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Chapter

Sports Science and Efforts towards Sub-Two Hour Marathon Performance

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Abstract

Performance in different athletic activities has continued to improve over time, with some athletes from diverse parts of the world registering new world records from time to time. With stiff competition from athletes from different parts of the world, constant upgrading of sports science based approaches to training and competition are employed to achieve more success. However, some approaches used to improve sports performance may pose ethical concerns and may challenge sports as a concept of celebrating natural human abilities. This book chapter interrogates the factors associated with efforts towards improvement of performance in endurance sports events, with a specific focus on marathon races, and the future implications for training, competition, and the nature of sports. While the interplay between nature and nurture determines the unique psychophysiological responses to training and competition, technological exploits leading to advanced sports products coupled with favourable natural and/or manipulated internal (body) and external environmental conditions will ensure continued improvement in performance. However, there is a need to censor commercial interest as well as safeguard safety and the nature of sports as a medium to celebrate natural human abilities.

Keywords: athletic competition, athletic performance, athletic training, endurance running, Olympic motto

1. Introduction

The Olympic motto "Citius – Altius – Fortius" which expresses the aspirations of the Olympic Movement as captured in the Olympic Charter [1], resonates perfectly with the innate human desire to do and accomplish more in life. The three Latin words mean Faster - Higher – Stronger (modified by adding '-Together' in 2021) and were first expressed by Dominican priest Henri Didon during the opening ceremony of a school sports event in 1881 [2]. These words were adopted by Pierre de Coubertin, who was present that day, as the Olympic motto and included in the first Olympic Charter in the 1890s. It expresses the aspirations of the Olympic

Movement in its athletic and technical sense as well as from a moral and educational perspective [2]. This desire has led human beings to seek ways to work efficiently and improve their performances in the diverse aspects of life. Over the years, many sports practitioners have turned to sports science to develop and use a variety of ergogenic aids. Great efforts have been made to discover innovative ways that can help athletes to achieve an edge over their opponents in the sports arena [3]. Techniques or substances used for the purpose of enhancing sports performance are referred to as ergogenic aids and they act by improving energy production, energy control, or energy efficiency [4]. These come in many forms including –but not limited to, physical, mechanical or technological, nutritional, psychological, and pharmacological methods that either directly improve physiological variables associated with exercise performance or remove subjective restraints that may limit physiological capacity [5, 6]. As the variety of ways athletes seek to improve their chances of winning are becoming increasingly difficult to distinguish from doping concepts [7, 8], there are growing legal, ethical, and safety concerns that threaten the integrity and survival of sports as a socio-economic institution and one of the largest industries, with an estimated global turnover worth over 1.3 trillion USD in 2017 [9, 10]. The aforementioned is exemplified by running sports -both short-distance and long-distance events. This chapter focuses more on distance running, particularly on the marathon.

1.1 Historical perspective of endurance running

Distance running is said to have been used as a means of hunting for food, survival, and mode of transportation during early civilisation [11, 12]. However, it developed into an endurance physical exercise and a popular major athletic sport that it is today. As an exercise, it serves to improve cardiovascular system, strengthens bones, improves knee health, boosts mood or self-esteem, and alleviates stress [11, 13–15]. As a sport, distance running comes in different forms, including track events and road races, the marathon being the most popular. The history of the marathon race dates back to the ancient Greek civilisation. In 490 B.C., a Greek soldier named Pheidippides ran from Marathon to Athens, Greece (roughly 25 miles), to deliver news of a military victory against the Persians at the Battle of Marathon, immediately after which he kneeled, fell over and died -probably because he had not trained for the extensive running feat [11, 16]. During the onset of the modern Olympic Games in 1896, a "marathon" race was organised to pay tribute to Pheidippides, spanning from Marathon Bridge to Olympic Stadium in Athens, with an estimated distance of 24.85 miles [17]. The marathon race was later established as 26.2 miles at the London Olympics in 1908. Many more marathon races continued to be organised within and outside the Olympic Games. The Boston Marathon was first held in 1897, this being the oldest marathon after the initial event in the first modern Olympic Games in 1896 [17]. The road-running sports industry has continued to expand with an estimated value of $1.4 billion in 2015 in the U.S. alone, with the running shoe business alone said to be worth about $3 billion [11, 18, 19]. An increasing number of people are taking part in marathon races both for recreation, fun, and as a professional pursuit, with some of the major events such as the Abbott World Marathon Majors registering more than 50,000 runners each year [11].

1.2 Efforts towards sub-two hour marathon

Performance in the marathon race has gradually improved over time, with top athletes recording times just short of two-hour mark (by less than 5 minutes in the recent times since September 2003) [20]. According to the World Athletics records,

the all-time top 100 performances thus far range from 2:05:47 by Marius Kimutai in Amsterdam on 16 October 2016 to 2:01:39 by Eliud Kipchoge in Berlin on 16 September 2018 [20]. It is important to note that athletes from the East African region account for about 90% of all-time marathon performances, with Kenyans accounting for 47% and Ethiopians 41%. This phenomenon has continued to attract researchers all over the world, with no consensus on the reasons behind the world dominance in distance running performance, although several factors have been proposed [21, 22].

With race performance times edging closer and closer to two hours in recent times, it is believed that it is a matter of time before a sub-two-hour marathon performance is achieved. Efforts have been made to achieve this sooner [23], particularly by athletes from East Africa, with their agents working hard towards this elusive mark. One such effort has been made by the World and Olympic champion Eliud Kipchoge, who ran the world's first sub-two-hour marathon, clocking 1:59:40 in Vienna in 2019. However, the performance was not recognised in the official world records because of what was said to be the 'use of pacemakers who were getting in and out of the race', pacing laser beams, as well as 'placing of refreshment into his hand instead of him picking them', which are privileges that are not found in normal race conditions [24, 25]. Kipchoge who had set the marathon world record of 2:01:39 in Berlin in September 2018 was recorded saying that "Running Berlin and running Vienna are two different things; Berlin is running and prepping a world record, Vienna is running and making history in this world, like the first man to go to the moon" [26]. The feat was accomplished running on a straight flat course through the Prater Park with curved turns at each end. The event was organised by Sir Jim Ratcliffe, the INEOS chairman and CEO [27], a few years after similar efforts by Nike in 2017 fell short of the target by 26 seconds [28]. With the race hyped up through the 'No Human is Limited' slogan, he aimed to inspire humanity to realise that we can stretch our limits in our lives and we can do more than what we think we can do, to inspire others to believe they can overcome their own personal barriers. Even though the performance is not recognised as a world record, it gets a step closer towards realisation of similar performances in a competitive race situation.

2. Sports science and training methods

Over the years, athletes and coaches have sought better training methods to improve their performance. Running a marathon race requires adequate preparation in terms of training. Although exceptional cases of people who ran and finished a marathon race reportedly without known training for the same have been recorded, they are just a few unique cases. One of these is the original marathon race by the Greek soldier Pheidippides cited above, with the apparent lack of training for the race leading to his sudden death soon after the race –after delivering the important message which may have been the key motivation. The other recorded cases are the first African Olympic marathon athletes who participated in the third Olympic Games hosted at St. Louis, USA in 1904. The event was hosted by the USA as a part of a "World's Fair" where various Olympic events were slotted between other attractions at the Fair. With disappointing international participation (Athletes from only thirteen countries entered), the organisers invited everybody at the "World's Fair" to participate. Among those who took this opportunity were two African workers, Len Tau and John Mashiani, who were at the Fair participating in "Anglo-Boer War Historical Libretto" show, a revue that re-enacted scenes from the Anglo-Boer War (1899–1902). Len Tau, who ran barefoot, finished ninth in the marathon, and Jan Masiani thirteenth. They became not only South Africa's first Olympians, but also the first athletes from Africa to participate in the Olympic Games. It is said that Len

Tau was chased off course by a stray dog, and it is estimated that he lost up to six minutes in the process and thus, could have performed much better [29]. Although the escapades of Pheidippides, Len Tau and John Mashiani cited above are hailed as cases of great feats of outstanding performance in marathon races without specific training, it is worth noting that all of them were battle-hardened soldiers [11, 30], probably with the advantage of years of physical training and mental resilience from prolonged wars. This resonates with the fact that early sports' training was intertwined with training of warriors [31].

Over the years, better training plans have been constantly sought, with sports science advancement providing evidence-based methods and procedures to continue achieving more success. The principles of training, such as overload and recovery, have been known since ancient times. The legendary Milo of Croton who was a six-time Olympic Champion in 6th century BC is said to have begun carrying a young calf as a young man on his shoulders each day and walk around a large stadium. And as the animal grew, Milo also grew stronger and eventually he was able to carry a fully-grown bull [32]. It has long been understood that gains in fitness occur when we rest and adapt to the challenges of our workouts [33]. Before the 1900s, most distance runners mainly used continuous forms of training by doing a few long runs and incorporating periods of long walks into their weekly routine, often incorporating a short (half-mile) speed run in early morning and in the evening. The term 'scientific training' was gradually used to refer to the training of athletes, but most training methods continued to rely heavily upon the accumulated experience of successful athletes and trainers [13]. In the early 20th century, interval training -a form of repetition training started becoming popular among runners [11, 34]. In the 1930s, "hill repeats" and "fartlek" (involving varying the speed throughout a run, often alternating fast and slow or fast and medium on varying terrains) emerged as training methods. In the more recent times (late 20th century and early 21st century), the concept of 'Lactate Dynamics Training' or the 'New Interval Training' which combines some aspects of fartlek and interval training is gaining traction. Fartlek training is a training method that was first developed in the late 1930s by the Swedish coach, Gösta Holmér [13, 34] as a response to the Swedish distance athletes' apparent lack of success against the Finnish teams of the day, and also due to limited access to specially built training facilities in Sweden at that time [34]. The word 'fartlek' itself comes from the Swedish word for 'speed play' and indicates the nature of this training method which provides for a variety of speeds or paces, combining continuous aerobic emphasis training with faster-than-race-pace efforts. Fartlek allows the athletes to run whatever distances and speeds they wish and to 'play' with varying intensity -occasionally running at high intensity, other times at lower intensities -and varying the terrain [34]. It is an incredibly powerful method for all endurance athletes to develop their natural rhythm and accompanying 'lactate dynamics' abilities away from the track with elements of fun and stimulus variations [34, 35].

The new interval training also referred to as lactate dynamics training takes the physiological principles that are similar to fartlek training and adds to it the development of pace and rhythm techniques on the track. It aims at developing race-pace rhythms by raising athlete's awareness through accurate feedback, in the track environment. The 'lactate dynamics training' term is used to specifically classify the training for the lactate shuttle, the dynamic utilisation and clearance of lactate so that lactate is optimally used around the body [34–36]. The emphasis is to avoid suddenly slowing down at the end of the faster repetition and then speeding up at the next repetition -as in classic interval training, but rather to transition smoothly and quickly from the pace of the faster repetition to the pace of the active roll-on recovery. At the end of the roll-on recovery, there should be an equally smooth and

rapid transition back to the faster pace of the repetition. The goal is the optimal development of the lactate energy system by training at fluctuating intensities where lactate production, utilisation, and clearance are encouraged. This lactate clearance from the body is accelerated when lactate is shuttled to areas of high oxidative activity while maintaining an active running pace [34–36].

In addition to running exercise, weekly training programs for distance runners of late also incorporate two to three days of interval or circuit-based workouts interspersed with days of long running mileage [11]. They include some other activities in their fitness routines, mainly strength/resistance training to keep their core strong, flexibility exercises, and low-impact activities like water exercise and elliptical or cycling for therapeutic reasons and to target muscles that are not activated by running [11]. This ensures that more parts of the body work together cooperatively to improve running efficiency, thus boosting performance. There is also ongoing discourse among sports scientists on improving training outcomes by matching training loads to athletes' individual hemodynamics and heart function [37–39] as well as leveraging on the much sought after 'endurance running genotype' [40, 41]. Polishing running technique for maximum efficiency by optimising both lower and upper body kinematics has also been subject of continuing biomechanics research [42, 43]. Emerging technology involving electronic pills is also likely to influence performance in distance running and other endurance sports. So far there are reports of the technology having been used on experimental basis in Doha 2019 World Athletics Championships and in Tokyo 2020 Olympic games to monitor endurance athletes' vital signs in real time [44, 45]. These are indications that sports science has impacted and will continue to impact the future of endurance running sports in diverse ways.

3. Sports science and pursuit of better sports apparel and products

Together with advancements in training methods, sports science has led to the evolution of sports products that continue to stretch performance limits over time. Technologically enhanced running shoes, apparel, and sports drinks are some of the fronts where sports science is being applied to improve training and performance in endurance running.

3.1 Role of shoes and shoe technology in running performance

Despite evidence of a few distance runners recording good performance while running barefoot [29, 46, 47], running shoes play a significant role in running performance [48]. One of the exceptions is Len Tau, one of the two first athletes from Africa to participate in an Olympic Games, who is said to have run barefoot and finished ninth during the third modern Olympic Games, St. Louis, USA, despite the lack of specific training for the race and after being chased off-course by stray dogs [29]. According to Lieberman et al. [46] and Rothschild [49], there is evidence of improved intrinsic foot strength and improved physiological economy when running barefoot, but no evidence for injury reduction or improved performance. Several studies support barefoot running and minimalist shoes for the proposed advantages of improved sensory feedback and proprioception and reduced impact forces [46]. Another unique exception that might imply less contribution of running shoes is the case of Jim Thorpe, the first and only athlete ever to win both pentathlon and decathlon Olympic gold medals at a single Olympic Games during the Games of the V Olympiad held in Stockholm, Sweden in 1912. Someone had stolen his shoes just before he was due to compete on the final day, but he found a mismatched pair of replacements, including one from a trash can, and won the

gold medal wearing them [50]. Additionally, some Kenyan athletes are known to have won medals while running barefoot, including Sabina Chebichi, who won her first marathon in 1973 while barefoot and wearing a petticoat [47]. Despite these few recorded cases, the importance of running shoes and their roles in safety and performance have been well appreciated over the years.

Running shoes have continued to evolve since early times, with Adolf Dassler making running shoes in the form known today in the early 1920s [7, 11]. Earlier, there were efforts to make special running shoes, including Japanese five-toed shoes, albeit with no recorded impact on performance; however, this inspired the concept of minimalist shoes even present today such as the Vibram Five Fingers. More impactful distance running shoes currently include prime offerings such as the Nike Vapourfly and Alphafly series, Hoka One One Bondi series, New Balance Fresh Foam, Asics Gel-Nimbus, and Adidas Ultraboost [51]. Appreciating the uniqueness of each runner, some companies offer sneakers customised to specific runners' individual gait type and shoes for those who need stability or have flat feet [11, 52]. Adolf Dassler offered shoes that were made especially for running certain distances, some of which had spikes and were used by successful athletes such as Jesse Owens in the 1930s. In the 1960s, New Balance offered what would be the first mass-produced sneaker weighing less than 11 ounces, and then Nike entered the game with its Waffle Trainer in 1974. Later in 2016, the same company came up with carbon fibre plate (CFP) and foam technology shoes with the vaporfly series, and lately (2019) the Alphafly series –used by Eliud Kipchoge during the INEOS 159 Challenge [7, 53]. Other shoe manufacturers, such as Hoka One One carbon X brands, have also adopted CFP and foam technology. Since this innovation, every women's and men's world records from 5 km to the marathon have been broken [7, 48]. This is largely attributable to innovations in shoe technology leading to increased elastic properties of the shoe which is associated with reduction in the energy cost of running. The latest CFP and foam technology running shoes are said to influence performance by optimising the running technique biomechanics and efficiency, reducing potentially harmful impact forces from the foot ground strikes and returning energy to the runner [7, 52]. Their use is said to aid performance in endurance running by reducing mechanical energy resulting from minimal flexion of the forefoot, with the athlete using midsole foot-ground strike as opposed to the common forefoot landing, and maximising the energy returned from the bounce [7, 48, 53, 54]. The stiff carbon fibre plate within the midsole may also help by redistributing positive lower limb joint work from the knee to the joint of the toes above the ball of the foot, as well as by storing and returning energy to the runner [52]. The CFP and foam technology running shoes are acknowledged to increase running economy by more than 4% [55], corresponding to a greater than 2% improvement in performance/run time [7].

However, the use of CFP shoes has provoked debate on the impact of shoe technology on the essence and credibility of sports. Concern has been raised that, although the true impact of CFP shoes on running performance is yet to be scientifically tested in the field, there are indications that the recent improvements in long-distance running times are technologically driven rather than physiological [7, 28]. Moreover, access to this performance-defining technology may become the primary differentiator of sporting performance in elite athletes. The high cost of the technologically improved shoes would be out of reach for most athletes, especially those from underdeveloped countries such as East Africans who have dominated long-distance running worldwide for more than 50 years, thus alienating them [56]. Another downside dimension could be the financial exploitation of athletes as they go all out to invest in specially made running shoes by manufacturers and/or generic counterfeit vendors in the hope of gaining the widely advertised but scientifically unproven benefits in running training and competitions. This is not remote given

that several African runners have registered excellent marathon performance running barefoot [29, 46, 47]. In his response to allegations that advanced shoes give him undue advantage, Eliud Kipchoge said that 'records are broken by individuals not footwear'. He however observed that checks and balances are important as running technology evolves [57].

3.2 Apparel innovations and running performance

Over time, diverse commercially available running apparel have been shown to improve performance for both sprints and distance running. These include a range of singlets and shorts as well as bodysuits with properties such as stretchability, water vapour permeability, and thermoregulation compression fabrics. These properties -separately or in combination, aid in training, recovery, and performance. Many renowned athletes are known to have achieved outstanding performances while wearing aerodynamically optimised apparel [58]. These include Eliud Kipchoge during his first and second attempt to run a sub-two-hour marathon, eventually succeeding on the second attempt in 2019 at the unofficial marathon race dubbed the INEOS 159 challenge.

Infrared attire technology is another recent development that is creeping into sports apparel development. Far-infrared ray-emitting clothing is currently being tested and utilised to enhance training, recovery, and performance during actual sports events [59, 60]. A study by Loturco et al. [60] investigated the effects of far-infrared (FIR) ray-emitting clothes on indirect markers of exercise-induced muscle damage and recovery after a bout of plyometric physical performance among soccer players. This study found that FIR clothes may reduce perceived delayed onset muscle soreness after an intense plyometric session. A systematic review by Bontemps et al. [59] revealed that studies investigating the beneficial outcomes of FIR clothes related to exercise performance or recovery are scarce and the results are largely inconclusive. However, the author acknowledges that some studies in this relatively recent field indicate positive outcomes associated with far infrared effects on the body's thermoregulation and hemodynamic function [59]. It is possible, therefore, that this recent development in sports apparel will influence training and performance in a variety of sports, including distance running.

3.3 Sports drinks and nutritional supplements: manipulating the internal environment

Fluid and electrolyte replacements are another area in which sports science has focused on improving endurance running. Electrolytes lost through sweating in a long race include sodium and chloride -in high concentrations, and potassium, magnesium, and calcium in low concentrations. All these electrolytes are essential as they work together to maintain fluid balance in the body at rest and during physical activity. Buffering acidosis is another crucial role of electrolytes such as sodium bicarbonate, thus regulating acid–base balance (blood pH) [61]. Therefore, it is important to replace any lost electrolyte in order to maintain a stable internal environment for optimal metabolic processes. This is recommended for high-intensity exercise with an extended duration of more than 61 min, where heavy sweating is expected, especially in environmental conditions of high ambient temperature and humidity. Moreover, replenishing fuels, in the form of blood glucose, are important for such exercise in order to avoid early fatigue and exhaustion. In this case, it is recommended to athletes to take sports drinks or nutritional supplements that top up carbohydrate reserves and electrolytes during and after long runs [62, 63]. Sodium in a sports drink helps the body absorb and retain body fluids, and utilise

carbohydrate. Endurance-specific electrolytes and calorie sports products such as the First Endurance Electrolyte Fuel System (EFS), Gatorade Endurance Formula, Luna Electrolyte Splash, Hammer Motor Tabs, and Powerbar Endurance Sports Drink are designed to offset higher losses of fluids and electrolytes through heavy sweating associated with muscle cramping [62]. There are also supplements such as beetroot juice, caffeine, and glycerol, which are said to boost performance and help the body cope with the demands of marathon training. However, their effects vary among athletes and may depend on training content, physical condition and habits [64].

Recent advancements in sports drinks seem to have triggered a fuelling revolution in the use of hydrogel technology by Maurten, the company that brought a new kind of sports drink mix and gel to the market in 2017. The Maurten sports drink has been widely embraced after being used by high-profile athletes -including Eliud Kipchoge in 2017, when he set a new marathon record twice, as well as in his epic trials to break two-hour barrier [65–67]. For many years, nutritionists and exercise physiologists have recommended that marathon runners consume no more than 45–60 g of carbohydrate per hour. Taking in more has been associated with increased risk of bloating, nausea, diarrhoea, and other gastrointestinal problems that affect 30–50% of runners [67]. However, some researchers believe that higher carbohydrate intake would likely result in better performance than lower intake in events lasting longer than two hours [65, 67]. In 2015, Maurten seemed to make a breakthrough when he discovered a way to encapsulate carbohydrate molecules using hydrogel technology. This is said to allow carbohydrates to move through the acidic stomach and to the intestines, where they can be absorbed more easily and help sustain performance. This lets one fuel more by taking in more calories without increased risk of gastrointestinal problems, and enable one to perform better in the race [65–67]. It is important to note that there are no empirical data so far that scientifically validate this notion. The product company website indicates that a number of studies are currently evaluating their technology and products and they are expecting that the first peer-reviewed paper will soon be published in support of their technology [66]. This will be necessary, just as with many other products of this nature, to reassure the users of the efficacy and safety as well as to dispel the notion of commercial interest as the key force behind the product's popularity.

4. Fluid dynamics: manipulating the external environment

Wearing aerodynamic running kits has been adopted by many athletes and is appreciated as a great way of reducing resistance, hence contributing to better performance times, as one moves through the fluid (water for swimmers, air for runners and cyclists) [24]. This has been taken positively, as even race organisers seem to be quick to judge whether the race times are 'wind assisted' or not [68]. With a long race like a marathon that takes more than 2 hours to complete, air current is a key consideration; thus, the above efforts are needed. While aerodynamic body frames and apparel have been shown to reduce air resistance encountered by runners [69], runners and coaches have also explored running in different positions and formations to take advantage of favourable air currents [24]. This has been augmented by the case of INEOS 159 Challenge, where a formation known as the delta formation, with a group of rotating pacers, was said to have been adopted to remove wind resistance from the main runner, Eliud Kipchoge [24, 70]. Even though the organisers indicated that they extensively tested different formations using manikins, the effects of the formation adopted on the main runner were not specified. Moreover, the choice of the running venue (The Prater Park in Vienna) and a straight and tree-lined course which runs through the heart of the park was said to have been preferred because of its 'optimum

conditions' [70], which obviously included relatively calm air. Thus, it was incoherent to think of the running formation as being designed to avoid wind resistance.

We conducted a study to investigate the drafting effects on dummy models of marathon runners using a wind tunnel (San Technologies Co. Ltd) in the Laboratory of Sports Fluid Mechanics, University of Tsukuba, in September 2020. The dummy models were wooden, 0.4 m high and 0.09 m wide. The indoor temperature and humidity were 25.7°C and 68% respectively. The effect of drag force changes in different dummy model positions was evaluated at a wind speed range of 0–56 m/s. The position, distance and angle of the model were changed to test the influence of wind drag force on the main model under different conditions (Group 1–4). A total of 11 tests were conducted in this study. The results showed the following: 1. The wind drag force of the single model was the largest (See **Figure 1** Group 1). 2. When a wooden model is set at 0.3 m and another at 0.7 m in front of the main model at the same time, the wind drag force is very close to when a single model is set at 0.7 m in front of the main model (See **Figure 1** Group 2). 3. When a wooden model is set at 0.35 m in front of the main model, its wind drag force is close to that of two wooden models with a space of 0.045 m in front of the main model (See **Figure 1** Group 3). The influence of the 0° and 45° angles of the wooden model was not significantly different on the wind drag force. 4. Two wooden models were set up side-by-side (no space) in front of the main model. Owing to the influence of the air vortex, some traction force was exerted on the main model (See **Figure 1** Group 4). The wind drag forces were G1 > G2 > G3 > G4. The authors concluded that setting a guard just in front of a runner may be more effective in reducing the wind force than a formation. However, it should be noted that the experiment did not assess a formation similar to that used in the INEOS 159 Challenge.

In another experiment conducted at Kenyatta University, we tested the effects of turbulence induced by moving wooden models in a formation similar to the one used in the INEOS 159 Challenge (Video 1). The models, which were about 2.5 cm wide with a slight oval cross-section (similar to human trunk), were inserted in still water (temperature; 12°C, density; 0.99 g/ml) in a pool and moved at an average speed of 0.41 m/s. Considering the relative size of an adult marathon runner's trunk of about 40 cm in cross-section, the relative speed of the model runners was about 6.56 m/s, which is close to the INEOS 159 Challenge average speed of 6.86 m/s. The effects of the turbulence were observed at the position of the main model by removing it and placing a loose piece of wood in its place. The loose piece of wood was seen pulled along the wood model formation for a distance of 5 meters (Video 1), confirming tail

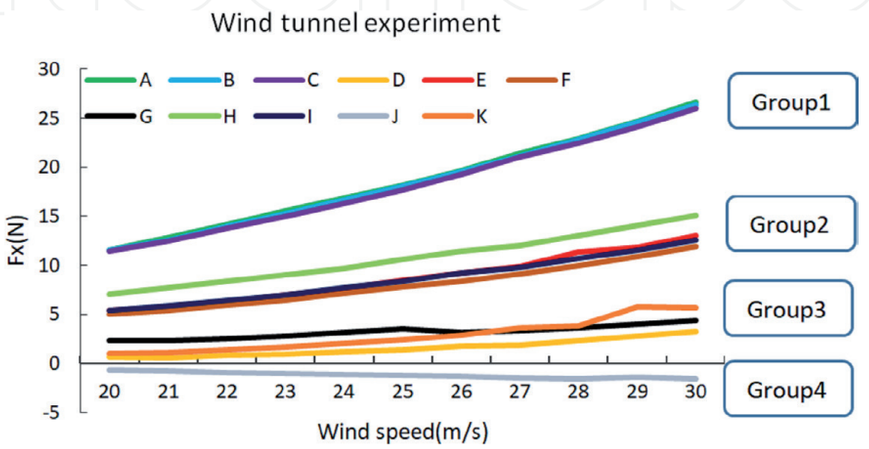

Figure 1.
Wind tunnel experiment results showing wind drag force changes (on the main model) with different positioning of dummy models of marathon runners at different wind speeds.

suction/vortex forces at the position of the main model. Even though the magnitude of forces generated in water are higher than in the air due to difference in densities, the study concluded that the INEOS 159 Challenge formation generated tail suction/vortex forces which may substantially reduce the energy cost of running for the main runner.

With the preceding evidence that air turbulence can be manipulated to improve performance, the dynamics of applying it in an actual race may not be easy. However, we are likely to see more runners trying to apply the concept in the field with their sponsored pacesetters. If several groups of athletes try this at the same event, jockeying and jostling for spaces is likely to ensue, and this could substantially change endurance running competitions from the way we know it.

5. Psychological aspects: power of the mind and motivation

Mental toughness and preparation often separate the best from the rest, as most top athletes are in outstanding physical condition and are technically exceptional [71, 72]. Mental attributes, such as motivation, confidence, focus, perseverance, resilience, and managing nerves are critical in sports performance, even though they are more often neglected in training. Sports science has shown the importance of incorporating mental training directly into an overall sport training regimen to unlock the power of one's mind through various techniques [71, 72]. It is evident that some top marathon athletes, like Eliud Kipchoge, use some of these sports psychology techniques. This is exemplified by hypnosis and self-belief in the 'no human is limited' slogan, as well as the mental boost gained from encouragement by running teammates [70].

6. Legal, ethical, and safety considerations

The advancement of sports apparel and products that continue to stretch performance limits over time have raised legal, ethical, and safety concerns. There are serious implications on rules and regulations, the nature of sports, and the health of athletes that require attention as technology continues to evolve at an ever-increasing rate.

In response to the widespread concern about the impact of shoe technology on the nature of sports as an avenue to promote and celebrate natural human endeavours, World Athletics (WA) has recently (early 2020) modified rules governing competition shoes for elite athletes. This includes sole thickness regulated so as not to exceed 40 mm and not to contain more than one rigid embedded plate [7]. However, the amendment also allowed development shoes to be worn in international competitions prior to their availability to public upon approval of the shoe specifications by WA. Coupled with a popular shoe company releasing a shoe with the said 'maximum' specifications soon thereafter, these raised suspicion on the timing of the new regulations [7]. It has also been noted that the magnitude of race performance improvements by athletes running using CFP shoes which is estimated to be approximately 4% [55] is similar to those expected from substances and methods included on the prohibited list of the World Anti-Doping Agency (WADA), such as blood doping and erythropoietin use [73]. This has elicited a feeling that WA may be abetting "technological doping" and doing little to protect the principle of fairness in sports competition [7]. The scenario is a clear indication that unregulated sports science and technological advancement can threaten the true essence of sports which is based on ethos that exalts natural human effort.

There also exists a controversy related to the ineffectiveness of interpreting the doping concept. It has been observed that the anti-doping process, despite

ever-increasing restrictions and control, still produces suboptimal results and is currently not as effective as stakeholders in sports and the public at large would like it to be [7, 8]. With many athletes being reported to have used doping agents post hoc (well after the event), there is increasing scepticism about any outstanding sports performance, which may lead to reserved, truncated, or partially withheld celebration of sports victories. These unfortunate developments will fundamentally affect the nature of sports in the future. Pitsiladis et al. [8] observed that there is an urgent need to increase the quality and efficiency of the anti-doping processes to rebrand and restore the credibility of sports. The authors recommended a holistic anti-doping approach comprising at least three primary anti-doping pillars or 3Ps to prevent doping, protect the clean athlete, and promote performance without doping. There is evidence of implementation of some of these recommendations like in allowing 'clean' athletes from Russia to participate in Tokyo 2020 Olympic Games under ROC after WADA banned Russia from international sports competitions until 2022 due to what was seen as state-sponsored doping cover up scheme [74, 75]. However, it is daunting task to ensure clean sports, but one which must be accomplish through concerted efforts to safeguard the future of sports industry.

With the evidence that air turbulence can be manipulated to generate tail suction/vortex forces which may substantially reduce the energy cost of running, thus improving performance (such as in the INEOS 159 Challenge), we are likely to see more runners trying to apply the concept in the field with their sponsored pacesetters. However, the dynamics of its application to an actual race may not be easy. If several groups of athletes try this at the same event, jockeying for spaces is likely to ensue, which could substantially change endurance running competitions from the way we know it in terms of strategies, tactics, and rules.

Another concern is that advanced sports products are only available to a few privileged members of society. This raises the issue of whether it is ethical or if it amounts to unfairness by disenfranchising the majority of the population who cannot afford the high costs associated with such products. In addition, claims on efficacy and/or side effects of most of these sports products are largely not yet proven, determined, or validated in controlled randomised studies. This raises concerns about possible unfair commercial practices as well as the long-term safety and health of athletes.

7. Conclusion and recommendations

From the aforementioned, it is clear that sports science has continued to play an important role in improving performance in sports in general, and in endurance running in particular. Athletes from diverse parts of the world have continued to register improved performances in different athletic events over time, with occasional new world records. With stiff competition from athletes from other parts of the world and the higher stakes in the sports arena, constant upgrades and innovations in approaches to training and competition will continue to fuel more success. However, some approaches pose challenges to the nature of sports as a concept of celebrating natural human abilities. Efforts towards improving performance in marathon/road races and other endurance sports events have been accompanied by technological advancements in sports products such as running shoes, apparel, and sports drinks, which are out of reach to the majority of the population. Moreover, such new sports products have been introduced and widely popularised even before verification or validation through independent controlled studies, posing ethical and safety concerns. Manipulations of racing environments to create and take advantage of favourable air currents/vortex forces have been noted and are likely to impact the nature of endurance races in the future.

The interplay between nature and nurture determines the unique psychophysiological responses to training and competition, and technological exploits leading to advanced sports products coupled with favourable natural and/or manipulated training and competition environmental conditions will ensure continued realisation of the Olympic Motto 'Citius, Altius, Fortius' (Faster, Higher, Stronger). However, there is a need to constantly adjust the rules of the game to censor commercial interest and safeguard the safety of athletes and the nature of sports as a medium to celebrate natural human abilities. This is even more apparent as the IOC moves to expand the Olympic Motto by adding '–Together', to mitigate the effects of differences in access to sponsorship, sports products, and technology, as well as training environments among people of diverse natural athletic talents and backgrounds.

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Conflict of interest

The authors declare no conflict of interest.

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References

[1] International Olympic Committee [IOC]. Olympic Charter. [Internet]. 2020. Available from: https://library.olympics.com/Default/doc/SYRACUSE/355508/olympic-charter-in-force-as-from-17-july-2020-international-olympic-committee [Accessed: 2021-01-05]

[2] International Olympic Committee [IOC]. What is the Olympic motto? [Internet]. 2020. Available from: https://olympics.com/ioc/faq/olympic-rings-and-other-olympic-marks/what-is-the-olympic-motto [Accessed: 2021-01-05]

[3] Anderson O. Running Science. Champaign: Human Kinetics; 2013.

[4] Silver MD. Use of ergogenic aids by athletes. The Journal of the American Academy of Orthopaedic Surgeons. 2001; 9(1), 61-70. https://doi.org/10.5435/00124635-20010 1000-00007

[5] Robergs RA, Roberts SO. Exercise Physiology: Exercise, Performance, and Clinical Applications. Chicago: Mosby; 1997.

[6] Shelton J, Kumar G. Sodium Bicarbonate -A Potent Ergogenic Aid? Food and Nutrition Sciences. 2010; 1(1): 1-4. https://doi.org/10.4236/fns.2010.11001

[7] Muniz-Pardos B, Sutehall S, Angeloudis K, Guppy FM, Bosch A, Pitsiladis Y. Recent Improvements in Marathon Run Times Are Likely Technological, Not Physiological. Sports Medicine. 2021. https://doi.org/10.1007/s40279-020-01420-7

[8] Pitsiladis Y, Ferriani I, Geistlinger M, deHon O, Bosch A, Pigozzi F. A Holistic Antidoping Approach for a Fairer Future for Sport. International Perspectives. 2017; 16 (4): 222-224.

[9] Johnson LM, Zhang JJ, Pitts BG. Managing Resources and Opportunities in Globalized Sport Business. In: Pitts BG, Zhang JJ, editors. Global Sport Business. New York: Routledge; 2019.

[10] Plunkett Research. Sports Industry Statistic and Market Size Overview, Business and Industry Statistics. [Internet]. 2017. Available from: https://www.plunkettresearch.com/statistics/Industry-Statistics-Sports-Industry-Statistic-and-Market-Size-Overview/ [Accessed: 2020-12-20]

[11] Abbate E. A brief history of running. [Internet]. 2017. Available from: https://www.24life.com/a-brief-history-of-running/ [Accessed: 2020-12-07]

[12] Bramble DM, Lieberman DE. Endurance running and the evolution of Homo. Nature. 2004; 432(7015): 345 https://doi.org/10.1038/nature03052

[13] Carter N. Science and the Making of the Athletic Body. In: Medicine, Sport and the Body: A Historical Perspective. London: Bloomsbury Academic; 2012. p. 81-104. http://dx.doi.org/10.5040/9781849662062.ch-004

[14] Fetters KA, Mahtani N. 13 Benefits of Running That'll Convince You to Lace up Your Sneakers, Stat: Heart health and strong bones are just the beginning. Women's Health. [Internet]. 2020. Available from: https://www.womenshealthmag.com/fitness/g33655800/benefits-of-running/ [Accessed: 2020-12-07]

[15] Malm C, Jakobsson J, Isaksson A. Physical Activity and Sports-Real Health Benefits: A Review with Insight into the Public Health of Sweden. Sports. 2019; 7(5): 127. https://doi.org/10.3390/sports7050127

[16] Karnazes D. The Real Pheidippides Story. [Internet]. 2016. Available from: https://www.runnersworld.com/runners-stories/a20836761/

the-real-pheidippides-story/ [Accessed: 2020-12-07]

[17] Spencer A. The History of the Marathon. [Internet]. 2012. Available from: https://www.marathon trainingacademy.com/the-history-of-the-marathon [Accessed: 2020-12-07]

[18] Singh N, Ananthanarayanan N. Marathon high: India's road running culture spawns big business. Hindustan Times. [Internet]. 2017. Available from: https://www.hindustantimes.com/other-sports/marathon-high-india-s-road-running-culture-spawns-big-business/story-U4fjeFqUgm Vumj9R0MXdOI.html [Accessed: 2020-12-07]

[19] Wahba P. Why Big Business loves marathons. Fortune. [Internet]. 2015. Available from: https://fortune.com/2015/10/26/business-marathons/ [Accessed: 2020-12-07]

[20] World Athletics [WA]. Marathon men: All time toplists. [Internet]. 2021. Available from: https://www.worldathletics.org/records/all-time-toplists/road-running/marathon/outdoor/men/senior [Accessed: 2020-12-07]

[21] Larsen HB, Sheel AW. The Kenyan runners. Scandinavian Journal of Medicine & Science in Sports. 2015; 25 Suppl. 4: 110-118. https://doi.org/10.1111/sms.12573

[22] Wilber RL, Pitsiladis YP. Kenyan and Ethiopian distance runners: what makes them so good? International journal of sports physiology and performance. 2012; 7(2): 92-102. https://doi.org/10.1123/ijspp.7.2.92

[23] Soong K. A sub-two-hour marathon, once seen as 'impossible,' could happen much sooner than experts thought. The Washington post. [Internet]. 2016. Available from: https://www.washingtonpost.com/news/early-lead/wp/2016/12/13/a-sub-two-hour-marathon-long-seen-as-impossible-could-happen-much-sooner-than-experts-thought/ [Accessed: 2020-12-07]

[24] English T. The Aerodynamics of Running: What Can You do to Run Faster? How can you use engineering principles to optimize your run? [Internet]. 2020. Available from: https://interestingengineering.com/the-aerodynamics-of-running-what-can-you-do-to-run-faster [Accessed: 2021-04-06]

[25] Woodward A. A Kenyan runner finished a marathon in under 2 hours, sprinting at a 4:34-mile pace. Here's why his record doesn't count. Business insider. [Internet]. 2019. Available from: https://africa.businessinsider.com/sports/a-kenyan-runner-finished-a-marathon-in-under-2-hours-sprinting-at-a-434-mile-pace/37pernr [Accessed: 2020-12-07]

[26] Browne K. Eliud Kipchoge runs first ever sub-two hour marathon. Olympic Channel Services. [Internet]. 2019. Available from: https://www.olympic channel.com/en/stories/news/detail/eliud-kipchoge-first-sub-two-hour-marathon/ [Accessed: 2020-12-07]

[27] INEOS. History made. [Internet]. 2019. Available from: https://www.ineos159challenge.com/history-made [Accessed: 2020-12-07]

[28] Total Running Productions. Eliud Kipchoge's 1:59 Marathon Nike Shoes Break the Internet. [Internet]. 2020. Available from: https://www.youtube.com/watch?v=XcbxjK7kTE4 [Accessed: 2021-02-17]

[29] South African History Online [SAHO]. South Africa and the Olympic Games. [Internet]. 2021. Available from: https://www.sahistory.org.za/article/south-africa-and-olympic-games [Accessed: 2021-01-10]

[30] Otoole S. Story of South Africa's first black Olympians keeps us guessing. [Internet]. 2016. Available from: https://mg.co.za/article/2016-07-07-00-story-of-south-africas-first-black-olympians-keeps-us-guessing/ [Accessed: 2021-01-10]

[31] Leonard J. The Value of Athletic Glory in Ancient Greece. [Internet]. 2016. Available from: https://www.greece-is.com/athletic-glory-shadow-zeus/ [Accessed: 2021-01-10]

[32] Fisher R. How to train like an Ancient Greek Olympian. BBC. [Internet]. 2021. Available from: https://www.bbc.com/future/article/20210804-how-to-train-like-an-ancient-greek-olympian [Accessed: 2021-04-06]

[33] Morente A. Sports training in Ancient Greece and its supposed modernity. Journal of Human Sport and Exercise. 2020; 15(1): 163-176. https://doi.org/10.14198/jhse.2020.151.15

[34] Thompson PJ. New interval training. [Internet]. 2010. Available from: https://www.newintervaltraining.com/fartlek-training.php [Accessed: 2021-04-06]

[35] Thompson, PJ. Introduction to Coaching. Monte Carlo, Monaco: International Amateur Athletic Federation. 2009.

[36] Gladden LB. A lactatic perspective on metabolism. Med Sci Sports Exerc. 2008; 40(3): 477-485.

[37] Knez WL, Sharman JE, Jenkins DG, Coombes JS. Central hemodynamics in ultra-endurance athletes. Journal of Science and Medicine in Sports. 2006; 11(4): 390-395. https://doi.org/10.1016/j.jsams.2006.11.005

[38] Kuznetsova Z. Effect of Different Power Loads on Athletes With Different Types of Blood Circulation Central Hemodynamic Index. In: Proceedings of the ICSEMIS 2016 Olympic Games conference 31st August - 4th September 2016: Santos, Brazil.

[39] Shishkina A, Tarbeeva N, Alimpieva O, Berdnikova A, Tarbeeva A. Miasnikova T. Hemodynamics Monitoring in Sport - Using Hemodynamic Monitor for Sport Training Planning. In Proceedings of the 2nd International Congress on Sports Sciences Research and Technology Support (icSPORTS-2014), 2014. p. 103-110. ISBN: 978-989-758-057-4 https://doi.org/10.5220/0005094301030110

[40] Kikuchi N, Miyamoto-Mikami E, Murakami H, Nakamura T, Min S, Mizuno M, Naito H, Miyachi M, Nakazato K, Fuku N. ACTN3 R577X genotype and athletic performance in a large cohort of Japanese athletes, European Journal of Sport Science. 2016; 16(6): 694-701. https://doi.org/10.1080/17461391.2015.1071879

[41] Moir HJ, Kemp R, Folkerts D, Spendiff O, Pavlidis C, Opara E. Genes and Elite Marathon Running Performance: A Systematic Review. Journal of Sports Science & Medicine. 2019; 18(3): 559-568.

[42] Folland JP, Allen SJ, Black MI, Handsaker JC, Forrester SE. Running Technique is an Important Component of Running Economy and Performance. Medicine and science in sports and exercise. 2017; 49(7): 1412-1423. https://doi.org/10.1249/MSS.0000000000001245

[43] Mwangi FM, Wanderi PM, Wamukoya EK, Onywera VO, Gitonga ER. Effects of Different Arm Kinematics on Performance in Long Distance Running: International Journal of Current Research. 2011; 33(6): 185-190.

[44] Dineen R. Exclusive: Electronic pill that protects against heat exhaustion to be trialed in Doha. The Telegraph.

[Internet]. 2019. Available from: https://www.telegraph.co.uk/athletics/2019/08/20/exclusive-electronic-pill-protects-against-heat-exhaustion-trialled/ [Accessed: 2021-08-11]

[45] Dineen R. Tokyo 2020 athletes took an ELECTRONIC pill during Olympics as part of groundbreaking experiment into measuring vital signs - such as body temperature - in real time. Daily Mail. [Internet]. 2021. Available from: https://www.dailymail.co.uk/sport/olympics/article-9873809/Tokyo-Olympics-Athletes-took-ELECTRONIC-pill-groundbreaking-experiment.html [Accessed: 2021-08-11]

[46] Lieberman DE, Venkadesan M, Werbel WA, Daoud AI, D'andrea S, Davis IS, Mang'eni RO, Pitsiladis Y. Foot strike patterns and collision forces in habitually barefoot versus shod runners. Nature. 2010; 463(7280): 531-535.

[47] Setrana R. Kenyan Runners: Why They Are Exceptional In Marathon. [Internet]. 2021. Available from: https://talesofafrica.org/kenyan-runners-are-exceptional-at-marathon/ [Accessed: 2021-02-24]

[48] Total Running Productions. Eliud Kipchoge's Nike Zoomx Alphafly Next%. [Internet]. 2020. Available from: https://www.youtube.com/watch?v=_cD4Gx83KQY [Accessed: 2021-02-17] (Online). Accessed on February 17, 2021.

[49] Rothschild C. Running Barefoot or in Minimalist Shoes: Evidence or Conjecture? Strength and Conditioning Journal. 2012; 34 (2): 8-17. https://doi.org/10.1519/SSC.0b013e318241b15e

[50] Jenkins S. Greatest Olympic athlete? Jim Thorpe, not Usain Bolt. The Washington Post. [Internet]. 2012. Available from: https://www.washingtonpost.com/sports/olympics/greatest-olympic-athlete-jim-thorpe-not-usain-bolt/2012/08/10/f9114872-e33c-11e1-ae7f-d2a13e249eb2_story.html [Accessed: 2021-02-17]

[51] Solereview editors. Best running shoes for marathons. Solereview. [Internet]. 2021. Available from: https://www.solereview.com/best-running-shoes-for-marathons/ [Accessed: 2021-02-17] (June 18,

[52] Allen T. Running shoes: how science can help you to run faster and more efficiently. The Conversation. [Internet]. 2019. Available from: https://theconversation.com/running-shoes-how-science-can-help-you-to-run-faster-and-more-efficiently-127634 [Accessed: 2021-02-17]

[53] Nike. Nike Air Zoom Alphafly NEXT%. [Internet]. 2020. Available from: https://www.youtube.com/watch?v=6fs1oT9cBgE&t=163s [Accessed: 2021-01-11]

[54] Dunne J. Eliud Kipchoge's running form. [Internet]. 2019. Available from: https://www.youtube.com/watch?v=andAaS6Lyc8 [Accessed: 2021-02-17]

[55] Hoogkamer W, Kipp S, Frank JH, Farina EM, Luo G, Kram R. A Comparison of the Energetic Cost of Running in Marathon Racing Shoes. Sports Medicine. 2018; 48: 1009-1019. https://doi.org/10.1007/s40279-017-0811-2

[56] Kelland K. Nike Vaporflys: World Athletics set to clamp down on 'technological doping' [Internet]. 2020. Available from: https://www.independent.co.uk/sport/general/athletics/nike-vaporflys-world-athletics-record-rules-soles-latest-news-a9299%20951.html [Accessed: 2021-03-20]

[57] Business Today. Kipchoge Finally Responds to Critics About His Shoes. [Internet]. 2020. Available from: https://businesstoday.co.ke/kipchoge-finally-responds-to-critics-about-his-shoes/ [Accessed: 2021-03-20]

[58] Pallis JM, McNitt-Gray JL, Hung GK. Biomechanical Principles and Applications in Sports. eds. Springer Nature. 2019.

[59] Bontemps B, Gruet M, Vercruyssen F, Louis J. Utilisation of far infrared-emitting garments for optimising performance and recovery in sport: Real potential or new fad? A systematic review. PLoS ONE. 2021; 16(5): e0251282. https://doi.org/10.1371/journal.pone.0251282

[60] Loturco I, Abad CC, Nakamura FY, Ramos SP, Kobal R, Gil S, Pereira LA, Burini FH, Roschel H, Ugrinowitsch C, Tricoli V. Effects of far infrared rays emitting clothing on recovery after an intense plyometric exercise bout applied to elite soccer players: a randomized doubleblind placebo-controlled trial. Biol Sport. 2016; 33(3): 277-283.

[61] Goncharov N, Maevsky E, Voitenko N, Novozhilov A, Kubasov I, Jenkins R, Avdonin P. Nutraceuticals in Sports Activities and Fatigue. In: Ramesh C. Gupta (Editor). Nutraceuticals. Academic Press; 2016. p. 177-188. ISBN 9780128021477. https://doi.org/10.1016/B978-0-12-802147-7.00014-0

[62] Dolan SH. Electrolytes: Understanding Replacement Options. The American Council on Exercise (ACE). [Internet]. 2021. Available from: https://www.acefitness.org/certifiednewsarticle/715/electrolytes-understanding-replacement-options/ [Accessed: 2021-07-25]

[63] Food and Nutrition Board, Institute of Medicine. Dietary reference intakes for water, potassium, sodium, chloride, and sulfate. Washington D.C.: National Academy Press; 2004.

[64] Kim J. Nutritional Supplement for Athletic Performance: Based on Australian Institute of Sport Sports Supplement Framework. Exercise Science. 2019; 28(3): 211-220. DOI: https://doi.org/10.15857/ksep.2019.28.3.211

[65] Burfoot A. Top Marathoners Swear By This High-Carb Drink -Even Without Endorsement Deals. [Internet]. 2018. Available from: https://www.runnersworld.com/news/a20731143/top-marathoners-swear-by-this-high-carb-drinkeven-without-endorsement-deals/ [Accessed: 2021-07-25]

[66] Maurten. Science is a part of our nature. And vice versa. [Internet]. 2021. Available from: https://www.maurten.com/innovation [Accessed: 2021-07-25]

[67] Munson M. The Science Behind the Hottest Sports Fuel: Why endurance athletes can't get enough of Maurten sports drinks and gels. Men's Health. [Internet]. 2021. Available from: https://www.menshealth.com/fitness/a35636532/maurten-sports-drinks-gels-upgrade-fuel/ [Accessed: 2021-07-25]

[68] Spathopoulos VM. An Introduction to the Physics of Sports. Dynamics Physics; 2013.

[69] Shephard RJ, Astrand PO. Endurance in Sport. John Wiley & Sons. 2008.

[70] INEOS 1:59 Challenge. Explaining the INEOS 1:59 Challenge Pacemaker Formation. [Internet]. 2019. Available from: https://www.youtube.com/watch?v=KIzZgDXfm18 [Accessed: 2021-02-17]

[71] Pierce P. Mental Combat: The Sports Psychology Secrets You Can Use to Dominate Any Event! Amazon Digital Services LLC. 2020.

[72] Taylor, J. Train Your Mind for Athletic Success: Mental Preparation to Achieve Your Sports Goals. Rowman & Littlefield Publishing Group. 2017.

[73] Durussel J, Daskalaki E, Anderson M, Chatterji T, Wondimu DH, Padmanabhan N, Patel RK, McClure JD.,

Pitsiladis YP. Haemoglobin Mass and Running Time Trial Performance after Recombinant Human Erythropoietin Administration in Trained Men. PLoS ONE. 2013; 8(2): e56151. https://doi.org/10.1371/journal.pone.0056151

[74] Pereira I. Why Russian athletes are competing under the ROC at Olympics. [Internet]. 2021. Available from: https://abcnews.go.com/Sports/russian-athletes-competing-roc-olympics/story?id=79069924 [Accessed: 2021-08-11]

[75] World Antidoping Agency [WADA]. Progress of the Anti-Doping System in Light of the Russian Doping Crisis. [Internet]. 2019. Available from: https://www.wada-ama.org/sites/default/files/20190122_progress_of_the_anti-doping_system.pdf [Accessed: 2021-08-11]