent pre- and postnatal stimuli contribute to prolonged functional metabolic changes that can lead to physiological programming of the offspring has received substantial attention.[2 3] Living organisms have an immense capability of adapting to the environment in which they find themselves. The specific early life cues triggering a particular phenotype are mostly undiscovered, but may, at least in part, contribute to later life biological adjustments that translate into enhanced physical performance. Let us consider the East African cohort of exceptional athletes that dominate marathon performance. Since entering international marathon competition in 1960, East Africans have competed at the front of the pack and now hold the top 10 men's marathon times.[4] Just recently, they swept the 2500 year anniversary of the Athens Classic Marathon, setting a new record for the event. Their exceptional performance in long-distance events has intrigued biologists, geneticists and other enthusiasts who have spent considerable amounts of time conducting experiments to expose biological reasons for East African domination. Potential explanations include, but are not limited to, training at high altitude, increased levels of physical activity, fatigue resistance, differences in running economy and genetics.[5] The important connection between early life factors and elite performance, however, has not yet received much attention.

Prenatal exposure to high altitude generates important vascular adjustments, particularly in individuals of multigenerational high-altitude ancestry.[3] Indeed, these adaptations are not reported in shorter-term residents of highland destinations who often demonstrate reductions in birth weight with increasing altitude.[6] The strong protective influence of high-altitude ancestry on foetal growth stems from genetic adaptations causing increased blood flow in the uterine artery, the main provider of oxygen delivery to uteroplacental circulation.[7] This adaptation exerts a strong influence on the offspring's cardiopulmonary function that may reduce the incidence of arterial desaturation observed during heavy exercise in elite performers. That these adaptations at high altitude can contribute to the development of a later life phenotype preprogrammed for prime physical performance is a matter that remains elusive. Yet, organisms have the ability to adapt in order to improve their fit with the environment that has a lasting influence on later life biology. For example, Tibetans, whose ancestors have been living at altitudes >3000 m exhibit exceptional running economy during submaximal exercise compared with acclimated lowlanders.[8] Tibetans diverged from the Han population in China approximately 2750 years ago and now exhibit considerable genetic differences from the Han people.[9] This important finding indicates a very fast rate of natural selection to cope with the stress of hypoxia. Generally, genetic adaptations in humans require longer time periods; for instance, the frequency of lactase persistence allele in northern Europe rose within the course of about 7500 years.[10]

Developmental plasticity also appears to be 'moulded' for the convenience of 'fitting' with an organism's lifestyle. This concept of different developmental trajectories in response to the environment is well characterised in many insect and vertebrate species.[11] It is, therefore, no surprise that early physical activity levels are associated with healthier later life phenotype.[2] For example, postweaning access to a running wheel prevents the development of obesity in rats prone to develop diet-induced adiposity.[12] Moreover, adult rats that were physically active early in life also show lower circulating levels of inflammatory cytokines and a leaner phenotype, characterised by lower body mass, and increased lean mass.[2] Horses also harness structural adaptations dictated by physical loading during early life that, in turn, translate into improved later

Br J Sports Med 2011;45:1000–1001. doi:10.1136/bjsports-2011-090198

life functional joint capacity.[13] In humans, early life physical activity contributes to increased left ventricular mass, myofibrillar protein, motor coordination and reduced inflammatory cytokine levels during adulthood.[14] Furthermore, this early life physical activity is also linked with information processing speed, possibly due to the stimulation of trophic factors and neuronal growth or from augmented cerebral circulation through increased vascularisation of the brain.[15]

Increasing lines of evidence support that exposure to altitude and early metabolic adjustments during critical periods of early development exert a strong influence in later life physical performance.[2 3] Indeed, these factors are common features of the East Africans currently dominating marathon running– the prime archetype of a human physical endeavour. For instance, the birthplace of the current top 13 marathoners, all of East African origin, was above 1500 m, confirming an early life exposure to altitude.[16] Additionally, considerable levels of physical activity are inherent in East African early life, and their effects on physical prowess have been previously confirmed.[17] It appears, therefore, that East Africans' success may stem, at least in part, from early life factors that favourably mould their biological systems. That multigenerational protection of foetal growth at high altitudes results from genetic adaptations raises interesting questions regarding the possibility of multigenerational genetic adaptations from physical activity. No one biological factor will explain why an individual excels in elite physical competition, which causes complications when examining a single theory such as early life influences on later life physical performance. Perhaps these early lifestyle factors collide with a genetic advantage to induce biological changes that allow for a more robust biological response to training in later life. But does the genetic advantage occur from multigenerational adaptations? Genetic endowment is often reported as a plausible explanation for why the small group of individuals from the Kenyan Kalenjin tribes dominates marathon performance. Indeed, it has been reported that the Kalenjin people migrated to their present location over 2000 years ago and therefore, may have experienced genetic adaptations similar to those reported in Tibetans.[18] In light of this, an interesting avenue for future work is to examine the genetic differences between Kalenjin people and lowlander Kenyans, as well as other multigenerational high-altitude populations such as Tibetans. A clear understanding of how different systems develop and work together to create a human phenotype ideal for prime physical performance should continue to be projected in future research.

Funding This work was supported in part by funding from the European Union 7th Framework Program (FP7-PEOPLE-IRG-2008 grant no. 239521).

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. **Flouris AD**, Spiropoulos Y, Sakellariou GJ, *et al.* Effect of seasonal programming on fetal development and longevity: links with environmental temperature. *Am J Hum Biol* 2009;**21**:214–16.
2. **Buchowicz B**, Yu T, Nance DM, *et al.* Increased rat neonatal activity influences adult cytokine levels and relative muscle mass. *Pediatr Res* 2010;**68**:399–404.
3. **Julian CG**, Wilson MJ, Moore LG. Evolutionary adaptation to high altitude: a view from in utero. *Am J Hum Biol* 2009;**21**:614–22.
4. IAAF. http://www.iaaf.org/statistics/toplists/inout=o/age=n/season=0/sex=M/all =y/legal=A/disc=MAR/detail.html (accessed 10 March 10 2011).
5. **Holden C**. Peering under the hood of Africa's runners. *Science* 2004;**305**:637–9.
6. **Wilson MJ**, Lopez M, Vargas M, *et al.* Greater uterine artery blood flow during pregnancy in multigenerational (Andean) than shorter-term (European) high-altitude residents. *Am J Physiol Regul Integr Comp Physiol* 2007;**293**:R1313–24.
7. **Julian CG**, Vargas E, Armaza JF, *et al.* High-altitude ancestry protects against hypoxia-associated reductions in fetal growth. *Arch Dis Child Fetal Neonatal Ed* 2007;**92**:F372–7.
8. **Marconi C**, Marzorati M, Sciuto D, *et al.* Economy of locomotion in high-altitude Tibetan migrants exposed to normoxia. *J Physiol (Lond)* 2005;**569**:667–75.
9. **Yi X**, Liang Y, Huerta-Sanchez E, *et al.* Sequencing of 50 human exomes reveals adaptation to high altitude. *Science* 2010;**329**:75–8.
10. **Itan Y**, Powell A, Beaumont MA, *et al.* The origins of lactase persistence in Europe. *PLoS Comput Biol* 2009;**5**:e1000491.
11. **Fusco G**, Minelli A. Phenotypic plasticity in development and evolution: facts and concepts. Introduction. *Philos Trans R Soc Lond, B, Biol Sci* 2010;**365**:547–56.
12. **Schroeder M**, Shbiro L, Gelber V, *et al.* Post-weaning voluntary exercise exerts long-term moderation of adiposity in males but not in females in an animal model of early-onset obesity. *Horm Behav* 2010;**57**:496–505.
13. **Brommer H**, Brama PA, Laasanen MS, *et al.* Functional adaptation of articular cartilage from birth to maturity under the influence of loading: a biomechanical analysis. *Equine Vet J* 2005;**37**:148–54.
14. **Mattocks C**, Deere K, Leary S, *et al.* Early life determinants of physical activity in 11 to 12 year olds: cohort study. *Br J Sports Med* 2008;**42**:721–4.
15. **Rogers RL**, Meyer JS, Mortel KF. After reaching retirement age physical activity sustains cerebral perfusion and cognition. *J Am Geriatr Soc* 1990;**38**:123–8.
16. **Flouris AD**, Carrillo AE. Influence of early life factors on elite performance. *J Appl Physiol* 2011;**110**:284; discussion 294.
17. **Saltin B**, Larsen H, Terrados N, *et al.* Aerobic exercise capacity at sea level and at altitude in Kenyan boys, junior and senior runners compared with Scandinavian runners. *Scand J Med Sci Sports* 1995;**5**:209–21.
18. Wikipedia. Kalenjin people. http://en.wikipedia.org/wiki/Kalenjin_people (accessed 10 March 2011).

BJSM

Early life mammalian biology and later life physical performance: maximising physiological adaptation

Andres E Carrillo, Yiannis Koutedakis and Andreas D Flouris

Br J Sports Med 2011 45: 1000-1001 originally published online July 27, 2011
doi: 10.1136/bjsports-2011-090198