Are Champions Born Or Made?

Yashvendra Singh *

October 18, 2023

Abstract

Champions hold the world's attention and their performances both inspire and generate curiosity. Whether they are born champions or are the product of scientific training mechanisms and tremendous hard work is a debate that rages on with every convincing victory that throws up an invincible winner. Sporting history is replete with examples where the sporting fraternity was forced to research characteristics and traits that marked their invincibility. Some studies showed that the complete domination of Kenyan and Ethiopian runners in the middle- and long-distance events and Usain Bolt's phenomenal success could also be attributed to their higher haemoglobin and slow twitch muscle fibres suited for endurance running and speed. Many believed that Michael Phelps's wider wingspan, and unique genetic disposition of producing less lactic acid gave him an unfair advantage over his competition. There are many such examples that keep bringing back the question – are champions made or born? The more pragmatic researchers who emphasize on scientific training, hard work and personal motivation too have not been able to dismiss the role of genetic predisposition. Given the level of competition and hard work that these champions endure to become winners makes this an interesting case study. This paper analyses the complex interplay between the roles played by genetic disposition and training in an athlete's performance.

1 Introduction

The impact of genetics on sports performance is a hugely contentious debate in the sporting fraternity. While some like Michael Phelps were hailed as supernatural and genetically blessed because of his unusually wide wingspan, double-jointed ankles and his physical distinctiveness wherein his body apparently produced half the lactic acid as compared to his fellow competitors, which gave him a huge biological advantage over his fellow athletes, others like Caster Semenya, the two time Olympic champion from South Africa, became the subject of controversy. Her body allegedly produced higher testosterone levels than most

*Advised by: Bridget Callaghan

women–a finding that led the Court of Arbitration for Sport to rule that she would have to lower her testosterone levels through medication to compete in the women category [Ing19,SEM16], making her a prominent face in the annual list of "50 People That Matter" for unintentionally instigating "an international and often ill-tempered debate on gender politics, feminism, and race, becoming an inspiration to gender campaigners around the world" in the 2010 edition of the British magazine New Statesman.

The absolute domination of the Kenyan long-distance runners is another trigger that sparked the debate on genetic endowment. Physiological advantages of Africans have recently been studied by Weston et al, whose studies revealed that "Africans had elevated citrate synthase and 3-hydroxyacyl CoA dehydrogenase activity and enhanced resistance to fatigue in a treadmill trial designed to imitate the stresses involved in 10 km running". [AR99]. They also demonstrated lower blood lactate concentrations at higher speeds. Another study revealed that they had relatively higher haemoglobin and haematocrit, metabolic efficiency and helpful skeletal-muscle-fibre composition and oxidative enzyme profile that gave them the advantage over equally motivated and trained athletes. [WR12] Research has shown that one of the main factors that contributes to strength/power which is essential to be a sports champion is also biomechanically based, highlighting genetics once again. Since most sports demand agility and brute force, "joint torque – this is how fast and/or powerfully a joint can move based on the force that a muscle applies to it" is important. [Coy07]. This enhanced joint torque helps an athlete generate greater power and speed in rotational movements, helps in maintaining better balance, enhances precision in movement towards a given goal/target even at odd, angled movement, enhances endurance and facilitates faster recovery; all of which are crucial for an athlete's performance. [Mus23] Interestingly, orthopaedic research on reconstruction of joints and/or soft tissue attachments has shown that attachment site of a tendon is a crucial determinant of the range of motion of a joint and joint torque at various positions [Yam07,Miz23]. These muscle attachment mechanisms and positions are all genetic. Strength and endurance is also dependent on the muscle fibre type [Tes85]. It is proven that fast twitch muscle fibres produce more force and power than slow twitch fibres – primarily because they are larger in size, giving players with the former a genetic advantage especially in sprinting. This was often one of the attributes that supposedly made Usain Bolt unstoppable and matchless. [DLCS76]. The type of muscle fibre may have a direct bearing on the athlete's performance. For example, the slow- support long distance runners and the fast-twitch support quick, powerful movements needed for sports like sprinting or weightlifting. [TP85,ME19]

There is empirical evidence of the fact that "professional bodybuilders more than likely have some sort of myostatin mutation that allows them to build and maintain such muscle mass". [Sch04] Furthermore, the research findings that elite marathon runners are simply better at dissipating heat than other runners due to efficient tendon hysteresis and have higher maximum oxygen capacity again takes us back to genetic predisposition [FEMNes, MD94] .

The genetically blessed dilemma has always stayed enigmatic. Let's use India

as an example as it has the largest population of young people in the world. Are Indians genetically better at excelling in chess than soccer and Basketball? The query assumes increased pertinence as an 18-year-old Indian Chess grandmaster, Rameshbabu Praggnanandhaa takes on Magnus Carlsen in the final of the FIDE world cup at Baku, Azerbaijan. He is an exceptional talent, motivated by the likes of fellow Indians like Vishwanathan Anand who himself has been a champion earlier. While some might wonder why the most populous country with a population of 1.4 billion has never qualified for Soccer or Basketball at the Olympics/world cup and has only a handful Olympic medals in athletics, others might argue how India's cricketing prowess also throws confusing signals, where two of its most renowned players Sachin Tendulkar and Sunil Gavaskar became legends in their craft despite very small physical frames. They were known to take on the might of some of the fastest physically well-endowed bowlers from other cricketing nations. The world is replete with such examples with footballers like Lionel Messi and Deigo Maradona making it to the very top despite a shorter frame, belying the genetics argument to some extent.

Interestingly in the same vein, while on one side we see a distinctive edge enjoyed by black athletes in all sports requiring high speed and force and the complete domination of black athletes over their Caucasian counterparts in the popular NBA, we see Asians and Caucasians dominate racket sports like Tennis and badminton which also require high levels of agility and brute force. Such contradictions trigger a counter argument that genetic predisposition is a significant but not the sole prerequisite for excelling in a particular sport.

With the advent of technical tools to make sports training more scientific, this debate leads to a larger debate of sports genomics. We attempt to analyse whether champions can be trained and made or if they need to have a certain genetic predisposition for training to yield the desired results. Add to this the role played by hard work, motivation, and the role of a supportive team in the athlete's success as expanded by Ericsson's theory of deliberate practice and its significance in champion development lends an interesting dimension that cannot be ignored. [Eri93]

2 The Key Fundamentals of Sporting Excellence:

2.1 Physical

The physical qualities of the athletes and players are among the most frequently studied contributing factors of performance [Fal04] (e.g., Falk, Lidor, Lander, & Lang, 2004). Sports is built on a strong physical foundation. It is an unavoidable principle. Unfortunately, sports training has become a lucrative business industry of trillions of dollars where parents and athletes are given false assurances and introduced to a tough regimen that they cannot keep up with. The parameters of physical fitness may vary based on the sport. For example, one can't have a diminutive basketball player, but the same player might turn out to be lethal in sports like soccer/ cricket/golf where height is not the only

advantage. Recreational sport may be for everyone, but competitive sports at any level involves fierce competition and one must have the physical endurance to take on the challenge. This prerequisite can be ignored for sports like chess and other board games that do not involve any physical activity. This is not as simple and straight forward as it seems as different sports have different physical requirements. As Vaeyens et al. (2008) argued, the nature of the sport discipline itself defines to what extent the uni dimensional components intervene [Vae08]. Moreover, even within specific sport disciplines, the physical requirements will vary greatly, depending on the position of the players on the field; This position-specific adaptation has been observed for various sports, including volleyball [She09] (Sheppard, Gabbe, & Raebery, 2009), handball [Zap11,Del13] [Zapartidis, Kororos, Christodoulidis, Skoufas, & Bayios, 2011], and rugby [Delahunt et al., 2013]. These studies reveal that the specifics may vary. For decades, coaches have obsessed with the "the tale of the tape," to measure height, weight and reach to determine a player's suitability at a competitive level. Now new research out of UC Berkeley suggests that the relative length of an athlete's arms to their height might be even more important than previously believed in sports like NBA, [Bah18] making the term "wingspan" a key element in NBA. The same advantage was exploited by Michael Phelps to perfection in his sporting career. Despite variations in the basic sports type and role, the one thing most studies agree with is that physicality matters in sports.

2.2 Technical

Technique in any sport is important. Grosser, M. (1982) defines technique as the ideal model of a movement relative to a specific sport activity. [Roc86] It refers to the methodology adopted in terms of movements and postures to maximise impact, optimize performance, prevent injuries, ensure consistency under pressure with minimal wastage of effort and force. This technique is the key to success in sports. These techniques are crucial and are worked on very scientifically and personalised for champions after careful analysis of their physical attributes and natural abilities and strengths. Michael Phelps' perfecting the deep catch or sculling technique to propel him faster and Michael Jordan using biomechanics to perfect his famous fadeaway are all examples of sportsmen perfecting techniques to get a competitive advantage.

Michael Jordan's accomplishments are attributed to his brilliant athleticism and superior technique. "His planted foot was attached to the floor, making it easier for him to explode away from his defender at just the right moment"–a small example of a technique used to perfection."While others rely on instinct or muscle memory to make their shots in moments of white-hot pressure, Federer can delay the moment when he must commit to a shot until impossibly late" [Fyl09]which is another example of a technique used to perfection by the legendary tennis player Roger Federer.

2.3 Tactics and Strategy

Brute force and physical attributes mean nothing without a refined skill set. That is why athletes spend time adding tactical elements to their training and work on a winning strategy. Athletes have to have a comprehensive understanding of the strategic aspects of the game and how these strategies withstand the test of a real time game/competition and not just be secure within the precincts of their training arena. For this they don't only plan and strategize for themselves but also carefully analyse the strategy of their competitors to ensure that they can have the winning edge by keeping in mind all contingencies and the counter for it. This is crucial as it "requires players to maintain high quality of perception, concentration and decision-making for a long time, even when the player is physically and psychologically overloaded". [PP18] "Tactics therefore elaborates the strategic intention of preparing the player or team in real conditions of a match and solving situations in match. Tactics point to the possibilities of solving certain sub-situations within the strategy. It focuses on the practical implementation of such situations in the match". [SO18] Tactical preparation is the process of equipping a sportsman with knowledge, practical learning and skills that enable the player to choose the optimal solution in each game situation and apply it effectively. This is crucial for success.

2.4 Psychological Power

Winning is also a mind game. It takes a strong mind and personality to withstand the pressure of competitive sports and to remain focussed and determined in a real time competition that has its fair share of unpredictable variables. "The psychological factor is usually the determinant that differentiates a winner and a loser in sports" [Bre09] (Brewer, 2009). In studies conducted by Gould, Dieffenbach, & Moffett (2002) [Gou02] involving ten Olympians, it was reported that "mental toughness is one of the highest ranked psychological characteristics that determine a successful performance". Given the levels of competition at the highest level, it comes as no surprise that Athletes, coaches, and applied sports psychologists have consistently referred to mental toughness as one of the most important psychological characteristics related to outcomes and success in elite sport.

Grit, optimism, resilience, and perseverance are traits that set apart champions from the others. They are required to be mentally tough to be able to sustain the pressure of competition and have to be tough to keep their self-determined motivation and optimism regardless of the variables and changing dynamics of the environmental and surrounding factors.

3 Impact of Genetics on the Key Fundamentals of Sporting Excellence:

3.1 Impact of Genetics on Physical Force and Strength:

It is widely acknowledged that a favourable genetic profile, when combined with an optimal training environment, is important for elite athletic performance. [GL13]. As of 2009, more than 200 genetic variants have been associated with physical performance, with more than 20 variants being associated with elite athlete status [BM09] and given the extremely slim margins between victory and defeat. This is undoubtedly a substantial advantage to possess, ensuring a favourable head start.

Key basic physical traits like height, which is critical for success in some sports, is highly heritable, with about 80

The tremendous success of many Kenyan athletes has brought back the focus to the role of genetics in a sportsman's success. Studies have shown that African distance runners have reduced lactic acid accumulation in muscles, increased resistance to fatigue, and increased oxidative enzyme activity, which gives them the advantage of high levels of aerobic energy production.[WAik] Larsen et al., (2015) studied the anthropometric characteristics of elite Kenyan distance runners and reported that they had longer legs (5

The dynamic cyclist Miguel "Big Mig" Induráin won five Tours de France from 1991 to 1995 and the Giro d'Italia twice was known to have a remarkably huge lung capacity and an exceptional heart that allowed his blood to transport 7 liters of oxygen throughout his body per minute compared to 3 to 4 liters pumped in an average individual.

Basketball greats like Michael Jordan whose 6'6" frame was bestowed with a wingspan of 6'11", used his reach to a completely different level. Dwight Howard's wingspan of 7 feet 5 inches with a 6 feet 11 inches tall frame made him formidable; at 7 feet 1 inch tall and 325 pounds, Shaquille O'Neal is a with size 22 feet used his overpowering physical assets to dominate the court and so does LeBron James who stands 6 feet 8 inches tall and weighs 250 pounds. His massive legs allow him to make 700 pounds of pressure per leap making him faster than most other point guards [Hay17].

3.2 Impact of Genetics on The Technical, Tactics And Strategy Aspect Of Sports

Technique in any sport is important. Grosser, M. (1982) defines technique as the ideal model of a movement relative to a specific sport activity. [Roc86] As mentioned earlier it refers to the methodology adopted in terms of movements and postures to maximise impact, optimize performance, prevent injuries, ensure consistency under pressure with minimal wastage of effort and force.

Agility, speed, force, endurance are key factors to perfecting technique and it is apparent above that genetics has a crucial role to play in all of them. Athletic

performance is a complex mix of both genetic and environmental factors. Since every movement and technique is greatly impacted by the physical traits and the strength of muscles used for movement (skeletal muscles) and the predominant type of fibers that compose them, genetics again becomes a focus. These muscle fibres can't be created artificially and are nature's gift. These fibres are primarily of two types, Slow-twitch muscle fibers contract slowly and can work tirelessly for a longer duration and hence are an asset for any sport that needs endurance. Fast-twitch muscle fibers contract quickly but tire rapidly; these fibers are good for sprinting and other activities that require power or strength. Other traits that have a direct bearing on whether a trained sportsman can stick to technique in a high pressure competitive environment is also related to aerobic capacity, muscle mass, height, flexibility, coordination, intellectual ability, and personality; all of which have a direct genetic connection.

Basketball and soccer are two of several combination anaerobic and aerobic sports in which athletes need power, speed, quickness, agility, and strength [NSC17] and studies have revealed how genetic composition can have a direct bearing with them. There is no doubt that a motivated athlete could train harder to overcome odds and defy the genetic advantage of an opponent, but champions need only that fraction of an advantage to take the lead sometimes, and that minuscule advantage might be the defining difference.

The ability to generate maximal power during complex motor skills is of paramount importance to successful athletic performance across many sports [Cor11] and has a direct bearing on their ability to implement technique to perfection. This is why there is emphasis on power training to improve maximal power production in dynamic, multi-joint movements. Muscle strength is directly related to its fibre composition and hence genetics comes in. Studies have been consistent in their findings to indicate the significant role of genes in the way an individual's body responds to exercise and strength training which have a direct bearing on whether an athlete can execute a given technique to perfection. A recent study found that up to 72

Technique, tactics, and strategy are perfected through training and other factors like diet and nutrition. Research on aerobic endurance shows that some people respond more to training than others. Genetically gifted athletes are likely to respond better to training as compared to equally motivated less genetically blessed athletes and their bodies are likely to have increased number of mitochondria in cells that produce Adenosine triphosphate (ATP), the source of energy usage and storage at the cellular level [MJ19a]. Tactics and strategy are another key pillar of sporting success. A powerful athlete can implement this strategy with brute force and impeccable precision and is also capable of destroying that of his opponent however well prepared. Any race/match is won because the winner has the capacity to outdo and outperform the tactics and strategy of his/her opponents. All athletes at the highest level come with the highest levels of training and motivation, as one cannot compete at the highest level without it. In the face of this intense competition, studies focused on similarities and differences in athletic performance within families, including between twins, suggesting that genetic factors underlie 30 to 80 percent of the differences among

individuals in traits related to athletic performance[AI15,AI16,WN15,YX16], which is percentage that cannot be ignored.

3.3 Impact of Genes On Psychological Power

Athletes' success or failure is not unidimensional rather it is multifactorial; it is a combination of multiple factors including physical, tactical, technical, and psychological factors. The psychological factor is usually the determinant that differentiates a winner and a loser in sports [Bre09a]. (Brewer, 2009). Studies by Weinberg and Gould (2003) [Wep03] indicated that mental ability contributed over 50

Clough et al. described mentally tough individuals "as tending to be sociable and outgoing as they can remain calm and relaxed, they are competitive in many situations and have lower anxiety levels than others. With a high sense of self-belief and an unshakable faith that they control their own destiny, these individuals can remain relatively unaffected by competition or adversity." [CP12a,CP02,CP12b]. It is a well known fact that mental/brain health, like our physical health is a complex interplay of genetics, epigenetics, and behaviour. Scientists estimate that 20 to 60 percent of our temperament is determined by genetics and their complex variations or (polymorphisms). For example, variants in the DRD2 and DRD4 genes have been linked to a desire to seek out new experiences, and KATNAL2 gene variants are associated with self-discipline and carefulness. [BD17,PR15] Genes like the; SLC6A4, AGBL2, BAIAP2, CELF4, L3MBTL2, LINGO2, XKR6, ZC3H7B, OLFM4, MEF2C, and TMEM161B are known to contribute to anxiousness or depression. Researchers also point to the genetic variation called ADRA2b which influences the neurotransmitter norepinephrine , and is linked to intense emotional responses and sensitivity . Given the significance of psychological factors on sports, one cannot ignore this crucial genetic factor.

4 Deliberate Practice and Expertise Acquisition

There is a counter belief encouraged by increasing scientific application in the training of elite athletes that ace athletes can be nurtured and even if they do not have special natural advantages. There is a relatively widespread belief that if individuals are innately talented, they can easily and rapidly achieve an exceptional level of performance once they have acquired basic skills and knowledge.

Schulz and Curnow (1988) drew attention to the fact that the performance of players over the Olympic history timeline had only improved in some cases by more than 50

Drawing a difference between regular performers and champions, these studies show that with more practice and experience, salient mistakes become increasingly rare, and "everyone's performance eventually reaches an acceptable

standard where the need for effortful concentration is minimised". If the individual persists and learns to adapt to situational demands, a stage could come when the tasks become increasingly automated and the individual could stop making intentional adjustments. This is where the ace or expert performers are different as they do not stop the learning curve. "Expert performance continues to improve as a function of more deliberate practice" [Eri03a]. "The challenge for aspiring expert performers is to avoid the arrested development associated with automaticity and to acquire new cognitive skills through their continued learning and improvement". By persistently practicing and harnessing one's unique talents, "this modification of complex cognitive mechanisms demands problem-solving skills and undivided concentration" [Eri02]. The key challenge is to be persistent with deliberate practice and to continue to pursue perfection in all eventualities with a focussed cognitive approach. Ericsson believed that "As a result of deliberate practice, many biological characteristics, such as width of bones, flexibility of joints, size of heart, metabolic characteristics of muscle fibers, and so forth, can be changed after years of intense and carefully designed training. Biochemical processes that preserve equilibrium during intense training influence these anatomical changes" [Eri03b]. (Ericsson, 2003c). Deliberate practice also helps the expert performers sharpen their "mental representations that allow the expert performer to bypass the information-processing constraints imposed by basic capacities" he added. Taking this cue, it could be inferred that the exemplary reaction mechanisms and superior force and speed exhibited by ace athletes' elite athletes in like returning tennis ball of an opponent, can be attributed to skilled anticipation of events by identification of early predictive cues and not by superior perceptual acuity or faster cognitive speed alone [ea08].

This theory of deliberate practice also stresses on starting early to give the potential players the years of practice needed to be an ace sportsman. "In many domains, such as music and sports, parents arrange for their children to start practice at very young ages, sometimes as young as 3–4 years of age". This early start gives them a huge advantage as they can sharpen their skill sets with deliberate practice as compared to the late starters. Studies have shown that beginning deliberate training early in life yields more refined and accurate adaptive responses and greater cognitive and neurological development.

"The foundations of brain architecture are established early in life through a continuous series of dynamic interactions between genetic influences, environmental conditions, and experiences" [Fri06,MM06]. This phase has a significant impact on the brain architecture and "each one of our perceptual, cognitive, and emotional capabilities is built upon the scaffolding provided by early life experiences" [GL15].

According to Benjamin Bloom, a professor of education at the University of Chicago, and author of the book "Developing Talent in Young People", which examined the critical factors that contribute to talent, "all brilliant performers had practiced intensively, had studied with devoted teachers, and had been supported enthusiastically by their families throughout their developing years His stud included the retrospective look at the childhoods of 120 elite performers who had won international competitions or awards in fields ranging from music

and the arts to mathematics and neurology [Blo85b]. His study focussed on deliberate practice and motivated training and overwhelmingly, leaned towards the concept that experts are always made, not born. These studies make a clear distinction between regular practice and deliberate practice with the latter more focussed towards refining the practice to cover all shortcomings and reaction to unpredictable variables that may stand in the way of an ultimate victory. "Not all practice makes perfect. You need a particular kind of practice—deliberate practice—to develop expertise. When most people practice, they focus on the things they already know how to do. Deliberate practice is different. It entails considerable, specific, and sustained efforts to do something you can't do well—or even at all. Research across domains shows that it is only by working at what you can't do that you turn into the expert you want to become" [KAEC07]. Deliberate practice involves two kinds of learning: improving the skills you already have and extending the reach and range of your skills. The enormous concentration required to undertake these twin tasks limits the amount of time you can spend doing them. The famous violinist Nathan Milstein wrote: "Practice as much as you feel you can accomplish with concentration. The general belief of most experts is even the most gifted performers need a minimum of ten years (or 10,000 hours) of intense training before they win international competitions, making it difficult and sometimes impossible for late starters to catch up with competitors who started earlier started earlier and maintained maximal levels of deliberate practice as rushing through the same levels of deliberate practice can lead to exhaustion and injuries. Ace Golfer, like Tiger Woods who started deliberate practice really young in life, is an example of this approach. Tennis great, Federer himself confessed that he didn't see himself as a genius but worked hard at it.

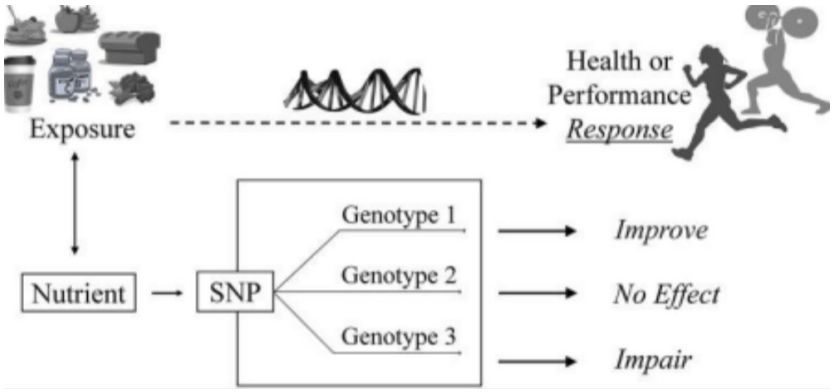
5 The Interplay of Genetics And Training - Epigenetics Context

Epigenetics explains how a gene's expression can be turned on and off due to external environmental influences, giving athletes an opportunity to work on the genes that favour their performance. These external influences include lifestyle choices, diets and nutrition, environmental pollution, stress and anxiety, quality, and quantity of sleep etc. role epigenetics plays in activating key SNPs that could eventually impact the various physical and mental parameters that are crucial for an athlete to perform optimally.

A fine example of this is the increasing emphasis on nutrigenomics research to provide a personalised nutrition plan to each athlete based on their genetic makeup to ensure favourable epigenetic transformation. This is the key as it is a well-known fact that athletic performance depends a great deal on the nutrition that is given to the athlete. As different body and genetic makeup types respond differently to the same type of diet regimens, it is essential that the athlete be given the nutrition that works well for his/her body type. The importance of

a personalized sports nutrition plan was highlighted by the American College of Sports Medicine which stated that "Nutrition plans need to be personalized to the individual athlete... and take into account specificity and uniqueness of responses to various strategies" [TD16]. These strategies encompass overall dietary patterns, macronutrient ratios, micronutrient requirements, eating behaviours (e.g., nutrient timing), and the judicious use of supplements and ergogenic aids.

Given the high stakes of building champions at the world stage, these studies also study the genetic variants which have a direct bearing on the way they absorb, metabolize, utilize, and excrete nutrients. [ND14]. Given the scientific foundation of this approach it has been found that given gene diet actionable advice has positively encouraged individuals and they are more likely to change health behaviors, including their dietary choices and intakes [HJ18], which is a welcome change. The positive outcome in terms of building muscle power and endurance levels, agility and speed and physical power and strength has made this field extremely popular and an increasing number of athletes are depending on individually tailored dietary and other performance-related information based on their DNA to stay competitive.



A fine example of this approach is the use of caffeine in the CYP1A2 rs726551 SNP, individuals with the AA genotype (fast metabolizers) to elicit a positive or "improved" response (i.e., performance). On the contrary, Individuals with the CYP1A2 AC or CC genotype may either show no effect or an impaired response to caffeine intake. [GN18]. Another usage example is the one to bring haemoglobin levels to the optimal level for athletes with diet and supplements. A low haemoglobin production decreases the oxygen carrying capacity of the blood, leading to a lack of oxygen to working muscles and resulting in impaired muscle contraction and aerobic endurance [HJ01].

Increasing interest in epigenetics is also leading to considerable research focus on research investigating individual variation in response to exercise training, playing sports and exercise genomics, a key factor in athletic training and performance enhancement. [VNipAAcFjs17]

6 Conclusion

Champions are a class apart and have always been the subject of fascination. It comes as no surprise that their 'making' has intrigued many, leading to some interesting debates on whether they are a product of nature or can be nurtured. This debate is as old as sport itself. Its theoretical context can be traced back to accounts of Hippocrates (460–370 BC), the father of medicine, in his Book 1 (Dietetics) where he stressed on the relative nature versus nurture contribution highlighting the importance of health and the role of a diet and exercise "regimen" in maintaining it. "Eating alone will not keep a man well; he must also take exercise. For food and exercise, while possessing opposite properties, yet contribute mutually to maintain health. For it is the nature of exercise to use up material, while of food and drink to restore them. And it is necessary, as it appears, to determine exactly the powers of various exercises, both natural and artificial exercises, and which of them contribute to the development of muscle". However, even though he seems to be making a reference to the 'nurture' aspect as a requisite for positive health, he, in the same book talks about heritability which immediately takes us to an individual's "genetic predisposition". Centuries later, Galton became the first academic to advocate a hereditary ceiling to physical and mental capacities [F69,FS92] and formally objected to "pretensions of natural equality" in his landmark paper "The history of twins as a criterion of the relative powers of nature and nurture".

It was Ericsson et al who questioned this notion of inherited talent and exceptional abilities with his theoretical framework for "deliberate practice", an alternative means to expert performance limiting the role of innate/inherited characteristics on optimal performance. [EK93]. Elite performance, they claimed, is the "product of a decade or more of maximal efforts to improve performance in a domain through an optimal distribution of deliberate practice", thus rejecting the Galtonian model of innate ability in the making of champions. Ericsson proposed a very structured approach claiming that "a specific volume of 10,000 h of training to be accumulated over a period of approximately 10 years, as necessary for achieving expert levels [KA.06]. His theory caught the imagination of a wider audience leading to very motivating publications like Outliers [M08], The genius in all of us [D.10] etc. These books fuelled a billion-dollar industry of nutrition and guided fitness.

However, all these theories were questioned based on the ground realities of the emerging champions, each more gifted than the other. Studies showed that despite the widespread appeal and popularity of Ericsson's Framework of deliberate practice, the more careful analysis of champions did not show an overwhelming impact of deliberate practice time. Studies show that only 28

Considering the number of body systems that must interact (musculoskeletal, cardiovascular, respiratory, nervous, etc.), athletic performance is one of the most complex human traits. Perhaps the first noticeable difference between athletes of different specialties is in body morphology (i.e., height and body composition), with specific body types naturally suited to specific sports. Beyond body morphology, endurance, strength, and power are primary factors

underlying athletic performance.

It is also important to factor that strategy and tactics is not a paper or a board exercise, it must be implemented in the sporting arena that has its fair share of real time dynamics. The athletes must be at their peak competency in terms of their mental, cardiovascular, respiratory, neuromuscular, metabolic, hormonal, and thermoregulatory systems; each of which have a genetic influence that is undeniable.

While deliberate practice and the role of environment and a support system is indeed critically important in the development of elite athletic abilities, dismissal of innate abilities resulting from genetic composition altogether in the making of elite athletes may not be correct. In fact, heritability studies on physical performance and functional adaptability provided strong evidence of a significant genetic component to various parameters that ultimately determine elite performance. Heritability estimates linked to sporting performance, such as 99

Ironically, these counter findings came mostly at a time when CRISPR gene editing began to make headlines, leading to a heightened interest in gene doping and genetic editing to make champions who would be no different from the natural ones, sometimes even surpassing them with an inserted genetic advantage. This turn of events has lent yet another scientific dimension to the nature vs nurture debate, one that is worrying sporting bodies as these genetic interventions are difficult to trace. [dA08] The raised concerns over genetic modification or "gene doping" for enhanced performance arise from impressive studies in genetically modified rodents where manipulation of individual genes has increased muscle mass, muscle strength, or running endurance, depending on the gene that was manipulated. Reviews of these animal studies conclude that such genetic manipulations could also improve human athletic performance [HL04, SA06, BA07]; inadvertently also solidifying the debate in favour of the advantages offered by nature. The only irony is that this nature's advantage could soon be nurtured.

Evidence from sporting champions clearly shows that both nature and nurture are critical to their success. However, all studies do show the slight advantage that inheritability offers, one that could make all the difference at the highest sporting levels. It would be safe to conclude that champions can be built but only from among those who are favoured by nature bringing us back to the prophetic statement of Galton, "there is nothing in what I am about say that shall underrate the sterling value of nurture, including all kinds of sanitary improvements; may, I wish to claim them as powerful auxiliaries to my cause; nevertheless, I look upon race as far more important than nurture."[100,101] He clearly implied that deliberate practice and environmental factors are undoubtedly both critical to sporting excellence, but they do not in themselves produce elite athletes. The future debate on this may not be as simple as the scientific community looks to create nature in laboratories.

References

[AI15] Fedotovskaya ON Ahmetov II. Current progress in sports genomics. adv clin chem. *Review. PubMed: 26231489.*, 2015.

[AI16] Gabdrakhmanova LJ Fedotovskaya ON Ahmetov II, Egorova ES. Genes and athletic performance: An update. *Med Sport Sci. 2016;61:41-54. doi: 10.1159/000445240. Epub 2016 Jun 10. Review. PubMed: 27287076.*, 2016.

[AR99] Weston AR. African runners exhibit greater fatigue resistance, lower lactate accumulation, and higher oxidative enzyme activity. *J Appl Physiol*, 1999.

[BA07] Rasko JE Emslie KR Baoutina A, Alexander IE. Potential use of gene transfer in athletic performance enhancement. *Mol Ther 2007;15:1751-66.*, 2007.

[Bah18] Joel Bahr. Study shows wingspan has a correlation to athletic prowess in the nba, mma. *Berkeley Research*, 2018.

[BD17] Vukasović T Bratko D, Butković A. . heritability of personality. *Psychological Topics, 26 (2017), 1, 1-24.*, 2017.

[BJ05] Deakin J Baker J, Côte J. Expertise in ultra-endurance triathletes early sport involvement, training structure, and the theory of deliberate practice. *J Appl Sport Psychol. 2005;17:64–78. doi: 10.1080/10413200590907577.*, 2005.

[Blo85a] B. S Bloom. Generalizations about talent development. in b. s. bloom (ed.), developing talent in young people (pp. 507–549). *New York: Ballantine Books.*, 1985.

[Blo85b] Benjamin Bloom. Developing talent in young people. *New York : Ballantine Books*, 1985.

[BM09] Pérusse L et al. Bray MS, Hagberg JM. The human gene map for performance and health-related fitness phenotypes: the 2006–2007 update. *Med Sci Sports Exerc;41(1):35–73.*, 2009.

[Bre09a] B.W. Brewer. Handbook of sports medicine and science, sport psychology. *.Chichester: John Wiley Sons Ltd*, 2009.

[Bre09b] B.W. Brewer. Handbook of sports medicine and science, sport psychology. *Chichester: John Wiley Sons Ltd*, 2009.

[Bry99] Harter N. Bryan, W L. Studies on the telegraphic language. the acquisition of a hierarchy of habits. *Psychological Review, 6, 345-375.*, 1899.

[CA12] Silva AJ et al. Costa AM, Breitenfeld L. Genetic inheritance effects on endurance and muscle strength: an update. *Sports Med. 2012 Jun 1;42(6):449–58*, 2012.

[CKT19] Kwa´sniak K. Czarnik-Kwa´sniak, J. and J. Tabarkiewicz. How genetic predispositions may have impact on injury and success in sport. *Eur J Clin Exp Med. 16, 366–375. doi: 10.15584/ejcem.2018.4.16*, 2019.

[Con09] Hanton S. Connaughton, D. Mental toughness in sport: Conceptual and practical issues. *In S. Mellalieu S. Hanton (Eds.), Advances in applied sport psychology: A review (pp. 317– 346). London: Routledge.*, 2009.

[Con10] Hanton S. Jones G. Connaughton, D. The development and maintenance of mental toughness in the world's best performers. *The Sport Psychologist, 24(2), 168– 193. https://doi.org/10.1123/tsp.24.2.168.*, 2010.

[Cor11] McGuigan M.R. Newton R.U Cormie, P. Developing maximal neuromuscular power. *Sports Med 41, 125–146 (2011)*, 2011.

[Coy07] E. F. Coyle. Physiological regulation of marathon performance. . *Sports Medicine, 37(4-5), 306-311.*, 2007.

[CP02] Sewell D Clough P., Earle K. Mental toughness: the concept and its measurement. *Solutions in Sport Psychology ed. Cockerill I. M. (Boston, MA: Cengage Learning;) 32–43.*, 2002.

[CP12a] Perry J. L. Crust L. Clough P., Earle K. Comment on "progressing measurement in mental toughness: a case example of the mental toughness questionnaire 48" by gucciardi, hanton, and mallett. *Sport Exerc. Perform. Psychol. 1 283–287. 10.1037/a0029771*, 2012.

[CP12b] Strycharczyk D Clough P. Developing mental toughness: Improving performance, wellbeing and positive behaviour in others. . *London: Kogan Page Publishers.*, 2012.

[Cru11] Lee Crust. Mental toughness in sport. *International Journal of Sport and Exercise Psychology Volume 5, Issue 3*, 2011.

[D.10] Shenk D. The genius in all of us: new insights into genetics, talent, and iq. *New York: Knopf Doubleday Publishing Group; 2010.*, 2010.

[dA08] World Anti doping Agency. World anti-doping agency. wada gene doping symposium calls for greater awareness, strengthened action against potential gene transfer misuse in sport. *WADA*, 2008.

[Del13] Byrne R. Doolin R. McInerney R. Ruddock C. Green B. Delahunt, E. Anthropometric profile and body composition of irish adolescent rugby union players. *Journal of Strength and Condition Research, 27, 32523258*, 2013.

[DL04] Baluch B Duffy L. Dart performance as a function of facets of practice amongst professional and amateur men and women players. *Int J Sport Psychol. 2004;35:232–245.*, 2004.

[DLCS76] W. Evans W. Fink G. Krahenbuhl D. L. Costill, J. Daniels and B. Saltin. Skeletal muscle enzymes and fiber composition in male and female track athletes. *Journal Of Applied Psychology vol.40 no.2*, 1976.

[DMM07] Cherkas LF et al De Moor MHM, Spector TD. Genome-wide linkage scan for athlete status in 700 british female dz twin pairs. *Twin Res Hum Genet. 2007 Dec;10(6):812–20*, 2007.

[ea08] Overney et al. Enhanced temporal but not attentional processing in expert tennis players. *PLoS One, 2008; 3 (6): e2380 DOI: 10.1371/journal.pone.0002380*, 2008.

[EK93] Tesch-Römer C. . Ericsson KA, Krampe RT. The role of deliberate practice in the acquisition of expert performance. *Psychol Rev. 1993;100(3):363–406. doi: 10.1037/0033-295X.100.3.363.*, 1993.

[EN16] Femia P-et al Eynon N, Ruiz JR. The actn3 r577x polymorphism across three groups of elite male european athletes. *In: Garatachea N, editor. PLoS ONE. 8. Vol. 7. 2012. Aug 16, p. e43132.*, 2016.

[] r96]XA85 Lehmann A. C.]Ericsson, K. A. Expert and exceptional performance: Evidence on maximal adaptations on task constraints. *Annual Review of Psychology, 47, 273–305.*, 1996.

[Eri93a] Krampe R. T. H. Tesch-Romer C. Ericsson, K. A. The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100, 363–406*, 1993.

[Eri93b] Krampe R. Th. Heizmann S. Ericsson, K. A. Ericsson, k. a., krampe, r. th., heizmann, s. (1993). can we create gifted people? in the origin and development of high ability: Ciba foundation symposium 178. *Chichester, England: Wiley.*, 1993.

[Eri96] K. A. Ericsson. The acquisition of expert performance: An introduction to some of the issues. *In K. A. Ericsson (Ed.), The road to excellence: The acquisition of expert performance in*

the arts and sciences, sports, and games (pp. 1–50). Mahwah, NJ: Erlbaum., 1996.

[Eri98] K. A Ericsson. Basic capacities can be modified or circumvented by deliberate practice: A rejection of talent accounts of expert performance. *A commentary on M. J. A. Howe, J. W. Davidson, J. A. Sloboda "Innate Talents: Reality or Myth?" Behavioral and Brain Sciences, 21, 413– 414.*, 1998.

[Eri99] K. A. Ericsson. The scientific study of expert levels of performance: General implications for optimal learning and creativity, creative expertise as superior reproducible performance: Innovative and flexible aspects of expert performance. *Psychological Inquiry, 10, 329–333.*, 1999.

[Eri02] K. A. Ericsson. Attaining excellence through deliberate practice: Insights from the study of expert performance. *In M. Ferrari (Ed.), The pursuit of excellence in education (pp. 21–55). Hillsdale, NJ: Erlbaum.*, 2002.

[Eri03a] K. A. Ericsson. The development of elite performance and deliberate practice: An update from the perspective of the expert-performance approach. *In J. Starkes K. A. Ericsson (Eds.), Expert performance in sport: Recent advances in research on sport expertise (pp. 49–81). Champaign, IL: Human Kinetics.*, 2003.

[Eri03b] K. A. Ericsson. The search for general abilities and basic capacities: Theoretical implications from the modifiability and complexity of mechanisms mediating expert performance. *In R. J. Sternberg E. L. Grigorenko (Eds.), Perspectives on the psychology of abilities, competencies, and expertise (pp. 93–125). Cambridge, England: Cambridge University Press.*, 2003.

[Eyn13] Hanson E. D. Lucia A. Houweling P. J. Garton F. North K. N. et al Eynon, N. Genes for elite power and sprint performance: Actn3 leads the way. *Sports Med. 43, 803–817. doi: 10.1007/s40279-013-0059-4*, 2013.

[F69] Galton F. Hereditary genius. an inquiry into its laws and consequences. *London and New York: Macmillan and Co; 1869.*, 1869.

[Fal04] Lidor R. Lander Y. Lang B Falk, B. Talent identification and early development of elite water-polo players: a 2-year follow-up study. *Journal of Sport Sciences, 22, 347–355*, 2004.

[FEMNes] Mike I. Lambert Frank E. Marino and Timothy D. Noakes. Superior performance of african runners in warm humid but not in cool environmental conditions. *Journal of Applied Physiology Vol. 96, No. 1*, Frank E. Marino, Mike I. Lambert, and Timothy D. Noakes.

[Fri06] A.D. Friederici. The neural basis of language development and its impairment. *Neuron, 52 (2006), pp. 941-952*, 2006.

[FS92] Galton FS. Hereditary genius. an inquiry into its laws and consequences. *New York: MacMillan Co; 1892.*, 1892.

[Fyl09] Kevin Fylan. Federer redefines notion of greatness. *Reuter, Sports News*, 2009.

[GL13] Roth SM. Guth LM. Genetic influence on athletic performance. curr opin pediatr. *Pubmed*, 2013.

[GL15] Safa Khayat Mughrabi Gerry Leisman, Raed Mualem. The neurological development of the child with the educational enrichment in author links open overlay panel. *Psicología Educativa*, 2015.

[GN18] Vescovi J El-Sohemy A Guest N, Corey P. . caffeine, cyp1a2 genotype, and endurance performance in athletes. *Med Sci Sports Exerc. (2018) 50:1570–8. 10.1249/MSS.0000000000001596*, 2018.

[Gou02] Dieffenbach K. Moffett A. Gould, D. Psychological characteristics and their development in olympic champions. *Journal of Applied Sport Psychology, 14(3), 172– 204.*, 2002.

[GR13] L. M. Guth and S. M Roth. Genetic influence on athletic performance. *Curr. Opin. Pediatr. 25, 653–658. doi: 10.1097/MOP.0b013e32836 59087*, 2013.

[GT98] McConnell A et al Gibbons T, Hill R. The path to excellence: Initial survey. *A comprehensive view of development of U.S. Olympians who competed from 1984– 1998*, 1984-1998.

[Had08] Adam Hadhazy. What makes michael phelps so good? do phelps's body shape and flexibility give the eight-gold medal winner a physical edge in swimming? *Scientific American*, 2008.

[Hay17] Jessa Hay. A gene ahead of the game: A look at sports genetics jessa hay eastern kentucky university. *Eastern Kentucky University Encompass*, 2017.

[HJ01] Brownlie TIV. Haas JD. Iron deficiency and reduced work capacity: a critical review of the research to determine a causal relationship. *J Nutr. (2001) 131:676S688S; discussion 688S-690S. 10.1093/jn/131.2.676S*, 2001.

[HJ18] O'Connor C Shelley J Gilliland J Horne J, Madill J. A systematic review of genetic testing and lifestyle behaviour change: are we using high-quality genetic interventions and considering behaviour change theory? *Lifestyle Genom. (2018) 11:49–63. 10.1159/000488086*, 2018.

[HL04] Sweeney HL. Gene doping. *Sci Am 2004;291:62-9.*, 2004.

[Ing19] Sean Ingle. Caster semenya accuses iaaf of using her as a 'guinea pig experiment. *The Guardian*, 2019.

[JE.70] Carter JE. The somatotypes of athletes–a review. *Hum Biol. 1970 Dec;42(4):535–69.*, 1970.

[KA.06] Ericsson KA. The cambridge handbook of expertise and expert performance. *New York: Cambridge University Press; 2006*, 2006.

[KAEC07] Michael J. Prietula K. Anders Ericsson and Edward T. Cokely. The making of an expert. *Havard Business Review*, 2007.

[Kel58] F. S. Keller. The phantom plateau. *Journal of the Experimental Analysis of Behavior, 1, 1- 13.*, 1958.

[KP73] Karvinen E. Komi PV, Klissouras V. Genetic variation in neuromuscular performance2. *Eur J Appl Physiol. 1973;31(4):289–304. doi: 10.1007/BF00693714.*, 1973.

[KP77] Havu M Thorstensson A Sjödin B Karlsson J. Komi PV, Viitasalo JH. Skeletal muscle fibres and muscle enzyme activities in monozygous and dizygous twins of both sexes. *Acta Physiol Scand. 1977;100(4):385–392.*, 1977.

[Lar03] Henrik Larsen. Kenyan dominance in distance running. comparative biochemistry and physiology. *Part A, Molecular integrative physiology. 136. 161-70. 10.1016/S1095-6433(03)00227- 7.*, 2003.

[LP13] G. Löffler and P Petrides. Biochemie und pathobiochemie. *Springer*, 2013.

[M08] Gladwell M. . outliers: the story of success. *USA: Little, Brown and Company; 2008.*, 2008.

[McP11] Perez-Schindler J. Degens H. Tomlinson D. Hennis P. Baar K. et al. McPhee, J. S. Hif1a p582s gene association with endurance training responses in young women. *Eur. J. Appl. Physiol. 111, 2339–2347. doi: 10.1007/s00421-011-1869-4*, 2011.

[MD94] Daniels JT. .Morgan DW. Relationship between vo2max and the aerobic demand of running in elite distance runners. *International Journal of Sports and Medicine*, 1994.

[ME19] Montel I. McGill E. Nasm's essentials of sports performance training (2nd ed.). *Burlington, MA: Jones Bartlett Publishing*, 2019.

[Miz23] Yasuhiro Mizuki. Extreme medialized repair for challenging large and massive rotator cuff tears reveals healing and significant functional improvement. *Arthroscopy - Journal of Arthroscopic and Related Surgery*, 2023.

[MJ04] Klissouras V. Missitzi J, Geladas N. Heritability in neuromuscular coordination: implications for motor control strategies. *. Med Sci Sports Exerc. 2004;36(2):233–234. doi: 10.1249/01.MSS.0000113479.98631.C4.*, 2004.

[MJ11] Geladas N Politis P Karandreas N Classen J Missitzi J, Gentner R. Plasticity in human motor cortex is in part genetically determined. *J Physiol. 2011;589:297–306. doi: 10.1113/jphysiol.2010.200600.*, 2011.

[MJ13] Misitzi A Geladas N Politis P Klissouras V Classen J. Missitzi J, Gentner R. Heritability of motor control and motor learning. *Physiol Rep. 2013;1(7):1–10. doi: 10.1002/phy2.188.*, 2013.

[MJ17] Joyner MJ. Exercise and trainability: contexts and consequences. *J Physiol (Lond). 2017;595(11):3239-3240. doi:10.1113/JP274031*, 2017.

[MJ19a] Joyner MJ. Genetic approaches for sports performance: How far away are we? *Sports Med. 2019;49(Suppl 2):199-204. doi:10.1007/s40279-019-01164-z*, 2019.

[MJ19b] Joyner MJ. Genetic approaches for sports performance: How far away are we?. *Sports Med. 2019;49(Suppl 2):199-204. doi:10.1007/s40279-019-01164-z*, 2019.

[MM06] C.J. Shatz M. Majdan. Effects of visual experience on activity-dependent gene regulation in cortex. *Nature Neuroscience, 9 (2006), pp. 650-659*, 2006.

[Mon98] Marshall R. Hemingway H. Myerson S. Clarkson P. Dollery C. et al Montgomery, H. E. Human gene for physical performance. *Nature 393, 221–222. doi: 10.1038/30374*, 1998.

[Mus23] Ossian Muscad. Unraveling the physics of sports: Why athletes need to understand the concept of torque. *Datamyte*, 2023.

[ND14] El-Sohemy A. Nielsen DE. Disclosure of genetic information and change in dietary intake: a randomized controlled trial. *PLoS ONE (2014) 9:e112665. 10.1371/journal.pone.0112665*, 2014.

[NSC17] NSCA. Sport performance and body composition by nsca's guide to tests and assessments. *kinetic select*, 2017.

[PM07] Loos RJF et al. Peeters MW, Thomis MA. Heritability of somatotype components: a multivariate analysis. *Int J Obes Relat Metab Disord*, 2007.

[PM09] Marzano C Moroni F Pirulli C Curcio G Ferrara M Miniussi C Rossini PM De Gennaro L. Pellicciari MC, Veniero D. Heritability of intracortical inhibition and facilitation. *J. Neuroscience. 2009;29(28):8897–8900. doi: 10.1523/JNEUROSCI.2112-09.2009*, 2009.

[PP18] Pavol Peráček and Janka Peráčková. Tactical preparation in sport games and motivational teaching of sport games tactics in physical education lessons and training units. *Intechopen*, 2018.

[PR04] Caspi A Plomin R, Happe F. Psychiatric, genetics genomics. *New York, NY: Oxford University Press Inc; 2004. Personality and cognitive abilities; pp. 77–112*, 2004.

[PR15] Pluess M. Power RA. Heritability estimates of the big five personality traits based on common genetic variants. *Translational Psychiatry (2015) 5, e604; doi:10.1038/tp.2015.96; published online 14 July 2015. PubMed: 26171985 PubMed Central: PMC5068715*, 2015.

[Pre08] Associated Press. Phenomenal phelps wins 7th gold by 0.01 seconds to tie spitz. *ESPN*, 2008.

[PZ11] Rawal J et al. Puthucheary Z, Skipworth JRA. Genetic influences in sport and physical performance. *Sports Med. 2011 Oct 1;41(10):845–59.*, 2011.

[PZ3] Kaliszewski P. Majorczyk E. Pokrywka, A. and ´ A. Zembron-Łacny. Genes in sport and doping. *Biol. Sport. 30, 155–161. doi: 10.5604/20831862.1059606*, 2013.

[Roc86] Martines Roca. Técnicas de entrenamiento. *Semantic Scholar*, 1986.

[SA06] Friedmann T Schneider AJ. Gene doping in sports: the science and ethics of genetically modified athletes. *Adv Genet 2006;51:1-110.*, 2006.

[Sch88] Curnow C Schulz, R. Peak performance and age among superathletes: Track and field, swimming, baseball, tennis, and golf. *Journal of Gerontology: Psychological Sciences, 43,113- 120.*, 1988.

[Sch04] Wagner K. R. Stolz L. E. Hübner C. Riebel T. Kömen W. ... Lee S. J. Schuelke, M. Myostatin mutation associated with gross muscle hypertrophy in a child. *New England Journal of Medicine, 350(26), 2682-2688.*, 2004.

[SEM16] What is an intersex athlete? explaining the case of caster semenya. *The Guardian*, 2016.

[She09] Gabbett T. Reeberg Stanganelli L-C Sheppard, J. An analysis of playing positions in elite men's volleyball: Considerations for competition demands and physiological characteristics. *Journal of strength and condition research, 23, 1858–1866*, 2009.

[SK08] Tynelius P et al Silventoinen K, Magnusson PKE. Heritability of body size and muscle strength in young adulthood: a study of one million swedish men. *Genet Epidemiol.*, 2008.

[SO18] Jaime Serra-Olivares. Sport pedagogy - recent approach to technical-tactical alphabetization. *IntechOpen*, 2018.

[SS13] Ficek K. Eider J. Leonska-Duniec A. Maciejewska-´ Karłowska A. Sawczuk M. et al Stepien-Słodkowska, M. The +1245g/t polymorphisms in the collagen type i alpha 1 (col1a1) gene in polish skiers with anterior cruciate ligament injury. *Biol. Sport 30, 57–60. doi: 10.5604/20831862.1029823*, 2013.

[TD16] Burke LM Thomas DT, Erdman KA. American college of sports medicine joint position statement. nutrition and athletic performance. *Med Sci Sports Exerc. (2016) 48:543–68. 10.1249/MSS.0000000000000852*, 2016.

[Tes85] Wright J.E. Vogel J.A. et al Tesch, P.A. The influence of muscle metabolic characteristics on physical performance. *Europ. J. Appl. Physiol. 54, 237–243*, 1985.

[The05] Weston N. Greenlees I. Thelwell, R. Defining and understanding mental toughness within soccer. *Journal of Applied Sport Psychology, 17(4), 326– 332.*, 2005.

[TM97] Maes HH Blimkie CJR Claessens AL-Marchal G Willems E Vlietinck RF Beunen GP Thomis MA, Van Leemputte M. Multivariate genetic analysis of maximal isometric muscle force at different elbow angles. *J Appl Physiol. 1997;82:959–967.*, 1997.

[TP85] Karlsson J. Tesch P.A. Muscle fiber types and size in trained and untrained muscles of elite athletes. *Journal Of Applied Psychology*, 1985.

[Uni21] Anglia Ruskin University. Genes play key role in exercise outcomes. *ScienceDaily*, 2021.

[Vae08] Lenoir M. Williams A.M. Philippaerts R Vaeyens, R. Talent identification and development programs in sport. *Sports Medicine, 38 (9), 703–714*, 2008.

[VNipAAcFjs17] Griffiths LR Wang G Pitsiladis YP Pigozzi F et al.Genetic testing for exercise prescription Vlahovich N, Hughes DC and injury prevention: AIS-Athlome consortium-FIMS joint statement. Genetic testing for exercise prescription and injury prevention: Ais-athlome consortium-fims joint statement. *BMC Genomics (2017) 18(Suppl. 8):818. 10.1186/s12864-017-4185-5*, 2017.

[WAik] Smith A Noakes TD Myburgh KH Weston AR, Karamizrak O. African runners exhibit greater fatigue resistance, lower lactate accumulation, and higher oxidative enzyme activityj appl physiol (1985). 1999 mar;86(3):915-23. doi: 10.1152/jappl.1999.86.3.915. pmid: 10066705. *J Appl Physiol (1985). 1999 Mar;86(3):915-23. doi: 10.1152/jappl.1999.86.3.915. PMID: 10066705.*, 1985Larsen, Henrik.

[Wep03] Gould D. Foundations of sport Weinberg, R.S. and exercise psychology. Foundations of sport and exercise psychology. *Champaign: Human Kinetics*, 2003.

[WN15] McNamee M Bouchard C Pitsiladis Y Ahmetov I Ashley E Byrne N Camporesi S Collins M Dijkstra P Eynon N Fuku N Garton FC Hoppe N Holm S Kaye J Klissouras V Lucia

A Maase K Moran C North KN Pigozzi F Wang G. Webborn N, Williams A. Direct-to-consumer genetic testing for predicting sports performance and talent identification: Consensus statement. *Br J Sports Med. 2015 Dec;49(23):1486-91. doi: 10.1136/bjsports-2015-095343. PubMed: 26582191. Free full-text available from PubMed Central: PMC4680136.*, 2015.

[WR12] Pitsiladis YP Wilber RL. Kenyan and ethiopian distance runners: what makes them so good? *International Journal of Sports Psychology and Performance*, 2012.

[XA6] The mental game plan: Getting psyched for sport.

[XA7] How do your genes influence levels of emotional sensitivity? a specific gene variation can make your brain more emotionally sensitive.

[Yam07] Itoi E. Tuoheti Y. Seki N. Abe H. Minagawa H. ... Okada K Yamamoto, N. Glenohumeral joint motion after medial shift of the attachment site of the supraspinatus tendon: a cadaveric study. *Journal of Shoulder and Elbow Surgery, 16(3), 373-378.*, 2007.

[YX16] Lidor R Eynon N. Yan X, Papadimitriou I. Nature versus nurture in determining athletic ability. *Med Sport Sci. 2016;61:15-28. doi: 10.1159/000445238. Epub 2016 Jun 10. Review. PubMed: 27287074.*, 2016.

[Zap11] Kororos P. Christodoulidis T. Skoufas D. Bayios I Zapartidis, I. Profile of young handball players by playing position and determinants of ball throwing velocity. *Journal of Human Kinetics, 27, 17–30*, 2011.