Avoiding the Pheidippides Effect: How Theories Contribute to Endurance Trail Practice

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Abstract

Ultra endurance sport has shown a significant increase during the last couple of decades. This paper focuses on theories which explain the phenomenal efforts ultra endurance athletes face when running extreme distances. These ultra athletes have to endure physical pain and mental distress for long hours or even days before crossing the finishing line. This extreme running on technical terrain requires considerable physiological effort (Millet, Hoffman, & Morin, 2012). Freund et al. (2012), states that as a consequence of running such distances, runners will experience muscle soreness, cramps, ruptured muscle fibres that lead to myalgia and myofascial pain, compartment syndrome, inflammation of tendons and joint capsules, and fatigue fractures. And yet, none of them succumb to their injuries or exhaustion under normal conditions, as in the case of Pheidippides.

Various theories argue that the body is a high functioning machine which depends on physical measures to determine its efficiency while others put the brain as central to endurance practice and argue that the brain is the ultimate regulator which is there to protect the body. The athlete can never be harmed as the brain is taking measures so that body systems are never in distress. The beating heart is protected and catastrophe cannot occur.

This paper illustrates various diverse theories which posit different arguments regarding extreme running and how it is actually achievable, without the athlete perishing due to the effort.

Keywords: *endurance, ultra distance running, physiological theories, brain centered theories*

Introduction

The history of ultra distance running can be traced back to two million years ago when the Homo species started evolving and exploring. A mummified male corpse of an ice man in the Swiss Alps offers evidence of the first recorded ultra distance journey (Rollo et al., 2006).

The International Association of Ultra runners (IAU) considers ultra running events as:

Road races, trail races or track running events either indoors or outdoors, beyond the distance of the Marathon; the standard distance recognized by the International Association Athletics Federation (IAAF) is the 100km on road; the other standard distances and events recognised by IAU (on road and track) are 50km, 6 hours, 100 miles, 24 hours, 48 hours, 6 days and 1000 miles, as well as the 100km on the track (www.iau-ultramarathon.org).

The first recorded ultra distances which surpass any other previous events were the Arctic expeditions of the early 20th century. Noakes (2006), describes the Herculean efforts of Robert Scott in 1911/12 and Ernest Shackleton in 1914/16 when they traversed extreme distances across the arctic and argues that such endeavors depend on the willingness and volition of the mind.

Ultra distance running has seen the most positive increase in popularity during the last decades. It has increased both in terms of registered races and also in terms of participants. During the year 2000, 43705 ultra runners participated in such races whereas in 2018 the number increased to 354616. (http://statistik.d-u-v.org/index.php).

Pathophysiology

Statistics show that athletes are finding appeal in extreme running events that require specific skills, endurance and fitness which are most likely to lead to injury either during the grueling training or during the race itself. Knechtle & Nikolidis (2018) confirm that ultra marathon running is stressful to various body systems including the immune, the cardiovascular, the skeletal, the digestive system and various organs including the liver and kidneys and that completing an ultra marathon has no “immediate health benefits” (p. 24).

The data is clear, ultra trail racing is becoming a very popular endurance sport albeit proving to be very difficult, demanding and high risk. But can all this pathophysiology lead to catastrophe as in the case of Pheidippides? Various theories argue in favour of long distance practice and explain how such feats of endurance are achievable.

Theories behind endurance race practice

Millet & Millet (2012), claim that ultra marathon running is “probably one of the most demanding physical exercise in humans, maybe only overpassed by polar expeditions” (p.1).

In their systematic review, Knetchtle & Nikolaidis (2018), quote Rüst et al., (2012) arguing that ultra marathon runners do more weekly mileage, albeit slower than marathon runners, have a higher pain tolerance (Freund et al., 2013) than other populations and this gives them the ability to run longer distances.

While studying North American Ultras, Hoffman et al. (2010), considered race results over a 30 year period (1977-2008) and found that the number of races and finishers has increased at an accelerated rate. Trail races which accounted for 51 out of the 53 hundred milers in North America, seemed more appealing than road ultras.

When running on mountain trails, ultra trail athletes run extreme distances and times while traversing mountain passes at high altitude in difficult conditions. The topography is mostly mountain and forest paths with exposed roots and rocks, streams and rivers, scree and huge elevations, kilometers long with extreme gradients. The sheer distance on uneven, non-elastic terrain, and long descents have a negative effect on the leg muscles (Giandolini et al., 2016; Eston et al., 1995), which become painful and damaged, the effects of which can last for two days post run (Giandolini et al., 2016; Easthope et al., 2010).

Athletes also run at altitude, and although the effects of anoxia are not debilitating at altitudes of 2000m-2500m, which are the typical elevations of mountain ultras, there is a noticeable effect on running performance (Marcora, 2009; Millet et al., 2012) so much so, that athletes experience nausea, headaches, dizziness and reduced VO_2 max (the optimal rate at which oxygen can be utilized), which overall reduce endurance and perhaps the will to continue.

Sleep deprivation (Drummond et al., 2006) is also a major issue ultra runners have to overcome when running an ultra of at least a 100km. Running for more than 24 consecutive hours means that the athletes have to run through 2 nights (long ultras start at midnight) and fight the urge to sleep while trying to keep on the trail using the light from their headtorch.

According to Marcora & Staiano (2010), any adverse stimulus increases the sense of effort and therefore reduces the endurance capacity because the activity feels more difficult. When Keramidas et al. (2018), studied the physiological and psychological data of well-trained subjects during a 2day training camp with partial sleep deprivation, they established that sleeplessness was correlated to, "cardiorespiratory and psychological strain, and reduced the high-intensity constant-load cycling capacity" (p.1378). Hurdiel et al. (2015), established that Ultra Trail du Mont Blanc (UTMB) participants who have to run through two nights during the 46.5 hours cut off time, suffered from reduced cognitive activity, loss of balance and one even suffered from transient amnesia for the duration of an hour.

Other painful physical stressors include gastrointestinal distress, (Stuempfle et al., 2013; Gil et al., 1998), exposure to heat and humidity, (Maughan & Shirreffs, 2010), vision loss (Høeg, 2015), dehydration (Hoffman et al., 2018) and also mental fatigue (Van Cutsem et al., 2017).

Millet et al. (2012), also acknowledge muscular damage and gastrointestinal distress as race stressors which need to be addressed during an ultra.

The body is a machine: Endurance depends on physiology

According to Joyner & Coyle (2008), endurance practice is determined by the VO_2 Max, lactate threshold and efficiency (ratio of output power to input power). These physiological measures have been investigated thoroughly and elite athletes tend to have high values of such parameters. In theory, these quantities ensure that an athlete has the physical attributes to be successful, but when actually racing with competitors who have similar measures, will physiology dictate the winner? Andrew M. Jones certainly thought so when he collaborated with Paula Radcliff when she trained and achieved the world record for the marathon. These factors were certainly the winning formula Radcliff used to set a new record in the female marathon distance. Jones (2006), reviews the evidence based physiological methods used to enhance endurance running output. This method based solely on values and numerical certainties presented world breaking results and "15 years of directed training created the 'complete' female distance runner…" (abstract, p.101). Jones' work on the physiology of running fuel the 'human machine' arena without acknowledging other factors like motivation.

The theory that human endurance is thoroughly dependent on the cell and muscle physiology was initially investigated by A.V. Hill (Hill & Lupton, 1923).

Hill's theory was based on the assumption that the body is a machine limited only by physical boundaries. He devised the first means of measuring the maximum uptake of oxygen by the muscles, called the VO_2 Max, which is still a very useful tool for measuring the efficiency of the human body nowadays. According to Hill's theory, one could only run as fast and last for so much time as long as the muscles were efficient in their uptake of oxygen and their tolerance to lactate. This oxygen would then be used in pathways to make the body run as fast as it could. When this efficiency decreased with inefficient oxygen uptake, the machine would stop functioning. At this point the heart would not be able to cope with the demands of the contracting muscles and would become ischemic and ultimately fail. This theory is therefore deemed as catastrophic as homeostasis is not maintained (Noakes, 2012).

Fatigue, according to Hill's theory would set in when the muscle fibers were all recruited, indicating that there is only one pace when running. Although Hill acknowledged that the beating heart was controlled possibly by the brain, which he called the governor, this part of his theory was neglected.

Hill's theory however, could not explain why athletes did not keep a constant pace during racing or why fatigue set in long before the athletes stopped running. According to Hill's theory no muscular fatigue should be present until all the muscle fibers were recruited. In a very interesting study by Saugy et al. (2013), it was shown that during very long ultra runs in the mountains, the muscles used for running were actually preserved. While studying the effects on neuromuscular alterations on well-trained participants running Tor des Geants (a 330km trail race with

24000m of positive elevation gain), the authors found that extremely long distance running, "revealed less neuromuscular fatigue, muscle damage and inflammation than in shorter Mountain Ultra Marathons. In conclusion, paradoxically, such extreme exercise seems to induce a relative muscle preservation process" (abstract). In addition, after 30-36 hours of running the authors also demonstrated that muscular voluntary activation loss does not decrease further. The authors theorized that this was probably due to the fact that competitors slowed down in longer ultras, a fact that A.V. Hill did not actually acknowledge when he proposed his theory.

The brain is Central: Endurance depends on the brain

i) The central governor theory

The importance of changing pace during racing was recognized by Tim Noakes who posited that anticipatory regulation is crucial during extremely long bipedal running events. When studying 32 mile records, Noakes et al. (2009), noted that the fastest lap was the last lap in the majority of cases which was also the case for longer running events. This led the authors to conclude that pacing was extremely important and the final spurt indicates that the body gets fatigued during the run in order to have a reserve at the end. Noakes' theory postulates that the brain, which he called the 'Central Governor', is actually what regulates endurance. The ultimate aim of the brain is to protect the body and maintain homeostasis. The brain regulates the pace according to various factors like mental fatigue, sleeplessness, caloric intake, core temperature and various other factors, and only allows the pace to increase when it deems the situation to be safe, like arriving to the finish of a race. In the authors' opinion, it is the reason why almost nobody dies of exhaustion while running. In such a scenario, catastrophe (heart failure) cannot occur as the brain is taking measures to protect it.

ii) The psychobiological theory

Samuele Marcora (Marcora & Staiano, 2010) believes that the most important factor on which endurance practice relies, is the perception of effort which lies in the brain. He argues that muscle fatigue is not really the limiting factor for endurance but rather, one stops doing exercise when he/she perceives that the effort to be too much. At that stage, the participant does not have the will to keep engaged in the pursuit.

Brain activity changes when a central motor command is fired and sends signals via motonuerones to the muscles. Every time this happens a copy of this command goes to the sensory area of the brain to create a perception of effort. (Marcora &

Staiano, 2010). Perception of effort is then influenced by various factors including sleep deprivation or mental fatigue which make the perceived effort harder. Marcora conducted various experiments on endurance performance, whereby he made the effort seem more difficult or easy without altering the physical parameters like heart rate or VO_2 max (de Morree & Marcora, 2012; McCormick et al. , 2018).

During a test to exhaustion, he asked test subjects to cycle to their maximum perceived effort and stop when they felt they could not go any further. When they stopped, he asked them to resume cycling as hard as they could and offered a monetary reward for the best 3 performances. The subjects were able to generate much more power despite the fact that they felt that they had reached exhaustion just moments before (Marcora & Staiano, 2010). By using monetary rewards and a sense of competition, the authors were able to influence the sense of effort and make the participants work harder.

Subtle signals can also affect the perception of effort and make a run seem more difficult or easy. To prove this, subjects were shown 18ms images of a smiling or frowning faces while cycling. The test subjects were not even aware of these images but the results yielded very salient findings. The cyclists who were shown the smiling faces performed better. Being social animals, humans are influenced by facial expressions and the fact that they were shown smiling faces reduced their perception of effort and made the cycling feel easier (Blanchfield et al., 2014). This might suggest that being positive and smiling during laborious running reduces the perception of effort and thus impact positively on endurance.

The will to endure and overcome powerful responses is built by the endurance athlete over the years by intense training (Astokorki & Mauger, 2017; O'Leary et al., 2017; Roebuck et al., 2018). If athletes are mentally trained not to succumb to powerful urges, endurance is not affected. Pageaux et al. (2014), established the effect of response inhibition on the outcome of exercise by having athletes do a tedious Stroop test to increase mental fatigue prior to running a 5k time trial. The test subjects took longer to finish the time trial when compared to the control group, and also felt that the perceived effort was higher, even though the measured lactate and heart rate not were altered.

The endurance runner, therefore, might find it extremely beneficial to start the race with a clear, fresh mind, with thoughts and worries brushed aside so that initially at least, the perceived effort is low. According to Jurek (2012), one of the most influential ultra runners, "An empty mind is dominant mind" (p.87). In such long races however, factors like sleep deprivation, mental exhaustion, increased core temperature or altitude add up and increase the perception of effort. Coping strategies like positive self-talk (Weinberg et al., 1984; Thelwell & Greenlees, 2003), mouth rinsing (Pottier et al., 2010) and caffeine (Duncan et al., 2013; Noakes et al., 2018) amongst others, which manipulate perception of effort will surely aid the runner towards achieving his/her goal by reducing the sense of effort.

iii) Interoception

Seasoned runners called "adventure racers" by Paulus et al. (2012), are more efficient in responding to stressful physical and psychological situations. This fact was revealed by experiments studying the insular cortex (Paulus et al., 2003), which according to the authors, shows enhanced activity when the athletes are getting ready for a demanding situation but which settles down when they are actually dealing with the situation (Paulus et al., 2012). Paulus studies interoception or how the brain responds to internal body signals in relation to external stimuli in order to maintain homeostasis.

Paulus et al. (2009), describe an extreme environment as "an external context that exposes individuals to demanding psychological and/or physical conditions, and which may have profound effects on cognitive and behavioral performance" (p.1080).

Paulus et al. (2012), believe that elite performers are very much in tune with their bodies and their outstanding training has exposed them to conditions where they prepare their minds in advance to cope with adverse situations. They argue that this population shows an enhanced and specialized brain activity consistent with quick adaptation to extreme environment. When anticipating a traumatic situation, their circular cortex shows heightened activity when visualized through an MRI, meaning that their body is getting ready for the situation ahead. During the adverse stimulus however, the brain activity is lower than that of the control group indicating much less anxiety in the test subjects. Paulus et al. (2012) conclude that: "Optimal performers are able to more quickly adapt to both bottom-up interoceptive afferents and top-down cognitive control brain areas that modulate mood and anxiety in regulating one's response to an aversive interoceptive perturbation" (p.9).

Conclusions

As the above theories demonstrate, extreme ultra running is a very demanding sport which might lead to injury and mental distress, and yet more athletes are being successful and not succumbing to the punishing conditions. The purpose of this paper was not to find the magic formula for success. The theories presented give more introspection into the sport and perhaps a clearer understanding of the demands behind those long hours, by looking at studies which put ultra athletes to the test.

What is actually true, is that this population is a special one. They have intuitively discovered what needs to be done to take them to that finish line hours or days after they started. The research presented tries to make meaning of these endeavors by looking at physiological and cognitive theories and how these might aid the athlete. In reality however, more caveats come into play like personalities, motivation, resilience and mental toughness. The most important conclusion though is that this extreme sport is a fertile ground for research both for studying the physical limits and also the mental capabilities of this population.

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Bio-note

Nadia Portelli is Senior Lecturer at the University of Malta Junior College. She has been teaching Physics for the past 28 years. During the past years she has participated in various Erasmus+ projects, including InterAct for Inclusion and Tolerance which saw the participation of various European countries. Portelli started her running career 29 years ago and has participated in road races locally and abroad. These past years, she has competed successfully, in some of the most prestigious mountain ultra trails. This year she will be participating in Ultra Trail du Mont Blanc (UTMB), a 171km race with an elevation gain of 10000m, around the Mont Blanc massif during the Ultra Trail World Summit.