Occasional pieces

Paleo-bioenergetics: the metabolic rate of marching Roman legionaries

Brian J Whipp, Susan A Ward, Mark W C Hassall

Plausible estimates for the metabolic demands, or limits, of sustained high energy activities are difficult to establish for ancient cultures. While the builders of the Mesopotamian ziggurats and Egyptian pyramids, and the trireme rowers of ancient Greece, for example, assuredly had high sustained rates of energy expenditure, the actual work rates involved are not known with sufficient accuracy to establish metabolic equivalents.

In Vegetius' *Epitoma rei militaris* (translated as *Epitome of military science*¹), however, there is detailed information about march speeds, distances travelled, and weight carried by the ancient Roman legionaries on their prolonged marches. We are informed, for example, that the legionaries were trained to march 20 miles in five summer hours at the "military step", or 24 miles in the same time at the faster "full step". When training at the full step, they were unladen; during the military step march they were required to carry 60 pounds, equivalent to the weight of the armour, weapons, and rations that would be required on a real combat related march.

As the Roman mile was equivalent to 1665 modern Imperial yards, the Roman pound was 0.721 pounds avoirdupois, and the hour was then a flexible unit of one twelfth of the daylight hours (the standard modern hour being a relatively recent—that is, 14th century—development), this corresponds to a march rate of some 3.4 mph at the full step and 2.85 mph at the military step, carrying 43 lb 4 oz avoirdupois. Estimating the equivalent metabolic rates therefore depends on reasonable estimates of the size of the legionaries. Vegetius informs us that "The height of recruits was, I know, always required to be up to the incommo so that men of 6 foot or 5 foot 10 inches were approved for the alares cavalry or the First cohort of the legions", a minimum height of between 5 foot 11 inches and 5 foot 9 inches in modern measure, with "broad chest, muscular shoulders, strong arms"; a body weight of 80–90 kg would therefore seem a reasonable estimate. To provide an appropriate context for this surprisingly tall minimum height, the excavations at Poundbury² suggest that 5 foot 5 inches was an average height and 5 foot 7 inches was considered to be "quite tall" for a male Briton of this Roman period.

On the other hand, there are also suggestions that runners in the Ancient Olympic Games, at

least sprinters, might also have been "surprisingly tall". In *Greek athletes and athletics*,³ Harris describes the discovery of what would now be termed starting blocks during the excavation of the stadium at Corinth: "Each man has a pair of holes cut in a stone slab, left foot in front of right, twenty-five inches apart—uncomfortable for a runner less than six feet tall."

The information from Vegetius therefore allowed us to estimate the metabolic demands of the prolonged marches of these Roman legionaries⁴ from the results of experiments on appropriately sized men walking on the level treadmill at speeds equivalent to the military and full steps. The unladen full step resulted in a mean $\dot{V}O_2$ of 1.43 (0.05) litres/min (mean (SD)). Interestingly, the military step, with the subjects laden with weights totalling 20 kg distributed to the ankles, wrists, and shoulders (5, 5, and 10 kg respectively), resulted in a $\dot{V}O_2$ response that was remarkably similar—that is, 1.42 (0.10) litres/min.

Additional contributions from terrain variations, unfavourable wind conditions, elevation

Department of
Physiology, St George's
Hospital Medical
School, London
SW17 0RE, UK
B J Whipp

Sports and Exercise
Science Research
Centre, South Bank
University, London
SE1 0AA, UK
S A Ward

Institute of
Archaeology,
University College
London, London
WC1H 0PY, UK
M W C Hassall

Correspondence to:
Professor Whipp.

Accepted for publication
13 February 1998

changes, further increases in body and muscle temperature, and a shift to a greater proportional contribution of fatty acids as the oxidative substrate (as glycogen stores become depleted) would be expected to add at least a further 20% to the average metabolic demands of the prolonged march.

As sustained activity of this duration is likely to be performed at or below the lactate threshold (on average, about 50% of the maximum $\dot{V}O_2$ in normal subjects), a value of 3.5 litres/min, or some 40 ml/kg/min, seems reasonable for the $\dot{V}O_{2MAX}$ of the most poorly accomplished of the first cohort. We know this, as failure to maintain the march pace was traditionally punishable by death.¹ How much higher might be characteristic of the most accomplished legionaries can only be conjectured.

These estimates of the paleo-bioenergetics suggest that the ancient Roman legionary was a

well trained endurance athlete, even by modern military standards. But it is also apparent from the equivalence of the metabolic rates of the unladen full step and the laden military step that the ergonomic advisers to the Roman military seem to have had a good understanding of the energy demands of sustained activity. How they established this challenges the imagination.

The authors are grateful to Dr Theya Molleson and Mrs Pat Chapman for helpful advice and discussion.

- 1 Milner NP. *Vegetius: epitome of military science*. 2nd revised ed. Translated Texts for Historians, vol 16, Liverpool University, 1996.
- 2 Molleson T. The anthropological evidence for change through Romanisation of the Poundbury population. *Anthrop Anz* 1993;50:179–89.
- 3 Harris HA. *Greek athletes and athletics*. London: Hutchinson & Co Ltd, 1974:67.
- 4 Whipp BJ, Ward SA, Hassall M. Estimating the metabolic rate of marching Roman legionaries. *J Physiol (Lond)* 1996; 491P:60.

Three miles high and one hundred miles from the nearest road

David Buckler

The Everest Marathon is no ordinary race. It is a biannual marathon starting at 17 100 feet, run over the full marathon distance of 26.2 miles. It is listed in the *Guinness Book of Records* as the marathon with the highest starting point in the world. Most runners take about twice as long as they would to complete a road marathon at sea level. Getting to the start is no easy task; the athletes spend 18 days trekking to the start line which helps them to acclimatise to the hypoxia of altitude. Each athlete must pass medical tests before being considered for entry, and on the day before the race there are further tests to exclude those not fit enough to run the distance.

In 1997, 88 prospective racers started the trek to base camp, 72 of whom were eventually able to complete the race and 14 of whom completed at least part of the race. There was a further 30 member support team, themselves backed up by 50 sherpas and porters. The medical team consisted of 10 doctors and an osteopath.

The runners were divided into three subgroups for the trek into Everest base camp, and I was one of two doctors looking after a group of 19. The trek to base camp was through an area where there was no prospect of medical aid in an emergency, so we had to be self sufficient. Base camp itself is “three miles high and 100 miles from the nearest road head.”

In our group there were 19 competitors, 15 runners, two doctors, one leader, and a marshall. We were also responsible for the wellbeing of our sherpas.

Of the 15 potential competitors, nine completed the race. One competitor was unable to start the trek because of a previous knee injury. An effusion was drained from his knee but he subsequently developed a septic effusion requiring parenteral antibiotics. One unfortunate lady developed chickenpox! This required evacuation back to base at Namche Bazaar. Two runners had altitude sickness sufficient to prevent them getting to the start line. The final runner seemed to lose interest in attempting the race, although no formal diagnosis was reached.

In spite of the widespread use of iodine, water boiling, commercial filters, and hand cleaning solutions, diarrhoea and vomiting were a problem that no participant escaped. This was treated symptomatically with fluids and Imodium. Giardiasis was diagnosed clinically in five people and all responded to treatment with metronidazole.

There was an extraordinary variety of injuries. Eight of the 14 competitors suffered blistering of the feet at some stage sufficient to merit medical advice; why do people buy new boots to trek to Everest? One person had an attack of cellulitis related not to blisters or trekking, but to the stasis of a prolonged airline flight; this responded quickly to flucloxacillin. There were two episodes of minor trauma, both related to overzealous athletes going for training runs on rocky terrain after a long days walk. Three people were stung repeatedly by bees after disturbing their nest.

Abington Medical
Centre, Beech Avenue,
Northampton
NN3 2JG, UK
D Buckler

Accepted for publication
8 May 1998

During the trek two people had severe anterior knee pain, especially after long descent days. Both had had this problem before and were treated with anti-inflammatories, exercises, and quadriceps stretches. One enthusiastic runner suffered an intra-articular effusion in an already osteoarthritic left knee, due to over-use. He took our advice to rest it before and after the 10 mile trek each day! One left anterior talofibular strain occurred when the athlete had taken his boots off for lunch and slipped on a discarded chapati (not quite a sports injury). A hyperextension injury to the left thumb occurred during a fall into a river; the thumb was strapped for the rest of the trip.

As we climbed above 13 000 feet the problems encountered changed, and there was greater risk of life threatening problems. At the highest altitude reached, 5500 m (18 450 feet), almost everyone had symptoms caused by the altitude; normally at this altitude 50% of people would be expected to suffer altitude sickness. We only attained this altitude for one afternoon. The trip was optional and anyone unsure about their acclimatisation were advised to avoid it.

The start line was at 17 100 feet and could be reached without going above this height. We had had three weeks of gradual acclimatisation and athletes were warned frequently of the signs of altitude sickness. Two runners took prophylactic Diamox as they had had one or more bouts of documented altitude sickness. Neither of them had altitude problems. Three others had altitude sickness sufficient to merit emergency evacuation to an altitude 1000 feet lower. One recovered the next day and had sufficient time to regain the height and run the

marathon. Two others were unable to regain the height and started the race from the 3 mile point. One completed the 23.2 mile course, but the other had to pull out at 15 miles.

The “Kumbu cough” (named after the icefall) is thought to originate from the dust on the path and the intense cold (down to -15°C). Many people had different remedies for this, varying from nasal sprays to nasal wideners. Requests for antibiotics were frequent as the start of the race came closer and needed careful explanation of the causation. Three people had chest infections needing treatment with antibiotics.

Before the final 1000 feet to the start, each athlete had to pass a medical examination. This consisted of questions aimed at detecting altitude sickness, chest auscultation, Romberg’s test, heel to toe walking, and finger to nose coordination. The runners’ numbers were used as their set of notes and all problems and medications were entered on these.

Our extensive pharmacy covered most eventualities. We also carried oxygen, dexamethasone, nifedipine, and a Gamov portable recompression chamber, although none of these were used.

On the day of the race there was 3 inches of fresh snow. Although the potential for medical disaster was high, the day passed relatively free of incident. One athlete slipped on a patch of ice and sustained a clinical fracture of his right fifth rib, and one doctor fell and fractured a finger.

The winning time was 4.15.29 hours, quite an achievement. There has never been a serious incident during this race, which, considering the terrain, is amazing, but the potential for disaster remains high.

American Institute of Sport facilities administration building, “Pole vaulter” by John Robinson. Reproduced with permission.

Looking back to 1953—from earliest days?

David Ryde

It seems so long ago; or was it only yesterday? As a house physician, mildly obsessional about sport and the health of athletes, I promptly responded to a 1953 *BMJ* advert proposing the formation of a “British Association of Sports Medicine”, and which led to eight original members. There was Sir Adolphe Abrahams (elder brother of Harold), physician to the 1948 British Olympic team, Sir Arthur Porritt, an Olympic sprint finalist, Dr Bill Tucker, an osteopath to Royalty, a Loughborough chest physician who was doctor to the national swimming team, three others whom I cannot recall, and myself. I vaguely recall the first BASM meeting, held I believe at the Meyerstein Lecture Theatre of the Westminster Hospital, and attended by a modest audience. It was chaired by Sir Arthur and addressed by Sir Adolphe.

From January 1954 there were regular BASM meetings, initially held at the Westminster, but also at the Middlesex and elsewhere, with growing audiences. When Sir Harold Himsworth, head of the MRC, spoke in the autumn of 1955, it was to a packed house at the Royal Military Hospital at Millbank.

These early BASM meetings were exciting, original, and informative and on what today could be considered basic subjects, such as the nature of stitch, oxygen consumption while running on a treadmill, the effects of smoking on exercise and health, the value of physiotherapy (I think that speaker was Donald Featherstone, physio to Southampton Football Club, in 1956), and should women compete in races over 880 yards or in early pregnancy? By the late fifties BASM lectures were attended by larger audiences, and a weekly sports injury clinic had opened at the Middlesex. I recall the dedicated work of Henry Robson, the *BASM Journal* editor for many years and other pioneers including John Williams and Peter Sperryn. Over nearly the past half century these doctors have turned BASM from a bunch of enthusiastic amateurs into a respected international association.

During this time I provided medical cover at many sports events, gave several lectures at Loughborough College, and submitted numerous articles and letters to sport and medical journals. “The effects of strenuous exertion on women” a completely original piece, finally

appeared in *The Practitioner* in July 1956 and drew 81 letters, from every continent, with comments and requests for copies. Authors received 100 reprints for distribution since copying facilities were then sparse and primitive. I even dared to suggest in one of my articles that gentle training under observation might be beneficial in some cases of heart disease! In those days a heart attack meant being confined to a hospital bed for six weeks!

In 1963 I was appointed the first Hon MO to the new National Sport Centre at Crystal Palace, although for a busy single handed GP this was at times a difficult task-master. I recall being one of the speakers at a BASM conference in 1963. There were speakers from Europe and America. I sat next to Dr Lou Blonstein, the Olympic boxing doctor, also a speaker. Lou was quite supportive of me, realising I had not spoken at that level before. My subject was “Psychology in sport”!

I have practised clinical hypnosis since 1956 which I often applied to sports and injuries. One of my papers appeared in *Minerva Medica* (an Italian sports medical journal with all articles followed by summaries in several languages) around 1965, being a study and follow up of 204 conditions, mainly injuries, many of them chronic, that had been unresponsive to conventional therapy. Some of my results were indeed gratifying. I did drop several gentle hints that I would be prepared to give a lecture on this subject to BASM, but there appeared to be little interest, especially in those days.

In the early days, sports medicine was an adventure into unknown but exciting territory, while today it is a specialty with subdivisions and much of it quite beyond me. I presume that players are better off because of this, although I do wonder at times if modern techniques, diet, and professionalism can push some people too far and too hard towards achieving records. Is training and sport quite the fun that we knew it to be? Does commerce dictate terms to players or demand too early a return to competition following sickness or injury? Or am I just getting old and out of touch? Maybe, but I still enjoy participating in many sports, and being a vegetarian of longstanding and a vegan for the past 12 years I’m always “starch loaded” and bubbling with energy.

17 Apsley Road,
Oxford OX2 7QX, UK
D Ryde

Accepted for publication
23 April 1998