

Award Holder

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Title of Research

Human locomotor versatility: Morphological trade-offs (or not) in the body proportions of climbing and bipedal athletes

Period of Field Work

Feb 2024 – Feb 2025

Amount of original award and expenditure to date

Original award: £5,574

Expenditure to date: £5,261.08

Period covered by this report (if different from 4. above)

Fieldwork: Feb 2024 – Feb 2025

Analysis: Feb 2025 – Feb 2026

Changes to original award

Changes to the original award were made as discussed in the previous interim report, shifting from international fieldwork with hunter-gatherer societies to UK-based fieldwork with athletes due to ongoing health issues. Since then, the proposed and piloted collaborative work with Swansea University as detailed in the interim report was removed, due to issues with feasibility and respirometry equipment on their side, shifting the entire focus of the project to the body proportion work with athletes across the UK and Ireland. This fortuitously allowed a much larger sample size to be achieved and, as a result, the some very interesting results as detailed below.

Publications

A journal article pertaining to this fieldwork is currently in preparation.

Dissemination

A journal article pertaining to this fieldwork is currently in preparation. The work has also been included in my PhD thesis, submitted August 19th 2026.

Report of work

Over the course of human evolution, our species has developed a highly specialised body plan suited for bipedal (two-legged) locomotion: running and walking. The conventional assumption is that this bipedal specialisation came at a cost to other forms of locomotion, and especially, climbing. This assumption permeates the field of evolutionary anthropology, forming the basis for a major tenet of fossil hominin behavioural inference. In such cases, similar morphological (anatomical) signatures to those found in humans are typically assigned to bipedal modes of locomotion, while those more in keeping with chimpanzee morphology are assigned to climbing.

However, this form-function paradigm of fossil hominin locomotor inference has been challenged repeatedly on numerous grounds. Not least, humans can climb, and remarkably well. Indeed, hunter-gatherers around the world exhibit high levels of proficiency in tree and rock climbing, with some societies depending on climbing for the majority of their subsistence at certain times of year. In some measures of performance, such as height climbed, humans have even been reported to outperform other predominantly arboreal great ape species. Recent research has shown that climbing is routinely engaged in by hunter-gatherer societies worldwide and is not restricted to only specific communities nor the product of unique society-specific adaptations. It is evident that, despite our species' derived bipedal morphology, we have found ways to climb to high levels of ability.

Not only does this throw a spanner into traditional methods of fossil hominin behavioural inference, but it also raises a major question: given an anatomy so specialised for bipedal locomotion, how is such high proficiency non-bipedal locomotion possible? The first step in answering this question is to understand exactly the extent to which said bipedal morphology actually affects high proficiency non-bipedal locomotion—does a progressively more specialised bipedal body plan actually detract from our ability to climb as the prevailing view suggests, or is it more nuanced? To understand this requires examining the limits of performance in each locomotor modality in the context of morphological variation, thus allowing an understanding of how changes in morphology lead to changes in performance potential.

Enter athletes. While the focus of much research, athletes from industrialised human societies have been studied only peripherally in the field of human locomotor evolution. However, they represent an abundant and accessible model by which to explore trade-offs in locomotor performance; indeed, athlete models possess several useful qualities. First, various sports represent direct analogies to the locomotor disciplines of human evolution. Second, athletes present an easily accessible source of data that spans a continuous range of locomotor proficiency, from recreational engagement to optimally trained elite performers, all consistently oriented toward the same overarching performance goals. Finally, athletes represent a unique case of maximal performance, in which, broadly speaking, each individual will attempt to demonstrate the limits of their ability subject to their specific constellation of morphological and physiological assets. At the top end, this inevitably tends to the maximal levels of performance for our species, as all factors of investment, morphology, physiology,

and their respective cultural influences are optimised. Such a model thus conveniently solves a central frustration in animal performance research, that it is impossible to know how close any given behaviour of animal is to its maximum proficiency. Knowing this, as with athletes competing at a maximal level, allows for more accurate enquiries concerning the link between morphology and performance. While sports science has a long history of morphology-performance enquiry, when viewed from an evolutionary perspective such research typically examines competency in each sport in isolation, with comparisons across studies and sports hindered by variation in the skeletal measurements examined, measurement protocols, and the outcome variables measured.

Thus, I set out to collect a standardised suite of body proportion data across both rock climbing athletes, and athletes of three bipedal sports: long-distance running, sprinting, and race walking. The hypothesis was that, if a morphological trade-off between bipedal and climbing performance does exist, then we would see athletes of the two domains diverge to opposite ends of the scale of morphological variation in body proportions of relevance.

Fieldwork began slowly, as I exploited the various sports clubs and college networks at the University of Cambridge to reach out to a variety of athletes and control (non-sporting) participants. As I measured increasingly more individuals, I gradually refined my initial suite of measurements to a set of about 12 measurements that I could conduct in about 20 minutes per individual. However, it soon became clear that I was running out of leads.

The first big breakthrough came when I managed to get an advert into the Cambridge Half Marathon mailing list, flooding my dataset with long distance runners of a broad range of ages and ability levels. However, after about 6 months of data collection my dataset was still very thin on climbers, sprinters and race walker, and most critically on elite athletes of all sports. For the study to work at all, I would need a good sample of athletes at the highest levels of performance. After all, one would not expect body proportions to make all that much of a difference in sport until all other determinant aspects such as training have been optimised across the board—something that is only true among the elites. Essentially, body proportions are obscured at lower levels of ability because training is by far the more important determinant of performance.

This was the point at which the Emslie Horniman Scholarship funding really pushed the project forward, allowing me not only to offer small monetary incentives for participation, but also to travel to groups of interest rather than relying on finding them in the vicinity of Cambridge. I was also able to employ research assistants, speeding up my rate of measurement by double.

I travelled around the country, visiting UK Athletics Talent Hubs in Leeds and Loughborough, working in climbing gyms in Sheffield—the home of UK rock climbing—and even travelling to Dublin to enter the bizarrely fascinating world of professional race walking. During these visits I met and measured some of the world's best rock climbers and runners, both present and of past decades. My sample size slowly grew to over 300 individuals—a huge sample by the standards of research conducted to date thus far in the field.

Finally, data collection finished, I sat down to analyse the results. After much deliberation, the analysis eventually took the form of a pair of Bayesian models that essentially looked at the association between each body proportion and performance. The first model tested associations between body proportions and proficiency while the second model tested for differences in body proportions between elite athlete groups as standardised to a control population. I then quantitatively compared the strengths and directions of these associations between sports to calculate the probability of morphological trade-offs between locomotor disciplines. This was conducted for each of the body proportions in turn, as well as in relation to control body proportions such as height to understand whether the patterns differed for absolute versus relative body proportions. An overview of the study is shown in Figure 1.

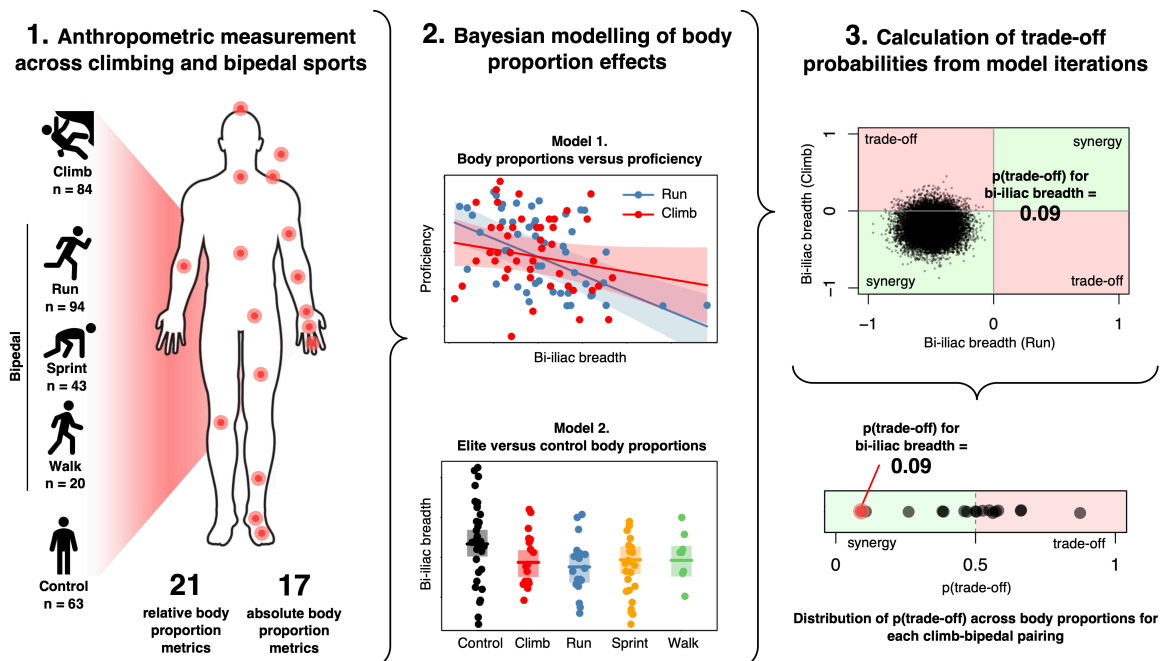


Figure 1. For each of body proportion metrics measured, effect was modelled (shown here for bi-iliac breadth, for illustrative purposes), both in terms of association with proficiency (in relation to running and climbing), and in terms of deviation of elite athletes compared to a control population (across all climbing, running, sprinting, and walking populations). For each model, sex, and climb-bipedal comparison, paired effects for each body proportion metric were then examined for climbing versus respective bipedal disciplines, and the probability of a trade-off (different effect sign directions) calculated. Across body proportions, a low mean $p(\text{trade-off})$ indicative of synergy of body proportions between climbing and bipedal sports was found for both models, sexes, and across all bipedal-climbing pairings.

The results were surprising. I had expected to find an inconclusive mosaic of associations with different body proportions mattering in different sports, perhaps with one or two clear trade-offs where a particular body proportion helped performance in bipedal sports but hindered performance in climbing. The findings however were far more interesting.

Overall, there were 304 total comparisons made; these included every combination of relative or absolute body proportions for climbing versus each bipedal sport, across male and female

participants, across the two statistical models in the analysis. Of these 304 comparisons, not even one exhibited a clear likelihood of a trade-off—that is body proportion effect direction in different directions—between climbing and bipedality. Instead, 22 comparisons demonstrated a high probability of synergy—that is, a body proportion effect in the same direction for both climbing and bipedal performance. What is more, when mean probabilities of trade-off were calculated across all body proportions, each of the climbing versus bipedal sport comparisons, across both sexes and both models, demonstrated a tendency towards synergy rather than trade-off.

In short, my data show no evidence for morphological trade-offs in skeletal body proportions between bipedality and climbing in human athletes. In many cases, traits that were good for bipedal performance were actually also good for climbing performance. Therefore, while functional trade-offs between climbing and bipedality in other physiological or anatomical domains may well exist, at least concerning the broad skeletal proportions of humans, our lineage has developed ways in which to climb that are complementary with the traits that promote bipedal proficiency. It isn't the case of climbing performance in humans just making the best of a bad situation but rather being actively aligned with a bipedal anatomy.

Evolutionary, these results support the continued persistence of high proficiency tree climbing alongside a bipedal lifeway in the context of an upright bipedal morphology, pushing back against the use of human-like anatomy as diagnostic of arboreal incompetence in fossil hominins. While the initial evolution of a bipedal body plan in early hominin evolution will of course have resulted in reduced climbing efficiency, my results raise questions as to the traditional assumption that such a trade-off continued into later human evolution.

Building on existing research that conclusively evidences that humans can climbing well, this work takes the existing research a step further. It begins to uncover how we have been able to achieve such climbing prowess despite our bipedal anatomy. The fact that human climbing appears to have been aligned with bipedal specialisation now sets the scene for further insight into how this is even possible—exactly how and when did hominin climbing techniques and physiology adapt to maintain high levels of ability under a fundamentally bipedally adapted body plan?