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A Gene Ahead of the Game: A Look at Sports Genetics

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The entertainment industry known as sports is one with high popularity all over the globe. Humans work their whole lives to be able to perform at the highest level, whether that be professionally or on the Olympic stage. However, people may train and train but always end up falling short. This is not due to their lack of dedication or commitment, but simply they are not genetically favored to play that sport. Our genetic makeup plays a bigger role in our athletic ability than we may think. Although training is important when it comes to excelling in the sports world, you will never be the best if you do not have the proper genes to be an athlete in that sport. This Honors thesis will start by explaining the basics of genetics and where our characteristics come from. Then, it will look at both nature and nurture of the sports world, while comparing the genetics of professional basketball players, Olympic swimmers and Olympic gymnasts.

Keywords and phrases: genetics, professional sports, Olympic sports, college athletes

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Chapter 1

Introduction

2016 was a notable year for sports fans all over the world. With championship series coming down to the final minutes and the World's nations coming together for the Summer Olympics in Rio de Janeiro, athletes were born and superstars were discovered. Two athletes that stood out above the rest were LeBron James of the NBA champion Cleveland Cavaliers and Simone Biles, the Olympic Gymnastics All-Around Gold Medalist. Both are elite athletes, but with one major difference: Biles stands tall at 4'8" while James is just a few inches shy of 7'0". Their heights, along with other noticeable anthropometric differences, makes it clear that their athletic success has come from within their genomes.

Our genetic makeup plays a bigger role on our athletic ability than we may think. A person may train their entire life for the sport they that love, but if they are not born with the athletic predisposition with the genes required to excel at that sport, they will unfortunately never become the best of the best. Professional basketball, Olympic swimming and Olympic gymnastics are three sports where genetic advantage has a major effect on the athletes who become stars. Although how the athlete trains is an important factor in their overall success, if an athlete is not genetically equipped with the proper genes needed for their sport, the professional level they seek may be just out of their reach.

The Basics of Genetics

No two individuals are alike. Every person has something different about their appearance and the way their body functions internally. This difference is due to genes that are within our cells that make us who we are. A gene is an element of the chromosome – which is found in the nucleus of our cells – that is the genetic determinate of an inherited characteristic (Bodmer et al., 1976). Without genes, there would be no way to distinguish between people because they would not have their unique appearance.

The terms genetics and genes are usually paired with the word heredity. The Oxford Dictionary defines heredity as the passing on of physical or mental characteristics genetically from one generation to the next (*Oxford*, 1992). You receive your characteristics through your parents' chromosomes – one set from your mother and one set from your father. One aspect of DNA to mention when talking about genetics is mitochondrial DNA. It may be only a small portion of our DNA, but human mitochondrial DNA was one of the first significant parts of the human genome to be sequenced, leading to the discovering of the rest of the human genome along the way ("Mitochondrial DNA", 2012). This is how all genetics works and why every individual is unique. Even siblings are different from one another because they have acquired different combinations of characteristics from each of their parents. All of this is done within our cells, and DNA is the chemical substance of heredity.

Deoxyribonucleic acid, or DNA, is the chemical substance contained in chromosomes that determines the outcome of an individual once the parents have passed on their genes to an embryo. DNA is made up of multiple units called nucleotides.

Theses nucleotides have three main components: a phosphate residue, a deoxyribose sugar, and one of four bases. These bases are the building blocks of all DNA and their combinations carry significant information that determines the genetic outcome of an individual. (Bodmer et al., 1976).

The four bases that can be found in DNA are adenine (A), cytosine (C), thymine (T), and guanine (G). These bases are broken up into two different classes based on their structure – purines and pyrimidines. Adenine and guanine belong to the purine class while cytosine and thymine are a part of the pyrimidine class. The difference between these classes is their structure, where purines are a two-carbon ring of nitrogen and pyrimidines are a one-carbon nitrogen ring ("Purines vs. Pyrimidines", 2017). Despite the difference in structure, purines and pyrimidines do not differ in function when it comes to the DNA.

To help form the structure of DNA, a purine has to be paired with a pyrimidine. There is a specific pairing that you will find in all DNA – adenine is always paired with thymine and cytosine is always paired with guanine. When examining DNA, these bases are always found in equal amounts. This means that there will always be equal concentrations of adenine as there is thymine in the DNA, and the same for the cytonsine-gunanine combination. This is just one of the major components when it comes to the structure of DNA.

DNA is a double helix strand, similar in shape to a ladder that is twisted. Each helical strand is considered a polynucleotide, made up of a deoxyribose sugar, a phosphate residue, and one of the four bases (Bodmer et al., 1976). The backbone of the strand is made up of the deoxyribose sugar and the phosphate residue. These two components are always alternating, which help determine the directionality of the DNA strand, which plays a major role in DNA replication and transcription and translation of a DNA strand into a protein ("Phosphate Backbone", 2014). The middle of the double helix, or the "rungs" of the DNA ladder, are made of paired bases. These paired bases are what helps the two helical strands match up by pairing the correct purine with the correct pyrimidine. This is where adenine will pair with thymine and cytosine will pair with guanine. For example, one strand will have the base adenine and the opposite strand – or the complimentary strand – will have the base thymine. These two bases will pair together through a weak hydrogen bond, and will stay together until that bond is broken for replication or transcription.

The reason why DNA's double helix has an importance in genetics is because it is the basis for DNA replication. When a cell needs to be duplicated due to damage or old age, the entire genome of the cell is copied so it can divide into two identical daughter cells. The DNA strand will separate into two separate strands, where each strand will serve as a template for the complimentary DNA strand that is created. Complimentary bases will attach to each template strand with enzymes called polymerases and eventually the entire DNA double helix strand will be duplicated and ready for the separation from one cell into two (Bodmer et al., 1976).

Mitosis and meiosis are two types of DNA replication that play important factors in genetics. Mitosis focuses on cells of the body – skin, blood, organ, etc. These cells are replicated once damage has been done or the cell is about to die; everything needs to be duplicated so the specific organ or body part is able to live on healthy. Meiosis, however, focuses on replication of the chromosomes that carry the genetic information that is used to create a new individual. The fertilization of the sex cells, called gametes, is what gives someone their 23 pairs of chromosomes. The reason why a person has 23 pairs of chromosomes is that they receive one chromosome from each of their parents. For example, a person will have a copy of Chromosome I from their mother and a copy of Chromosome I from their father. These chromosomes cross-over during meiosis, which gives siblings their individuality from each other while still having characteristics from their mother and their father. Sex cells will have 23 individual chromosomes until fertilization of the egg cell with a sperm cell, which ends in the creation of 46 total chromosomes – 23 pairs. These chromosomes create the genome for the new unique individual that is unlike anyone else.

People today do not look like the people that were around centuries before us. Even though the basics of our genome has stayed the same, our genes have mutated and developed based on the changing environments our world has gone through in order to survive.

Evolution has been the key to survival for any organism; if you are not genetically fit, then you will not be able to survive and pass on your genes to offspring. A lot of the evolution we have seen in organisms today is based on genetic mutations that have ended up increasing survival rates for certain traits found in different organisms. Changes in nucleotide sequence could lead to an extra gene copy or a mismatched gene, which could lead to new functional capacities for the organisms (Berg et al., 1992). New genes arise from new combinations of copies of exons, the coding regions of DNA. Exons can be shuffled, inserted, or skipped when the genes are being translated, which can code for a completely different protein than what was intended. These new proteins lead to a mutation, and that mutation can either help or hurt the organism. Those that have helped have gone on to survive the changing world around them with ease.

Mutations are not always a beneficial to the evolution of genetics, however. Diseases may arise from a mutation, which can lead to the organisms not lasting as long as they were meant to be. Genetically inherited disorders are caused by the mutation of one single gene. Genetically inherited disorders are recessive mutations, where recessive means that you need to have two mutated copies of the single gene in your genome to have the physical characteristics of the disorder. If both parents have a single mutated copy of the disorder, there is a 25% chance that their child will have the two mutated copies of the gene. The dominate gene which does not carry the disorder has the overall advantage, but there is still a chance the child will inherited the disorder. Mutations are beneficial when it comes to evolution of the fittest, but there are chances where it backfires, and that is what makes genetics a never-ending study.

With all of this said, it is clear that our genes have a major part of who we become in the end, which means that we have our parents to thank for the outcome of our basic characteristics. These characteristics include our athletic ability. Our height, muscle mass, length of limbs, and any other important component of a certain sport is permissioned based on the DNA that is within our body and there is nothing we can do to change that. Without certain genes for whatever sport a person may be involved with, they will excel above the rest if they are genetically capable of doing so. If the gene is not written into their genetic code, they will always fall short of being the best of the best no matter how much they may train.

The Genome of Sports: A Nature Look

Two of the most talked about athletes of 2016 were LeBron James and Simone Biles. James, with his team, made National Basketball Association history by defeating the Golden State Warriors, the previous national champions, by coming back from a three-to-one game deficient in a best of seven game series. The Cleveland Cavilers won three games in a row to become the new national champions, with their victories being led by James. We then turn to the world of Olympic gymnastics, where Biles tumbled her way into medaling in every event she participated in. Biles walked away with four gold and one bronze medal to add to her endless collection that defines her successful career.

Looking at these two athletes, there is a clear difference that one certain body type does not define a "perfect athlete." The difference in their heights, weights, length of limbs, etc. are the noticeable traits that any layman can see. There are also a lot of other traits – stamina, speed, cardiovascular strength – that also play a role in determining who succeeds and who falls short when it comes to the sports they play. Training your whole life will substitute for some of the genetic traits you do not have, but if you were not gifted by your parents with the correct genes, you will not find high success like James and Biles have.

With technology quickly developing before our eyes, we are able to test for essentially anything, including our own genome. Our genome is the complete set of genes or genetic material that is present in an organism. The genome contains all of the genes that make us who we are, and scientists are not only able to determine a basic map of the human genome, but are now able to map out an individual's full genome. Up until 2001 we did not even know about the genome and now we are able to get each and every person's genome. With this new testing ability, we are able to perform genetic tests to determine DNA variants. Genetic variance includes all inherited traits and traits that cannot be modified by external influences (Breitbach et al., 2014). These tests can tell us whether or not a DNA variant is directly or indirectly associated with the disposition for any kind of sports-related skills. Genetic markers can be identified that can help explain the variability of a single key factor that can help preclude the possibility of becoming an elite athlete (Massidda et al., 2014). Some of these markers include $ACTN_3$, ACE and AMPD1, which will discussed at a later time. An algorithm that has been discovered found that there is an "optimal" profile of genotype score, identifying the best combination of 23 polymorphisms that are involved in the endurance performance of athletes (Massidda et al., 2014). However, there is not one specific kind of DNA variant that determines whether or not a person becomes the professional athlete they desire to be. People can excel at a variety of different sports that are appropriate for the genetic makeup. The specific nature of each sport leads us to determine a specific phenotype – or set of observable characteristics of an individual that results from the interaction of its genotype with the environment – of someone who may become an all-star in their sport. One example of being made for a sport is observing some of the popular athletes in football and basketball.

In the National Football Association, 61% of the athletes are African Americans while the National Basketball Association has 72% of African Americans registered to play (Gnida, 1995). The media nowadays makes proclamations that the success of athletes in certain sports is dependent on their race. However, race has nothing to do with the success of the athletes in these sports. According to genetic research and genome sequencing, African Americans have greater muscle mass than their Caucasian teammates and opponents, which could lead you to be more successful in contact sports, such as football and basketball (Leonard, 1993). Without their genes that code for greater muscle mass, African Americans would have an equal chance as Caucasians to make it in the NFL or NBA, but their genetic advantage has allowed them to be ahead of the game.

Muscle mass plays a bigger role in the success of an athlete than we may think. Skeletal muscle mass is highly heritable and variants of it can determine who becomes successful in athletics and who does not (Naeyer et al., 2014). For example, in men muscle mass is determined by the genetic variations in the androgen receptor that helps code for the genes that make muscle mass. Genetic variations with this receptor can cause differences from male to male in the sensitivity of androgens (Naeyer et al., 2014). Even in healthy men, the variation still exists and is written in their genetic code, resulting in the skeletal muscle mass they are given.

The amount of energy a muscle can release is also predetermined by our genes. The adenosine monophosphate deaminase (AMPD) gene is very important in this, as it is a regulator of muscle energy metabolism during exercise (Gineviciene et al., 2014). Basically, the different variations of this gene, whichever is encoded in your genetic map, regulates how much metabolism your muscles have and how hard they can work when you are exercising. The reaction of AMPD is the initial start of the purine nucleotide cycle and also plays a central role in the rescue of adenine nucleotides. Both of these reactions combined are what make up the determination of energy charge in muscles

(Gineviciene, 2014). This gene is also determined by the amount of physical exercise that is put on the muscle, but the main part of it is genetically predispositioned.

Another type of gene associated with athletic ability is $ACTN_3$, otherwise known as the "speed gene." This gene is found in fast-twitch muscle fibers (Stein, 2014). $ACTN_3$ helps produce explosive bursts in speed and power athletes, specifically sprinters, who outrun everyone else (Coghlan, 2003). The majority of the elite sprinters in the world have at least one copy of this gene, giving them the advantage they have. Endurance runners and athletes can have a copy of this gene, but it is not as active in them because they were given slow-twitch fibers. The enzyme that helps determine the outcome of $ACTN_3$, called ACE, influences whether "fast" or "slow" twitch fibers are laid down, eventually telling $ACTN_3$ how much of the gene should be expressed (Coghlan, 2003). This interaction between gene and enzyme determines how much expression the gene should have, and that goes for all of the genes in our body.

The way some of the sports-related genes have arisen come from adaptations and survival of the fittest, causing mutations in the DNA of humans that result in greater and stronger genetics. One example of this is the rise of the ACE gene in endurance runners. An insertion allele (one of two alternative forms of a gene) along with a decrease level of circulating angiotensim II, reduces the vascular resistance and facilitates cardiac output during exercise (Franchini, 2014). This gives the endurance runners the type of cardio they need to perform for longer period. The variant of this gene arose from two closely related sub-branches of humans off of Africa that had to practice ritual fighting. Those who have come from these ancestors developed a mutation that became regular to have, giving them a higher endurance than someone who does not possess the gene in their genome. This is why athletes with higher endurance are able to compete and be successful in sports that require a greater input of energy, like today's form of boxing.

Sometimes, even elite athletes have disorders found in their genetic makeup that end up helping them get to their elite status. Women can be given an competitive advantage with one type of disorder of sex development (SDS) called 46,XY. This is a hyperandrogenism disorder, which means that women, despite having the correct female sex hormones, also have excessive secretion of androgens, the male sex hormone. The reason why this can make women with this specific SDS in team sports come out on top is due to their stature they are given from the genes they have. Team sports are a notable example of how stature is important in relation to sports performance. The gene for stature is found on the Y chromosome, which is why elite female athletes with 46,XY excel because they have the abnormal Y chromosome usually found in males (Furguson-Smith et al., 2014). Eligibility tests were used to find this connection, and the question of determining who should compete in athletic events is still undetermined, but sometimes even genetic disorders play a role in who becomes a champion and who falls short.

There are many more genes that help determine athletic success that have not been mentioned. Research is still being performed to make more definite conclusions about how much that genes plays a role in athleticism. Even though our final genome is the major source in determining where we may find accomplishment in sports, how much an athlete trains and their training regimen is also an important factor to consider when it comes to overall success of an athlete.

Training of the Athlete: A Nurture Look

Doing the minimum amount of training, even if having a genetic advantage, will not get you anywhere in the world of sports. Athletes like LeBron James and Simone Biles could not get to where they are today without having both genetics and training. Biles trains for 32 hours over 6 days, focusing on different combinations and workouts for each of the days ("Simon Bile Training Schedule Revealed", 2016). James starts off every practice by stretching, followed by working with the ball on the court or gym work ("LeBron James Training Regime", 2012). Both athlete's base their daily schedules around their workout routines, and if they did not train as hard as they do, you would not be hearing their names as much in the media. This goes for any kind of elite athlete.

Genetic variation is responsible for a huge part of the phenotypic differences that we see among athletes today, but these characteristics can be modified by experience and environmental factors. Some of these factors include diet and different forms of body exercises. Body exercises includes the exercises an athlete should do in order to reach their planned sports form (Stefanovicet al., 2015). No matter how genetically predispositioned they are to the sport they are playing, athletes need to have a general knowledge of what sports form will be most beneficial to them and how to achieve that specific sports form. Physical improvements are also an important aspect to look into when it comes to the training of an athlete.

When it comes to team sports, there are certain types of movements that when trained well work in competitive success. The explosive movements that take place during a sport – like kicking, tackling, jumping, turning, sprinting, and changing direction and pace – involve a lot of physical improvements to have a positive outcome (Slimani et al., 2016). Drills, such as plyometrics, can help improve these important parts of the game. Plyometric drills usually involve stopping, starting, and change directions in an explosive manner (Slimani et al., 2016). Training with these kinds of drills over and over again will show improvements and success, not just on the field, but within the team dynamic as well.

Training – specifically intensity training – does not just apply to the athletes around the world. Any kind of training or practice is required if you want to become the best at something. Advantage is given to those who have the genes to be dominant in whatever field they choose, but the 10,000-hour rule is one that applies to anyone trying to become the best.

In Malcolm Gladwell's novel, *The Outliers: The Story of Success,* one of the key things he mentions about becoming a master is the 10,000-hour rule. In the book it is indicated that elite performers had totaled ten thousand hours in practice time (Galdwell, 2008). The amount of practice time among individuals who were already given some kind of natural ability is what varied from in who would become elite and who would stay an amateur. In this study, two types of performers in arts, athletics, etc., were not identified – there were no "naturals" and no "grinds." A natural is someone who did well with little preparation or practice, while a grind was someone who worked harder than everyone else, but no matter how hard they tried they did not have what it took to be at the top (Gladwell, 2008). This fact shows that even someone who may have the genes or "natural talent" at a certain sport or activity will not exceed without practice.

Mike Piazza, a former Major League Baseball player, is one person in the sports world that comes to mind when thinking about an athlete who has worked hard his whole life so he could be at the top.

When Piazza was young, he worked as a batboy for the Los Angeles Dodgers whenever the team would play in Philadelphia (Whiteside, 1993). Little did that boy know that one day he would be in his own professional baseball jersey, but he had to work hard to get there. In an interview, Piazza stated that in the winter during baseball's offseason when he was a kid, he would come home from school, have a snack, watch TV and then start hitting. He cleared the snow off of the batting cage, would heat up the baseballs on a stove and wrap pipe insulation around his bat so his hands would not sting (Whiteside, 1993). Because of this training he did in the winter when it was not expected of him, he became a better hitter, as he said every spring he could see that he was hitting the ball farther and farther (Whtieside, 1993). Even though he already had the potential to become a great baseball player, his extra training when he was young made him reach his goal of becoming a professional more obtainable.

Even though the nature side of an athlete plays a bigger role in their potential outcome as being a success in the field or not, the amount that they train has a big impact as well. Even natural talent needs a little work, and without it, there would be no superstar athletes showcased in the media today.

To look more closely at how genetics plays a major role in the accomplishment of an athlete in a certain sport, we turn to professional basketball, Olympic swimming, and Olympic gymnastics. These sports all require a different kind of genetic makeup that will elevate some athletes above the rest. Is there a reason that certain teams or countries always seem to be the top of the leaderboard every year? The answer is found within their team's genome.

Chapter 2

Aim High: Genetics in Professional Basketball

When it comes to comparing genetics of athletes from one sport to another, the main component we look at are anthropometrics. Anthropometry is the measurements of external parts of the body, including body diameters, body circumferences, and somato types (Gaur, 2013). How the athlete performs is highly based on the anthropometrics they were born with. When it comes to studying the genetics of professional basketball players, there is one phenotype that stands out above the rest – height.

At the professional level, basketball is a sport played on an indoor court for four 12-minute quarters that requires some high preparation to be able to play successfully. Basketball is also a sport where both the upper and lower extremities are used, making it a more challenging game having to be coordinated in both parts of the body. Basketball players are also significantly heavier than athletes of other sports, such as soccer, as one study stated (Popovic et al., 2013). Being heavier and coordinated are just some of the genetic reasons for success in basketball players.

The average size of basketball players has increased significantly in the last 20 to 30 years (Popovic et al., 2013). This is because of the tactical skills that the sport of basketball requires. When a player shoots a basketball and the shot is missed, the teams' tallest players all fight for the rebound, and the team with the tallest player usually ends up getting the ball back. Basketball players need to be tall because there are situations like this where the ball will be over their heads and they will need to handle it with care in order to gain possession. Without height and long upper extremities, it would be much more difficult to grab a rebound, especially with taller players surrounding you all fighting for the same ball.

The height of a basketball player will also play an important role besides being able to reach towards the basket and defending the ball better against opponents. Height also permits a shot to travel a shorter distance, allowing the player to have the opportunity to take more shots close up under the basket. This makes it easier for the player to occupy the area under the net more and get the ball for their teammate to score. Height also gives players an advantage when it comes to blocking shots from their opponents. When a shorter competitor is going up to shoot the ball, the taller player has the advantage over them. The taller player can jump higher and is then able to reach the ball of the shooting opponent and block their shot without committing a foul. Being able to block shots without committing a foul is what separates the good teams from the great teams.

It does take more than just height to succeed in basketball. Because of the constant movement between offense and defense and having to play both for long periods of time in one game, basketball players also require a good anaerobic capacity.

Basketball requires many kinds of intermittent movements and directional changes continuously throughout the game in response to the different offensive and defensive situations. Players have to keep up with these quick changes, and their cardiovascular system needs to be up to par as well. The average work intensity of a basketball game is above 85% of maximal heart rate and above 80% of VO_2 max (Popovic, 2013). To be able to handle this kind of intense gameplay, basketball players have a high ability to work efficiently with anaerobic energy. Anaerobic energy is vital only to the performance of sprints, high-intensity run, and dual plays, which can all play a factor in the final outcome of any basketball game. Basketball players only use 20% to 25% of aerobic activity while they use 75% to 80% of anaerobic activity (Popovic et al., 2013). If a player is not suited to handle a game with that high intensity of anaerobic energy, then they will not be able to perform at their peak, and their team may suffer from it.

To compare how genetics plays a major role in professional basketball, we can take a look at the top National Basketball Association players from 2016 and see how they and their teams compared to each other.

The top 100 players of 2016 were determined before the season started by Sports Illustrated, and these players lived up to the hype they were given in the pre-season all year long. LeBron James was declared the number one player in the NBA, closely followed by Kevin Durant, Anthony Davis, and then Stephen Curry (Golliver et al., 2015). Of the top ten basketball players out of the list of 100, 40% were guards – usually the shorter of the positions – 50% were forwards, and 10% were centers – the tallest position. Of those top ten players, 90% of the were on teams that made it to the playoffs. Two players who made it to the playoffs were on teams that made it to the finals. Those two players were on the teams playing against each other, with LeBron James being on the winning Cleveland Cavilers and Stephen Curry being on the Golden State Warriors. Both phenomenal players on the court, but what is it about them that makes them dominate over others? It all lies within their genome.

To truly know what it means for your genes to play a major role on your athletic performance, we turn to LeBron James and his statistics to answer that for us. James has been in the media for years; he left his home team of the Cleveland Cavaliers to join the Miami Heat. After he and the Heat won two championships out of the three playoff appearances they made, James decided to return home to Cleveland in hopes that he would bring the championship title back to his original team. During the 2016 NBA Finals, James was able to complete that dream. His training regimen helped him throughout the season, but he would not have made it to number one on the list of best players in the sport of professional basketball without major help from his genome.

James is a 6’8” (with shoes) small forward for the Cavilers with a wingspan of 7’1.25” long (“LeBron James Stats, Bio, Video, Profile”, 2017). Being 250 pounds, James also carries a lot of muscle mass, giving him yet another advantage over the other small forwards in the game. Because of the way James was genetically predisposed, he has had a very successful career. James has started in 199 playoff games, averaging 28.0 points, 8.8 rebounds, 6.8 assists, and 1.8 steals in 42.1 minutes per game (“LeBron James Stats”, 2017). This has led him to be a three-time NBA Finals MVP for the last three times he has won the Championship.

When you compare James to the averages of all of the players in the National Basketball Association, there is no surprise why he dominates at his position. The average height (with shoes) of small forwards is 6’7.7” and the average wingspan is 6’10.9” (Willard, 2015). James is just above the average for height, but his wingspan is what triumphs. Having the extra four inches gives a player the advantage because he is able to reach up over his opponents more easily, giving him easier access to the net and to rebounds. Even though statisically a small forward is not someone who gets the most rebounds all of the time, James is 9th all-time in the NBA postseason for rebounds

("LeBron James Stats", 2017), and it is because he has those extra few inches of wingspan that his genes of longer than average limbs coded for.

Men are not the only ones given a genetic advantage to play the sport of basketball. The Women's National Basketball Association also has some stand-out stars that were given the advantage in the gene pool.

Like the NBA, the WNBA has a top list of the players in their league. The number one overall player was Maya Moore, followed closely by Candace Parker, Elena Delle Donna, and Diana Taurasi ("The Best Current WNBA Players", 2016). Of the top ten players, 90% of them were on teams that made it to the playoffs, with 40% of them being on one of the two teams that made it to the Finals. Even though 30% were on the number one ranked team – the Minnesota Lynx – they lost in the Finals to the Los Angeles Sparks, having only 10% of the top ten players on the team. The Lynx may have lost the championship in 2016, but they are where Maya Moore calls home.

Maya Moore is a 6'0" forward for the Minnesota Lynx ("Maya Moore", 2017). Moore has had a lot of success in her six years of professional play, like winning three Women's Basketball Association championships in 2011, 2013, and 2015, winning the Finals MVP in 2013 ("Maya Moore", 2017). Moore was also awarded with the 2014 WNBA MVP and the 2011 Rookie of the Year, after being selected as the number one overall pick in the 2011 WNBA draft ("Maya Moore", 2017). Moore's success – like James – has come from within her genome, making her the powerhouse she is today.

There is not a lot of research done with the Women's National Basketball Association to date, but it is known that the average player is just under six feet tall

(Palmer, 2012). Being six feet tall, Moore has the advantage over her counterparts who are under six feet tall. Since most of the women you see are not very tall compared to men, Moore being as tall as she is processes an extra tool to use when it comes to her playing basketball. With six feet being the WNBA average, there are a lot of women who fall under that height that currently play; it may not be a substantial drop off, but there is one. With her height and muscle mass, Moore will be a dominant player for the Lynx as long as she keeps up with an intense training program to give her an even greater edge.

Basketball is one sport where your genetics are the major role in how successful you will become. In the NBA and WNBA, if you do not have the key ingredient – that being height – then the odds are against you to become a professional. Wingspan was also shown as an important factor in the making of a basketball player; even if a player falls below the height average, their above average wingspan can save them, allowing them for better over-the-head control of the ball. All of this combined makes for a genetically-equipped professional basketball player.

Don’t Get Lapped: Genetics in Olympic Swimming

Every four years, the World gets together to put their athletes on the biggest stage of their career. The Summer Olympics are a time of watching the best athletes from each country compete for medals that they will proudly bring back home as a hero to their nation. The top three sports American viewers get together to cheer on the United States athletes are track and field, gymnastics, and swimming. Swimming is one sport that can sometimes come down a final stroke, and being born with a genetic marker for long limbs and lean muscle mass can help with that extra stroke so you do not get lapped.

Olympic swimming takes place in a 50-meter by 25-meter pool filled with 2,500,000 liters of water with races of varying lengths and sometime relays of up to four swimmers. Swimmers use their arms and legs to propel themselves from one end of the pool to the other, flipping against the wall when it is time to change directions. Swimming performance is dependent on muscular power, muscular endurance, anthropometric characteristics, and body composition in relation to vertical jump (Roy et al., 2015). With high muscular power genes functioning in the lower limbs, swimmers with certain genetic precursors are given an advantage from their competition right from the platform jump.

The bursting leap a swimmer makes from the start platform has one of the biggest impacts on their whole race. This can be seen as an explosive jump that requires a high force production over a short period of time (Roy et al., 2015). That jump can launch a swimmer further across the pool to get them an advantage over their competition. People who are born with the genes of high muscular functions in their lower limbs receive an advantage right from the beginning with the extra push they need to start strong.

Swimming can come down to the final hundredths of a second to determine the victor over the rest of the pack. One of swimming's most famous finishes was Michael Phelps in the 2008 Olympics, where Phelps took an extra stroke to give him a gold medal. Phelps was born with the genetic advantage of long limbs, something that is very crucial in the sport of swimming.

No matter the length of the race, having the longer limbs allows a swimmer to pull themselves further across the pool with each stroke. Being able to move more water behind you with each stroke will advance you ahead of competitors and are able to cover more ground at a quicker pace. When the race is coming down to the end and two swimmers are neck-in-neck, the swimmer with the longer upper limbs can reach out further than his competitor to touch the wall tenths of seconds ahead to win the race. Being able to touch the wall even by the slimmest of margins because of your arms makes all of the difference between a gold medal and a silver medal, just like it did for Phelps back in 2008.

Size and shape of the swimmers has gone through a genetic mutation so to speak throughout the last one hundred years of Olympic swimming. Genes of the athletes who become professional swimmers have developed and changed as the sport of swimming has developed and changed itself. This is one of the fascinating fact about genetics – with survival of the fittest our genes are always changing to make improvements we never thought possible.

Generally, the physique winning swimmers have is becoming taller and heavier. The tallest winner of the 100-meter freestyle – one of the fastest races – was a 6’7” male in the 1988 Olympics (Wood “100m Freestyle”, 2016). Ever since that Olympics of 1988, all winners have been 6’4” or taller. Winning swimmers have become taller because they need the extra length in the pool to get themselves to the end faster than their opponents, especially in a quick race like the 100-meter freestyle. The weight of athletes has also generally stayed in line with the changes in height – as the heights have increased so has the weights (Wood “100m Freestyle”, 2016). Swimmers are not known for being athletes that need a lot of muscle to succeed, but because they have gotten taller, their weights increased proportionally as their heights increased. The Body Mass Index (BMI) of swimmers varies from 20.6-26.8, which is considered an optimal weight, showing that swimmers have the proper muscle mass when it comes to the height their genes have coded for (Wood "100m Freestyle", 2016).

The 2016 Summer Olympics in Rio de Janeiro was one of the most watched television events in America last year. With the United States team predicted to be one of the top nations at the games, there is no surprise why it brought so much viewing traffic. As mentioned earlier, swimming was one of the top three sporting events watched during the Olympics. America was tuned into their televisions to see how Michael Phelps final Olympics would end.

Today Michael Phelps is recognized as one of the greatest athletes in Olympic history. By being one of the greatest in his sport, Phelps has earned the most medals of any Olympic athlete in the history of the games. Participating in five Olympic games, Phelps has taken home 23 gold medals, 3 silver medals and 2 bronze medals (Biography.com Editors, 2016). Phelps has been making history since his first Olympic Games in 2000 and has not disappointed. His most successful year was in the 2008 Olympic Games in Beijing, where he walked away with eight gold medals – one for each event he swam in. He set the all-time single Olympics gold-medal record, with new World Records in the 4x100-meter medley, 4x100-meter freestyle, 200-meter freestyle, 200-meter butterfly, 4x200-meter freestyle, and the 200-meter individual medley, and an Olympic Record in the 100-meter butterfly (Biography.com editors, 2016). Thanks to

Phelps' genetics, he was able to become this successful in his long career. One of the anthropometric traits Phelps is most well-known for is his enormous wingspan.

Phelps stands at 6'4" tall, but his wingspan is a long 6'7" (Biography.com editors, 2016). Having extra inches in wingspan allows Phelps to pull more water behind him, pushing him further along the pool to get ahead of his competition. Those who possess superior height and limbs are able to get across the pool with more ease than those who may be shorter or may not have the extra-long limb length. A few extra inches in limb length can also help when it comes down to the final seconds of a race, as this can allow the swimmer to touch the wall before the person they are close to finishing the race with. This was never more evident than one of Phelps' race in his reign of the 2008 Olympics, where he won by one hundredth of a second to get the gold in the 100-meter butterfly, as mentioned earlier. Thanks to his genetics, Phelps was able to reach his goal of another gold medal because of his famously long wingspan, something that only your genome can code for.

Another swimming superstar stood out above the rest for the women of Team USA this past Olympic Games. Katie Ledecky had accomplished so much before graduating high school, and continued her accomplishments in Rio de Janeiro in 2016.

Ledecky made her first Olympic appearance in 2012 in London where she broke the American Record in the 800-meter freestyle, earning her the gold medal for the games that year ("Katie Ledecky Bio", 2016). Between those Olympic Games and the next one in 2016, Ledecky continued to achieve and succeed, breaking World Records every year until her second Olympic appearance. Some of these records included the 800-meter freestyle, the 1500-meter freestyle and the 400-meter freestyle ("Katie

Ledecky Bio", 2016). 2016 rolled around and Ledecky was able to take home more medals and more World Records. A silver medal was won in the 4x100-meter freestyle, and gold medals in the 400-meter freestyle, the 200-meter freestyle, the 800-meter freestyle and the 800-meter freestyle relay ("Katie Ledecky Bio", 2016). Ledecky raced some of her fastest races, getting a new World Record in the 400-meter freestyle and the 800-meter freestyle, where she famously finished eleven seconds ahead of the silver medalist. Just like Phelps, Ledecky has her genome to thank for her tremendous success.

Ledecky is an above average female standing at 5'11" tall and 155 pounds ("Katie Ledecky Bio", 2016). Her height has already given her an advantage in the pool, but her muscle mass is what helps her finish so quickly. Ledecky's myostatin genes – the genes for thick muscles – are the genes that have given her the ability to gain the proper muscle mass she needs to be a swimmer. Swimmers have their muscles distributed all throughout their body, most of it being found in the limbs. Having a lower body fat percentage but a high muscle mass has an advantage in the initial start the swimmer takes off of the platform to start the race (Roy, 2015). Getting that explosive start gives the swimmer a competitive edge that they need to compete at the international level. Muscle mass comes from your genes, and with training, you can use those genes to the best of their ability.

Like basketball, swimming is a sport where your genetics play an important role in your success. Phelps and Ledecky would not have had the success they have in their Olympic careers if it was not for the genetics of height, wingspan, and muscle mass. These are characteristics that you cannot train for, so having the predisposition anthropometrically can determine who in the swimming world will become a World Champion.

A Perfect Routine: Genetics in Olympic Gymnastics

Along with swimming, the sport of gymnastics gets together internationally on the World's biggest stage every four years. Gymnasts train their whole lives for the opportunity to go to the Olympics. With teams getting smaller in number, the competition the Nations send to the Games is the best in the world. It takes a lot of power to be a gymnast, and genetics play a role in who is chosen to an Olympic team. Gymnasts may not be the tallest athletes around, but their size – along with other genetic characteristics – is what makes them great.

Artistic gymnastics is a sport that requires the use of your entire body in competition on various events. The set of events for male and female gymnasts varies. Female gymnasts compete in the floor exercise, the balance beam, the uneven bars and the vault. Male gymnasts also compete on the floor exercise and the vault, but they do not have the balance beam or the uneven bars. Instead, men participate in the pommel horse, the still rings, the parallel bars and the uneven bars. Scoring for gymnastics is not like your typical sport and recently changed back in 2005. Before, if a gymnast performed perfectly without any faults or mistakes, they would score a perfect 10. Now, the new scoring system is divided into a difficulty score and an execution score, which are added together at the end of the routine. The difficulty score starts at 0.0 and is increased every time a skill is performed by the gymnast. The execution score starts off at the perfect 10.0 and then the judges decrease the score as mistakes in the routine are found. These mistake can include stepping out of bounds, falling off the beam, or adding an extra step after landing a dismount. It is now considered impossible to achieve a perfect score, but getting in the 16s is one of highest achievement.

One of the most noticeable phenotypes of gymnasts is their height. Gymnasts have generally always been small because it gives them the advantage of better balance and easier rotation when they are in the air (Wood "Olympic Gymnastics", 2016). The trend of small and light gymnasts has been on the rise as the years have gone on, with the smallest and lightest gymnasts being the most successful. The average height, weight, and Body Mass Index (BMI) have decreased in All-Around champions since 1954, where it is more pronounced in women then it is in men (Wood "Olympic Gymnastics", 2016).

However, since then there has been a slight change in body shapes, as the athletes are remaining short but are getting a little heavier, while still maintaining a low BMI. This is due to the changing demands of the sport, where having muscle in all parts of the body makes you an even stronger competitor. Changing body shape is a way of showing how genes can mutate based on the demand of the sport. Although it becomes more difficult to gain muscle and maintain a low BMI, these gymnasts not only train for it, but their bodies are genetically equipped to handle this kind of change. In the last two Olympics, this natural process has been witnessed by observing the All-Around champions.

Being short and light is not the only factors that determine the best gymnasts from the ones that will not be on the Olympic stage. Other genetic characteristics athletes are born with also help identify the future someone may have in the sport of gymnastics.

High-level physical performance in gymnastics is influenced by numerous skills and many anthropometric factors. Some genes that are correlated with the sport of gymnastics are associated with body mass, explosive strength, and joint mobility (Tringali et al., 2014). Even though it takes a lot of muscle in all areas of the body to be a successful gymnast, most of these athletes are born with the capability to retain a very low body mass. By having a low body mass, specifically low fat mass, they are able to gain more muscle and use it for all of the flipping, twisting and sprinting they have the do for the different events.

Height and body mass are good starting points when it comes to looking at the genetics of gymnasts, but these traits go deeper into specifics when it comes to identifying a future All-Around Olympic champion.

Gymnasts – especially female gymnasts – have been described as shorter and lighter compared to the majority of the general female population. There are some specific features on a gymnast that can be easily observed. Besides height, the bulk of gymnasts that was measured were smaller around the head, chest, waist, hips, thighs, calf and ankle, but measured larger around the upper chest and biceps (Vercruyssen, 1984). The reason why there is a lot of muscle in the upper body is for events such as the bar events for males and females, the vault event for males and females, and the pommel horse and ring events for the males. These athletes need to be able to lift and twist their entire bodies around certain pieces of equipment and make it look flawless and easy. Many of the successful bar and ring gymnasts have been athletes with tremendous upper body strength, as those two event require more arms and chest strength. These smaller dimensions can also be an association with the younger age and reductions of height of the present gymnasts in the Games (Claessens et al., 1991). Although the upper chest and arms may measure as larger, the overall smaller dimensions a gymnast is born with contribute to a lot of their athletic success.

Gymnasts are considered to be some of the most athletic people in the world, and that was clearly proven during the Olympic Games. This year's Olympics was another exciting year for the sport. Looking at two successful gymnasts will show how the role of genetics helped in the athletes winning their medals. One of the male gymnasts that made news was Max Whitlock of the England team.

Max Whitlock made history for the British this past Olympic Games. In 2012, Whitlock won the bronze medal in the pommel horse and in the team events for the Olympics, but he made great improvements by the time he was ready to compete in Rio de Janeiro. Whitlock won gold medals in the floor exercise and pommel horse and also won bronze in the all-around event, being the first British gymnast to win an individual gold medal ("Max Whitlock MBE Gymnastics Profile", 2016). At the 2015 World Championships, Whitlock also won gold in the pommel horse and silver in the team and floor events ("Max Whitlock", 2016). There is no surprise that his body was born to be successful in the pommel horse and floor, and the genetics he was born with have helped him dominate in those events.

Whitlock stands at 5'6" tall, which is shorter than the average height of British males. As discussed, height is an important factor when it comes to the sport of gymnastics. With Whitlock being short in stature, he has a better sense of balance, which is an important characteristic to be born with when it comes to events like the pommel horse. The pommel horse is a mounting apparatus made of a metal body covered with foam rubber and leather with two plastic handles sticking out. During the event, male gymnasts have to perform at least one element from five different element groups. These groups include a single leg swings and scissors, circles and flairs, side and cross support travels, kehrswing, wendeswings, flops and other combined elements, and dismounts. Whitlock needs to incorporate good balance to perform all of the different elements, with all of the twisting that needs to be accomplished. Whitlock also has a lot of upper arm strength, which is beneficial because the pommel horse requires a lot of arms to perform all of the different moves. Being short does not always have to be a negative thing, especially when it wins you a gold medal like it did for Whitlock.

The United States women's gymnastics team was predicted before the Games even started to take home the majority of the medals that would be distributed for the sport that year. One of the key gymnasts on the Final Five team that would end up bringing home the most medals was Simone Biles.

Biles has been a superstar for American gymnastics ever since she won three consecutive U.S. National Championships and one World Championship all before the 2016 Olympics began (VanDeusen, 2017). During the 2015 World Championship, Biles walked away with gold medals in the all-around, the beam, the floor and the team events along with a bronze medal in the vault event. Her success continued into the 2016 Olympics, where she brought home gold medals in the all-around, the vault, the floor and the team events and a bronze medal on the balance beam (VanDeusen, 2017). If that is not impressive enough, Biles is the model of power with her signature floor move – a floaty double layout with a half twist at the end (VanDeusen, 2017). An element like this has never been performed before, so this move is now named after the creator herself.

The tremendous amount of success Biles has demonstrated is thanks to the genetics she was born with.

The most noticeable thing about Biles is that she is not a very tall athlete. At 4’8”, she was the shortest gymnast on the United States team. Biles’ short height allows her to perform at a higher level than her competitors; she is able to flip, twist, and fly through the air more easily without having to worry about a few extra inches being the difference by remaining in bounds without getting a deduction on her performance. Another anthropometric characteristic about Biles is that she has an extraordinary amount of muscle all over her body. She is an outlier in the trend of gymnasts becoming shorter and lighter, as Biles is toned and her muscle are defined. Although she is not considered heavy, this ability to have a well-defined muscle mass spread evenly throughout her body is what makes her packed with so much power. Many of her competitors wish they were able to have the muscle capacity that Biles has without being too big for the sport, and it is thanks to Biles’ genes that she is able to train so much and have so much muscle without it being a disadvantage for her while she is trying to perform.

Even though they may not be the tallest of athletes, gymnasts are some of the strongest athletes with the most defined muscle mass. Gymnasts’ low BMI and low percentage of body fat helps them utilize the greatest proportion of muscle they process and use it to the best of their ability. If they were not encoded with the genes to have these two distinct characteristics about them, then it can be said that they were not born to be gymnasts. Your genes play a big role in your athletic outcome, and this is one proven case where shorter is better.

Chapter 3

Conclusion

Looking back on the year 2016, sports played a big part of the entertainment world. With the Chicago Cubs and Cleveland Cavaliers both winning championships after a three-to-one game deficient, to the Villanova Wildcats making a buzzer beater shot to win the National Colligate Athletic Association Basketball Championship, to watching Michael Phelps' final Olympic Games, there is no doubt that we can see how genetics plays a role in all of these winning programs. There is no question that these winning athletes put in the long hours of training to become the best, but they need to first be genetically equipped with the proper genes to rise to the top and be labeled the best of the best in their sport. It has been proven that people are born with certain genes make them predispositioned to a certain sport; having the ACTN3 gene will give you a precursor to be a better sprinter because you are then born with fast-twitch genes is just one example. Our genome makes us who we are, and there is no way that we can change that.

Genetic advantage is coupled with hard work and intense amounts of training to become the best of the best. There are no "naturals" in the world that are automatically guaranteed a spot in the major leagues if they have not practiced more than their competitors. Mike Piazza would not have gotten to wear his own Major League Baseball jersey if he did not clear off his batting cage every day in the winter to hit baseballs. It is because of his hard work and dedication to the sport that he had the success he did while playing the sport that he loved.

Many of the sports we looked at, two of the biggest contributing factors for a champion was height and the amount of muscle mass someone has. These are characteristics that you cannot change through any amount of training. Height and muscle mass are just two simple ways to determine how much success you will have in your future sporting endeavors.

Along with training, genetics plays the main role in the athletics we enjoy. Even though some people may not be happy to hear the sad news that they will not become professional athlete if they are not genetically equipped for the sport they love, there is nothing stopping them from still playing the sport. Genetics is a topic with new information coming out every day, and the more we learn about it, the more accurately we can predict the future success of the athletes that we will see on the professional stage in the years to come.

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