Ford P, Hodges NJ, Williams AM (2013). Creating champions: The development of expertise in sports. In S. Kaufman (Ed). *BEYOND TALENT OR PRACTICE: THE COMPLEXITY OF GREATNESS (*pp391-413*)*. Oxford University Press. THIS IS A PRE-PROOF VERSION OF THE FINAL CHAPTER

Creating Champions

Chapter 18

Creating Champions:

The Development of Expertise in Sport

Paul R. Ford, Nicola J. Hodges, A. Mark Williams

Abstract

The outstanding performances of elite athletes are underpinned by physical, psychological, motor, and perceptual-cognitive attributes that are close to the limits of human capability. The dominance of athletes from certain countries in some sports (e.g. Jamaican sprinters, East African distance runners) suggests a strong genetic component to performance, but this dominance does not rule out the possibility that unique environmental factors may partly, or fully, explain this superior performance. In this chapter, we review evidence for the roles of “nurture” in terms of acquired attributes through experiences and “nature” through genetic factors. With the exception of genetic differences related to height, stature, and, to a lesser degree, muscle type , the current research on genetics has not shown a definitive role for genes in the development of expertise in sport. However, prolonged engagement in large amounts of high-quality sport-specific practice and other activities are necessary to achieve this outcome. There remains some debate as to what constitutes the optimal environment for the development of expertise in sport (e.g. early specialization vs. early diversification). Nonetheless, in order to develop future champion athletes, we recommend that practitioners should focus on creating optimal learning environments.

Keywords: genetics, hereditary, practice, environment

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Sporting champions, such as the tennis player Roger Federer and the golfer Tiger Woods, are famous and idolized by many people. They bring joy to millions of people with outstanding performances that are way beyond the capabilities of most other humans. These expert athletes often perform at the limits of human capability, which makes sport an important domain for scientists wishing to examine issues surrounding the development of skill and the relative contributions of nature and nurture. In this chapter, nature generally refers to the contribution of inherited genes to the development of expert performance in an individual. Therefore, "innate" talent is a genetically transmitted advantage for certain individuals that predispose them to show early indications of expert performance in that domain before environmental factors have caused adaptations (Howe, Davidson, & Sloboda, 1998). In contrast, nurture refers to the contribution of environmental factors to the development of expert performance. In certain sports there is a dominance of expert athletes from certain countries or regions, such as East African endurance runners and Jamaican sprinters. The dominance of certain countries and regions in some sports suggests a strong genetic component to performance, yet it does not rule out the possibility that unique environmental or cultural factors are responsible for the attainment of superior performance.

In this chapter, we critically review evidence for genetic and environmental influences in the acquisition of expert performance in sport. We show that while some characteristics, such as height stature, and to a lesser degree muscle and bone structure, are heavily influenced by genes and consequently favor individuals toward certain sports, the research on genetics is currently not sufficiently advanced to show whether or not genes limit the development of expert performance in sport. We present evidence to show that certain environmental factors are necessary for the attainment of expert performance in sport. We argue that practitioners and researchers should concentrate on creating optimal environments across the age continuum in order to "create champions" in sport. Such an environment would allow for childhood experiences that do not explicitly focus on performance improvement or adult-orientated competition within the primary sport and adolescent/adult experiences that do.

"Innate" Talent in Sports

In sport, innate talent usually refers to a non-trained, inherited performance or fitness characteristic or phenotype that advantages an individual in terms of athletic performance, such as a higher pre-training aerobic capacity or maximal oxygen uptake (V02max). Two main lines of evidence have been used to support the role of innate talent in sport. First, researchers have used twin and familial studies to show the heritability of these phenotypes. The rationale in these studies is that if the phenotypes are heritable, then the variance in the phenotype will be lower within sets of twins or nuclear families (i.e., both biological parents and siblings) than between the sets or families. Second, researchers have attempted to identify specific or candidate genes that are associated or linked with performance phenotypes or elite athlete status. We review these two lines of evidence in the following sections.

Heritability Studies

One of the most comprehensive sets of studies examining familial heritability is the HERITAGE project (HEalth, RIsk factors, exercise Training, And GEnetics; Bouchard et al., 1995; for an example of twin studies, see Bouchard Jr. et al., 1990). The first phase of the HERITAGE project assessed nuclear families containing both parents and three biological adult offspring for a number of sport performance phenotypes related to endurance (e.g., V02max), exercise intolerance (e.g., blood lactate), and response to training, as well as other phenotypes related to health. For example, in one study conducted by Bouchard et al. (1998), 86 Caucasian families comprising 429 sedentary individuals of 170 parents and 259 offspring were assessed for their maximal oxygen uptake (V02max). Maximal oxygen uptake (V02max) is one of a number of indicators of aerobic or endurance capacity and contributes to performance in many sports. The V02max score was adjusted for the effects of age, gender, and body mass. There was three times less variation in V02max within families than between families. Significant familial resemblance was observed for all measures. Several other studies from the HERITAGE project (e.g., Rico-Sanz et al., 2003) have shown similar familial resemblance in other performance phenotypes and have been taken as support for an inherited genetic effect on sports' performance phenotypes.

Ericsson (2003) reported two major criticisms of research studies examining the heritability of sports' performance phenotypes in twins and families. First, this research has typically been undertaken on sedentary individuals who are at the other extreme of performance compared to expert athletes. Therefore, the familial resemblance in a phenotype such as V02max for these individuals has not been subjected to the years of training that expert performers engage in, which can increase V02max scores significantly. The difference in V02max scores between sedentary individuals and expert endurance athletes can be vast. For example, the sedentary families examined by Bouchard et al. (1998) had mean V02max scores that ranged from 23 ml/kg/min for mothers to 42 ml/kg/min for sons. In contrast, the elite Kenyan and Scandinavian distance runners examined by Saltin et al. (1995) had V02max scores of around 80 ml/kg/min at sea level, while sedentary adolescent Kenyan boys in the same study had a mean V02max of 47 ml/kg/min. It is currently not known whether genetic factors, such as those that lead to sedentary individuals being high, medium, or low responders to a program of aerobic training (Skinner et al., 2001), environmental factors, or a combination of both, set the limits on the extreme V02max scores of elite endurance runners. The second limitation is that families and twins share their genes and environment, so it is difficult to separately estimate the influence of these two factors. Twins who are reared apart who are used to show that environment does not influence development are usually both reared in remarkably similar environments in the same country or culture (Hoffman, 1991). Such criticisms, as well as the completion of the sequencing of the human genome (International Human Genome Sequencing Consortium, 2001, 2004), a move by funding agencies toward supporting biomedical research (Rankinen et al., 2001), and advances in technology, have led researchers away from twin and familial resemblance studies toward an examination of the association between genes and performance phenotypes.

Candidate Gene Association Studies

Some genes can have two or more forms or alleles. In part, genetic variation between individuals stem from these polymorphisms and scientists have investigated their role in sport performance (Malina, Bouchard, & Bar-Or, 2004). The seventh and most recent update of the human gene map for performance and health-related fitness phenotypes produced by Bray et al. (2008) identified 239 genes and markers with evidence of association or linkage with a performance or fitness phenotype. Of these, 110 genes and markers have been associated or linked with the sport performance phenotypes of endurance, muscle strength, and exercise intolerance. For example, the angiotensin-converting enzyme (ACE) insertion/deletion (I/D) polymorphism, which is a gene located on the 17th chromosome of the human genome, is one of the most widely examined in relation to its association with performance cases, such as elite athlete status, and phenotypes (Bray et al., 2008). Support for the ACE I variant's association with improved endurance performance was provided by Myerson et al. (1999), among others. They examined this gene's distribution in 91 British Olympic-standard runners who competed in 12 distances ranging from sprint to ultra-marathon. They also examined 404 Olympic-standard athletes from 19 varied sporting disciplines in which endurance performance was not necessarily a key factor. They reported an increasing frequency of the I variant with distance running, although only the runners who competed at ≥5,000 m had a greater frequency compared to the multi-sport control group.

A number of studies that show no association or link between a gene (including the ACE gene) and a phenotype or elite athlete status are not included in the Bray et al. (2008) version of the human gene map for performance and health-related fitness phenotypes or in all previous installments of the map (e.g., Rankinen et al., 2004). For example, Scott et al. (2005a, see also Scott et al., 2005b) examined ACE gene variation in 70 international Kenyan endurance runners, 221 national Kenyan endurance runners, and 85 members of the general Kenyan population. ACE I/D frequencies did not differ between athletes and general population controls. Moreover, frequencies of the genotype at A22982G, which has been shown to associate more closely with ACE levels in African people, did not differ across groups. The conflicting findings between studies examining the same gene make it currently impossible to draw conclusions as to whether they are involved in human variation in athletic performance, leading some authors to question the methods employed. In particular, the studies have universally lacked statistical power; in many cases there has been only a single positive association made, and the method of assessing only single candidate genes has been called into question using the rationale that performance will involve networks of genes that interact with themselves and with the environment (Bray et al., 2008; Davids & Baker, 2007).

Phenotypes Attributed to Genetic Endowment

There are clear differences in performance between males and females in many sports. For example, the world record for the 5000 meters at this time of writing was 12.37 minutes for males, held by Kenenisa Bekele of Ethiopia, and 14.11 minutes for females, held by Tirunesh Dibaba of Ethiopia (International Association of Athletics Federation, 2010). To put this into context, the time difference between these two 5000-meter world records makes it possible for the male holder to have "lapped" the female holder on a 400-meter track. Humans are born with 23 pairs of chromosomes, of which 22 chromosome pairs are found in both males and females. The X and Y chromosomes determine a person's sex so that females are XX and males are XY. The genes as a result of these sex-differentiating chromosomes specify proteins that differentially affect growth and maturation (Malina et al., 2004). For example, males are significantly taller on average compared to females (e.g., Cavelaars et al., 2000). Height is one phenotype that does appear to be predominately determined by genes, with around 80% of the variation in height among individuals due to genetic factors (Visscher, 2008). For example, in a recent series of genome-wide association studies with sample sizes ranging from 14,000 to 34,000 participants, researchers reported a total of 54 polymorphisms affecting height variation in the population (Visscher, 2008).

Although these genetic differences can explain some of the performance difference between males and females, it is currently unclear as to what extent they influence this difference. In an attempt to measure the contribution of gender among competitive swimmers and triathletes, after controlling for current and previous practice-related activities, Hodges, Kerr, Starkes, Weir, and Nananidou (2004) found that gender differences accounted for more variance in performance times in the 100m and 200m freestyle swimming events (40% and 34%, respectively) than practice-related variables (31% and 29%, respectively). However, as the length of the event increased, and less emphasis was placed on anaerobic factors, this trend reversed (400m; 11% = gender, 63% = practice; 1.5k swim for triathletes; 1% = gender, 56% = practice). Variables related to height, such as longer reach, could be one potential reason for these persisting gender differences, especially at the shorter sprint distances, although other variables related to strength and power (i.e., muscle size, muscle to body fat ratios) are as or more likely to play a role.

Some phenotypes related to sport have been attributed to genetic endowment, such as muscle fiber type (e.g., MacArthur & North, 2005), bone structure (e.g., Cooper & Umbach, 1996) and cardiac hypertrophy (e.g., Jamshidi et al., 2002). For example, there are three common muscle fiber types in humans (type I; type IIA; and type IIB), although more recently these types have been shown to exist across a continuum based on a range of characteristics, such as myosin heavy and light isoforms (Ingalls, 2004). Type I muscle fibers, also known as slow-twitch, possess a high oxidative capacity and are associated with endurance performance, whereas type II muscle fibers, also known as fast-twitch, are more anaerobic in nature and are associated with generating power (Malina et al., 2004). Sprint and power-based athletes, such as elite power- and weightlifters, have a greater proportion of type II compared to type I muscle fibers (e.g., Fry et al., 2003), whereas elite endurance athletes have a greater proportion of I compared to II (e.g., Costill, Fink, & Pollick, 1976).

At birth, humans have a relative fiber type frequency of 40% type I muscle fibers and 45% type II (35% type IIA and 10% type IIB) with 15% undifferentiated or less differentiated (Malina et al., 2004), although individual differences in these proportions at birth can range from 30–60% of type I fibers (e.g., Oertel, 1988). Variation in the relative distribution of muscle fiber types at birth and in early life is, at least in part, due to two genes on chromosome 11 that encode actinin proteins for skeletal muscle: ACTN2, which is expressed in all muscles, and ACTN3, which is expressed only in type II muscles (MacArthur & North, 2005). The X allele at the R577X polymorphism prevents production of actinin 3 and is associated with a lower distribution of type II fibers (Vincent et al., 2007) such that the gene is more prevalent in elite endurance compared to power athletes, whereas the R577R genotype leads to a higher distribution of type II fibers and is found more so in power athletes (North et al., 1999). However, it is widely accepted that training causes a conversion of IIB fibers to IIA and, to a lesser extent, changes from type I to type II (e.g., Adams, Hather, Baldwin, & Dudley, 1993), and there is evidence that muscle fibers can radically change their functional properties following training (e.g., Trappe et al., 2006). Put together, the research suggests that some individuals are born with a relative distribution of muscle fiber types that favor them for either endurance- or power-based sports, but this distribution can be altered toward the optimum profile through extended amounts of endurance or power training.

Hormonal Influences

Another line of research based on hormonal differences between individuals has led to the suggestion that there are “innate” characteristics that predispose individuals to succeed within sport. The most compelling evidence for hormones affecting sport success has been presented by Manning and colleagues (Manning & Taylor, 2001; Manning, Morris, & Caswell, 2007). These researchers have shown a relationship between the length ratio of the index and ring finger (known as the 2D:4D ratio) and various athletic achievements (for a meta-analytical review, see Hönekopp & Schuster, 2010). The length ratio between these two fingers is thought to be a putative marker of prenatal testosterone (T), with smaller ratios (or longer ring fingers) indicating high T levels and greater athletic prowess, particularly in endurance events. The 2D:4D ratio correlated with endurance running performance in independent samples of 27 athletes (16 male), 43 male athletes, and 40 female athletes (Manning et al., 2007). It is unknown whether the relationship arises because prenatal T affects components of physical fitness (e.g., V02max) or motivational factors (e.g., competitiveness) (Archer, 2006; Hönekopp & Schuster, 2010).

Genetic Responses to Training

Scientists have started to examine the interaction between genetic polymorphisms and the response to training (for a review, see Woods, Humphries, & Montgomery, 2000). Montgomery et al. (1998; see also Williams et al., 1998; Myerson et al., 2001) examined the effect of variation in the ACE I/D gene in 23 Caucasian male British army recruits who performed repetitive elbow flexion holding a 15-kg barbell before, during, and after a 10-week physical training program. Although pre-training performance was independent of genotype, after the training program, time to exhaustion was greater for those individuals with the II and ID gene compared to the D. Therefore, variation in the genome, specifically the ACE gene, can affect the response to training, which would indicate that some individuals are advantaged in being able to improve at a faster rate than others following exposure to the same training stimulus. However, in contrast, there are a number of studies showing no association between a genetic variant and the response to training or physical activity. Williams et al. (2005) examined the effect of ACE gene variation on quadriceps strength before and after an eight-week program of dynamic strength training of the quadriceps muscle group in 44 untrained males. Although variation in the ACE gene before the training program was related to quadriceps muscle strength, there was no significant association with the 9–14% mean increases of muscle strength in response to the training.

In a similar manner to gene/training-response studies, scientists are beginning to reveal the association between the genome and learning. Frank et al. (2009; see also Frank et al., 2007; Frank & Hutchinson, 2009) have examined three candidate genes (e.g., the DARPP-32 gene located on the 17th chromosome of the human genome, now commonly referred to as PPP1R1B) that are linked to variation in dopamine levels in the striatum and prefrontal areas of the brain, which contribute to learning. Variation in these genes is related to better decision making after a simple reinforcement learning task in which participants learn from positive and negative outcomes. An association between variation in the genome and “better or worse” learning suggests that some individuals could be advantaged in acquiring skill. However, no test of the association has been made between these candidate genes and the acquisition of sport skills. Researchers examining the gene-learning and gene-training association have to date used short acquisition phases to demonstrate the association (e.g., Frank et al., 2009) as opposed to the large amounts of practice and activity in which expert athletes engage.

Acquiring Skill in Sports

The activities in which athletes participate in during their development appear to contribute significantly to expert performance in sport. Researchers have attempted to identify the type and amount of activity that elite athletes across many sports have engaged in over their careers in order to demonstrate which activities are necessary for success. Typically, the retrospective recall methodology that was initially introduced by Ericsson, Krampe, and Tesch-Römer (1993) has been employed to study the participation history profiles of elite athletes. Performers are required to recall via diaries, questionnaires, and/or interviews their levels of participation in various activities related to their primary sport since initial engagement. Of these activities, practice is the key variable that leads to improvements in performance. The Ericsson et al. study was the first to acknowledge that deliberate practice was a key activity in the development of expert performance. Deliberate practice is an activity designed to improve a specific aspect of current performance. It contains repetition and feedback, as well as being designed to reach beyond the performer’s current level (i.e., at the “challenge point,” Guadagnoli & Lee, 2004). It requires from performers their full attention, maximum effort, and complete concentration. In sports, it is also highly relevant to the actual competition performance of the athlete.

Several researchers across a variety of domains, including sports, have shown that hours accumulated in deliberate practice are closely, positively, and often monotonically related to the performer’s attained level of performance (for reviews in sport, see Hodges & Baker, 2011 Starkes & Ericsson, 2003; Ward, Hodges, Williams, & Starkes, 2004). Engagement in domain-specific deliberate practice and the unique constraints of the performance environment cause specific adaptations and improvements to the attributes of a performer (Williams & Ericsson, 2008). The attributes of expert performers in sport span a range of physiological (e.g., V02max), anthropometric (e.g., increased muscle mass), psychological (e.g., mental toughness), and skill (e.g., decision making) variables. There are many examples of practice and training providing an overload stimulus that causes adaptations and improvements in all of these attributes. For example, elite female cross-country skiers improved their time to exhaustion, which is a key attribute in this sport, following a nine-week program of maximal strength training that simulated double poling in cross-country skiing compared to appropriate controls (Hoff, Helgerud, & Wisloff, 1999). Scientists have shown that expert athletes engage in such domain-specific activities designed to improve their performance and specific aspects of it across an extended period of time, often from childhood onward. This process is encapsulated in “the 10-year rule,” which holds that it takes 10 years of training or more to attain expert levels of performance (Simon & Chase, 1973).

Scientists have also used the retrospective recall methodology to reveal a number of developmental pathways that athletes engage in across childhood and adolescence toward expert performance in adulthood. These pathways all contain periods of specialized, sport-specific deliberate practice, but they differ in terms of when during development it begins (i.e., childhood vs. early adolescence vs. late adolescence/adulthood). Some pathways are characterized by early engagement during childhood in the primary sport only, whereas others are defined by early engagement across several sports in addition to or instead of the primary sport. We have attempted to summarize these approaches very broadly in Figure 18.1 and explain these pathways in more detail below.

Childhood Start in Sport-Specific Deliberate Practice

The pathway that is characterized by sport-specific deliberate practice during childhood and beyond is called the early specialization pathway. It is defined as an early start age in the primary sport (i.e., 5 to 11 years of age); early involvement in one sport only or at least primarily; early involvement in focused, high-intensity training in that sport, also known as deliberate practice; and early involvement in competition in that sport through tournaments, competition meetings, and leagues (Baker, Cobley, & Fraser-Thomas, 2009). This pathway is shown in Figure 18.1 and appears to be prevalent in sports in which expert performance is required in early adolescence (for an example of international gymnasts following this pathway, see Law, Côté, & Ericsson, 2007). A number of negative consequences may be associated with early specialization (Baker et al., 2009; Wiersma, 2000). Baker et al. (2009) argued that early specialization can cause negative physical consequences for performers, such as overuse injuries, reduced enjoyment, compromised social development, dropout from sports, and burnout. Despite these predictions, there is no evidence for reduced enjoyment or motivation associated with early childhood involvement in organized practice in soccer (Hendry, Crocker & Hodges, in review; Ward et al., 2007).

[Insert Figure 18.1 here]

Early Adolescent Start in Sport-Specific Deliberate Practice

Several researchers have shown that during childhood, expert athletes engage in high amounts of an activity termed deliberate play, whereas the start of meaningful engagement in sport-specific deliberate practice is delayed until early adolescence (see Figure 18.1, pathways 2 and 3). Deliberate play is unstructured activity usually led by the children themselves using rules adapted from adult norms and engaged in with fun (rather than improvement) as the intention (Côté & Hay, 2002). In some cases, the childhood involvement in deliberate play activity occurs across several different sports (early diversification/play), whereas in other cases it occurs in the primary sport (early engagement/play).

The early diversification pathway involves engagement in a number of different sport activities during childhood, early involvement in sport activities engaged in with the intention of having fun, and late or delayed specialization during adolescence into deliberate practice in the primary sport (Côté, Baker, & Abernethy, 2007). There has been evidence to suggest that this pathway characterizes successful athletes, at least in some sports in certain countries (Baker, Côté, & Abernethy, 2003; Berry, Abernethy, & Côté, 2008; Carlson, 1988; Côté, 1999; Monsaas, 1985; Soberlak & Côté, 2003). The research used to support the early diversification pathway contains an important limitation. In most cases (Berry et al., 2008; Carson, 1986; Côté, 1999; Monsaas, 1985; Soberlak & Côté, 2003) the expert participants have engaged in some form of activity in their primary sport from a relatively young age. The possibility remains that this early participation in the primary sport causes or contributes to skill in that sport in adulthood, and that the engagement in various sports is peripheral to that outcome. The early diversification pathway may protect performers against the potentially negative consequences of the early specialization pathway, but it does not follow that it causes expert performance in the primary sport.

In certain sports, the childhood activity of expert athletes is mainly in deliberate play in the primary sport, with limited engagement in other sports or in sport-specific deliberate practice (for an example of elite soccer players, see Ford, Le Gall, Carling, & Williams, 2008). This has been termed the early engagement pathway (Ford, Ward, Hodges, & Williams, 2009). It has been suggested that these types of early unstructured activity experiences in the primary sport foster the development of decision-making ability (Roca, Williams, & Ford, 2011), attainment (Ford, Ward, Hodges, & Williams, 2009), “creativity” (Memmert & Roth, 2007), and potentially “adaptive” rather than “routine” expertise (Holyoak, 1991). In a similar vein, in as much as the physical activities were unstructured and not engaged in with the goal of performance improvement, is the finding that elite Kenyan athletes predominately ran to and from school every day during childhood (general Kenyan population = 22%, national athletes = 73%, international athletes = 81%) and covered greater distances as a function of their current status (Onywera, Scott, Boit, & Pitsiladis, 2006; see also Scott et al., 2003). Moreover, most of these elite athletes came from the Rift Valley province, an area of East Africa that lies mostly at altitudes of over 2000m above sea level and has an ingrained culture of successful distance running. For endurance runners, repetitive running of long distances at high altitude has been shown to be hematologically beneficial to quick distance running (Schmidt et al., 2002). Similarly, in the biography of the eminent distance runner Haile Gebreslassie, who is also from the Rift Valley in Asela, Ethiopia, it is reported that during his childhood he ran six miles to and from school for six days a week at altitude (Denison, 2004). These types of unstructured, yet sport-specific activities during childhood appear to characterize the early experiences of many elite athletes.

Late Adolescence/Adulthood Start in Sport-Specific Deliberate Practice

In some sports, it is possible for athletes to start engaging in their primary adult sport and in deliberate practice in that sport in late adolescence or adulthood and still achieve what would be considered elite-level status. This late engagement in the sport is sometimes referred to as “mature age specialization” (for a review, see Vaeyens, Güllich, Warr, & Philippaerts, 2009, and see Figure 18.1). Bullock et al. (2009) reported a national campaign run by the Australian Institute of Sport (AIS) in which they recruited adult females with a history of participation in sports involving explosive speed and successfully transferred some into the winter sliding sport of skeleton racing, in which 30m sprint time is a major part of performance. There are other examples of athletes who transferred into their sport late and ended up on the medals’ podium. For example, Rebecca Romero from Great Britain won a silver medal in rowing at the Athens 2004 Olympic Games and a gold medal in individual pursuit cycling at Beijing 2008. These examples, as well as concerns over the potential negative consequences of the early specialization pathway, have led to institutionalized “mature age talent identification” and “talent recycling” programs in which athletes are identified and developed at later ages in a number of countries (Vaeyens et al., 2009). Sports that may profit from such mature age specialization may be limited to those that rely largely on physiological capacities and sports that are relatively new or are less popular culturally, such as a number of winter Olympic sports, so that the competition field is much smaller and specialization can occur later than in more mainstream sports.

Measurement Issues

Measurement of the amount of practice hours that expert athletes have engaged in during their development (i.e., the quantity) does not indicate what the athletes have actually done during practice (i.e., the quality) (Singer & Janelle, 1999). There have been attempts to study the “microstructure of practice” in order to differentiate the specific practice experiences of experts and novices. Time motion analysis generally shows that athletes spend more time during coach-led practice in activity that repeats already acquired skills and that is less relevant for their actual performance compared to the challenging and highly relevant activity that characterizes deliberate practice (e.g., Starkes, 2000; Ford, Yates, & Williams, 2010). Moreover, coach-led practice can involve significant periods of waiting or resting, suggesting that it might not be the most efficient and effective type of practice (e.g., Deakin & Cobley, 2003).

There are also a number of activities that are not typically measured as practice but contain the characteristics of deliberate practice and that are probably necessary for expert performance in sports. For example, a cyclist who deliberately prepares and ingests a bland meal that is high in carbohydrates, proteins, and vitamins the evening before a race is deliberately changing activities in order to improve performance. One may view this activity as forming part of a “deliberate environment” in which the majority of decisions and behaviors made by expert athletes in their life are goal-directed toward improving their performance. The hours accumulated in activities such as structured eating, lifestyle, and thinking, in order to achieve gains in performance, are likely highly correlated to achieving success in sport. At least anecdotally, at the highest levels of competition, access to sports science specialists (e.g., nutritionists) and facilities are assumed to maximize opportunity for medal success, with the more affluent countries being able to allocate greater resources to such support structures compared to those who are less wealthy economically.

A further limitation of research measuring the developmental pathways of expert athletes is that by measuring only individuals who succeed, scientists are revealing only the current talent development program that is in place in that sport or country. It does not follow that the talent development programs that researchers unveil using this method are optimal in creating expert performers. The participants in these studies may just be the “survivors” of that program, and those who have dropped out along the way may have had the potential to be more skilled had the program been more optimally designed. Moreover, although this research reveals the talent development structure in that sport in that country, it is not possible to infer causality from this type of data in terms of which activities and experiences during development actually caused the expert performance and its attributes. Finally, there is usually relatively large variation in the number of hours accumulated by elite athletes in the same sample, suggesting that some other factor or factors other than the quantity of practice are important.

Other Environmental Influences

Coaches and significant others have been shown to be important factors in the development of expert performance in sport. Coaches often have complete control over the athlete's organization, practice, and competition environment (Côté, Young, North, & Duffy, 2007; Davids & Baker, 2007) so as to influence their personal and sporting development, as well as their achievement of goals (Ford, Coughlan, & Williams, 2009). Expert athletes tend to seek out and work with expert coaches (Monsaas, 1985). Although the characteristics of expert coaches have been outlined by researchers (e.g., Côté, Young, et al., 2007; Schempp et al. 2006), the effectiveness of coaching is difficult to measure because of its complexity (Ford et al., 2009). Further research is required to study the interactions between coaches and athletes to help identify the critical elements of good coaching at specific ages and stages of an athlete's career that lead to the achievement of elite status in sport.

Significant others, typically parents, also have an influence on the development of expert performance in sport. Côté (1999; see also Bloom, 1985) examined the influence of family on the development of expert performance in four elite athletes (three rowers and one tennis player). Interviews revealed that the athletes' development passed through three relatively distinct chronological categories named "stages of sport participation" (Côté et al., 2007). In the early phase, parents provided opportunities for their children to enjoy sports. In the middle phase, when the child became an adolescent, parents emphasized academic and sporting achievement, as well as making time and financial commitments to the young athlete. In the latter phase, when the child was in late adolescence, the parents showed great interest in their child athlete and helped him or her to fight setbacks such as injury, pressure, and loss of form.

Other environmental factors related to when and where an individual is born have also been shown to be factors in the attainment of expert performance in sport. In youth sports, children of similar chronological age are grouped together in an attempt to provide a "fair" practice and competition environment. Two definitive selection dates are applied in order to group children into age-related cohorts. For example, in English schools the selection year runs from September 1 to August 31. Children born in the month of September will be approximately 11–12 months older than peers born within the month of August. As a consequence, children who are born directly after the selection start date may gain several physical and psychological advantages over their relatively younger peers due to increased maturity and/or practice time (Barnsley, Thompson, & Legault, 1992). The children born early in the selection year that display these advantages are more likely to be selected onto sports' teams and into talent development programs compared to their relatively younger peers (Helsen, Van Winckel, & Williams, 2005). This selection bias offers relatively older children further advantages and leads to them being overrepresented in the sporting population (Cobley, Baker, Wattie, & McKenna, 2009). For example, a significant overrepresentation of athletes born in the first half of the selection year has been shown in the birthdates of 1013 male ice hockey players participating in the National Hockey League (Baker & Logan, 2007). This bias is termed the "relative age effect" (RAE). The RAE occurs mainly in youth sports in which more individuals wish to participate than the number of places available as determined by access to coaches and training resources (Wattie, Cobley, & Baker, 2008). It is particularly apparent in sports in which the identification, selection, and development of "talent" occurs in pre- or early adolescence (Wattie et al., 2008) and in those that contain ego-involving environments, such as leagues (Dweck, 1986).

Where individuals are born can equally affect their ability to achieve expertise in sport. Certainly, being born in the Rift Valley area of East Africa, with all its environmental and demographic "advantages" as well as the ingrained culture of endurance running and success, promotes the development of expertise in distance running. There are many examples of countries with other unique environmental and demographic advantages, as well as an ingrained culture for sport, where it is advantageous to be born and raised, such as Jamaica for sprinting. In North America, the population size of the individual's place of birth can also affect the chances of achieving expert performance in sport. Côté, MacDonald, Baker, and Abernethy (2006; see also Baker & Logan, 2007) found that the births of professional athletes were overrepresented, compared to the general population, in medium-sized cities of less than 500,000 and underrepresented in large cities of 500,000 and over. The bias toward more professional athletes being born in smaller cities may be caused by a number of possibly interacting factors, including access to sports facilities and coaches, as well as increased likelihood of being identified as "talented" due to less competition. It is also possible that access to space and parkland that would be conducive to early deliberate play could afford more opportunities for children from smaller towns, rather than larger cities.

Implications for Talent Identification and Development

The current scientific evidence leads us to suggest that practitioners should concentrate on creating the optimal environment for athletic development. We have briefly reviewed a number of developmental pathways that have been shown to lead from entry into sport in childhood to expert performance in adulthood. However, there is little consensus between researchers or practitioners as to the optimal developmental pathway from childhood to expert adult performance in sport. In the following section, we provide some implications for current practice and highlight avenues for future research.

One of the main implications from the research is that late adolescent and adult expert athletes should be engaging in relatively large amounts of deliberate practice activity in their primary sport. Deliberate practice activities should contain the characteristics outlined in our earlier definition, such as being designed to improve a specific aspect of current performance and being highly relevant to performance in competition. Late adolescent and adult expert athletes should also be immersed in what we term a "deliberate environment," in which the majority of their decisions and behaviors in their life are goal-directed toward improving or maintaining performance, including decisions and behaviors designed to avoid overtraining and burnout. An example of this appears in the biography of the eminent soccer player Johan Cruyff, when he describes how he often turned down party invitations so as to rest or practice soccer (Barend & van Dorp, 1998). Skilled adolescent athletes should be given the opportunity to engage in relatively large and ever-increasing amounts of deliberate practice in their primary sport.

The central prediction of the "mature age specialization" pathway is based on transfer of learning or characteristics acquired in one sport to another. Therefore, the ability of a mature adult to transfer into a sport is dependent on whether the athlete has previously engaged in activities that are highly relevant within the sport he or she is transferring into. Other factors that influence this transition are the skill level to be attained by experts in adulthood in the primary sport and its popularity in terms of participant numbers. For these reasons, the "mature age specialization" pathway appears to suit sports that have a smaller number of participants relative to more popular sports, have an emphasis on physical characteristics for successful performance rather than technical skill (e.g., rowing), and have very similar elements (e.g., diving and gymnastics).

There is a lack of consensus between researchers and between practitioners as to the activities that children should engage in between approximately 5 and 12 years of age so as to lead to expert performance in sport in adulthood. Several variables interact with one another to cause the lack of consensus, and these are summarized in Table 18.1.

[Insert Table 18.1 here]

These include when to start in the primary sport, when to start in deliberate practice in the primary sport, and when to start in adult-orientated competition in the primary sport. They also include whether the child or coach's main intention should be to improve performance or have fun, whether the child should spend the majority of time diversifying across a number of sports or in the primary sport only, and whether more time should be spent in non-coach-led (also called unstructured) activity or deliberate play compared to coach-led activities. Researchers should examine the effect of each of these variables on the development of expert performance in sports in adulthood, rather than combining the variables into generic terms such as "early specialization" and "early diversification," to reveal which variables lead to expert performance in the primary sport in adulthood and/or are associated with negative youth sports outcomes (Baker et al., 2009). Currently, we do not know, for example, whether associations between "early diversification" and the development of expertise are a result of a delayed start age in deliberate practice in the primary sport and in adult-orientated competition, the child's intention during the early activity to have fun, diversification across a number of sports, or a greater amount of time spent in non-coach-led activity compared to coach-led activity.

One potential solution to the lack of consensus between researchers or practitioners as to the activities that children should engage in is to apply evidence-based principles from the motor learning literature. Several principles and theories of practice and instruction exist in books and literature reviews (e.g., Davids, Button, & Bennett, 2008; Ford & Williams, in press; Ford, Yates, & Williams, 2010; Farrow, Baker, & MacMahon, 2008; Hendry & Hodges, in press; Williams & Hodges, 2004, 2005) that can be applied by practitioners involved in developing expert performers of the future so as to increase chances of success. An example of an evidence-based principle that can be applied by practitioners to enhance skill acquisition is that of allowing learners to direct or have more control over how they practice, in terms of the order in which they practice skills and when they receive feedback and instruction (e.g., Chiviacowsky & Wulf, 2002; Hodges, Edwards, Luttin, & Bowcock, 2011 Keetch & Lee, 2007). Similarly, there is a significant body of research on motivation principles that can be applied by practitioners so as to promote long-term athlete involvement within a sport and a desire to practice over an extended period of time (e.g., Deci & Ryan, 2000; Scanlan, Russell, Wilson, & Scanlan, 2003; Vallarand, 2007).

Early Talent Identification

The early identification of talent is defined as the process of recognizing participants who are less than 12 years of age who have the potential to become elite performers so as to enter them into structured programs of deliberate practice and competition from that young age. This early talent identification allows sports organizations to focus their limited resources on a smaller number of individuals (Williams & Reilly, 2000). The arguments against early identification have been provided by researchers showing the lack of stability due to growth, maturation, and experience from childhood through puberty into adulthood that affect all of the physiological, anthropometrical, psychological, and skill attributes of expert performers (e.g., Abbot & Collins, 2002; see also Malina, 2001). Overly rigorous early talent identification leads to a very small "pool of talent" to choose from in late adolescence and adulthood, which probably serves to reduce the overall skill level of the sport. In addition, as detailed above, the success of structured, formal coaching programs at young ages has been questioned. Therefore, we recommend keeping as many children involved in the sport as possible, which increases the "pool of talent" to choose from in adolescence and adulthood. However, some relatively broad banding of youth athletes by age and skill level is necessary during this period to enable fair and equal play (American Academy of Pediatrics, 2001). Moreover, practitioners should attempt to limit the effects of a child's relative age by using alternative methods of grouping players by age, such as the NOVEM system described by Boucher and Halliwell (1991).

In recent times there have been a number of reports (e.g., Macur, 2008) of children and athletes being tested for candidate genes (e.g., ACE gene) that have been associated with sport performance in some studies. These tests are being used for talent identification in an attempt to identify individuals with the genes that predispose them to become expert in sport. Our review of the association between genes and sports' performance shows that at best there are conflicting findings between studies examining single candidate genes and that those studies so far show no association to "skill" in sport. The current evidence has led Ericsson (2003, 2007) to state that height and body stature may be the only inheritable phenotypes that are not drastically altered by experience, and that research on genetics is not currently advanced enough to provide definitive answers regarding the development of expertise in sport. Therefore, we do not recommend the use of testing for candidate genes as a means to select which children receive sport experience and which do not.

Summary

Somewhere in the world, the next Roger Federer and Tiger Woods may just be starting out on their journey through sports and life . Certain environmental factors will be necessary for success, whilst some genetic factors will likely influence that outcome. Researchers are still unclear, however, as to whether environmental factors are sufficient and whether genetics ultimately set the "ceiling" on performance (Davids & Baker, 2007). Certainly, some genetic endowments, such as height, stature, bone structure and muscle fiber, may favor an individual to participate in certain sports. Researchers examining the association between single "candidate" genes and sports performance have found mixed results, raising the possibility that these genes play at best a minor role in expert performance or are peripheral to that state. It is most likely that genetic research is not currently advanced enough for firm conclusions to be drawn. In contrast, long-term engagement in practice and other activities such as competition appears to lead to drastic adaptations and improvements in performance and its underlying attributes and mechanisms. Expert athletes have spent many hours, weeks, months, and years in these activities, often from childhood onwards. For the next Federer or Woods, they too will engage in large amounts of this type of activity across their development. The motivation and commitment of these and other individuals to continue engagement in these activities across this extended time may be as important as the activity itself. Practitioners should concentrate on creating optimal environments so as to give the many aspiring young athletes engaging in sport the best chance of becoming the next generation of sporting champions.

Acknowledgements

The second author would like to acknowledge the support of the Social Sciences and Humanities Research Council of Canada (SSHRC) in preparing this chapter.

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Figure 18.1.

General developmental pathways that have been associated with success in sport and their relative contributions of sport-specific deliberate practice and playful experiences within or outside the primary sport as a function of age

“Early specialization” (age, yrs)

5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21+

Primary sport deliberate practice

Primary sport competition

"Early diversification/play" (age, yrs)

5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21+

Several sports

Primary sport deliberate practice

Playful activity

Primary sport competition

“Mature-age specialization” (age, yrs)

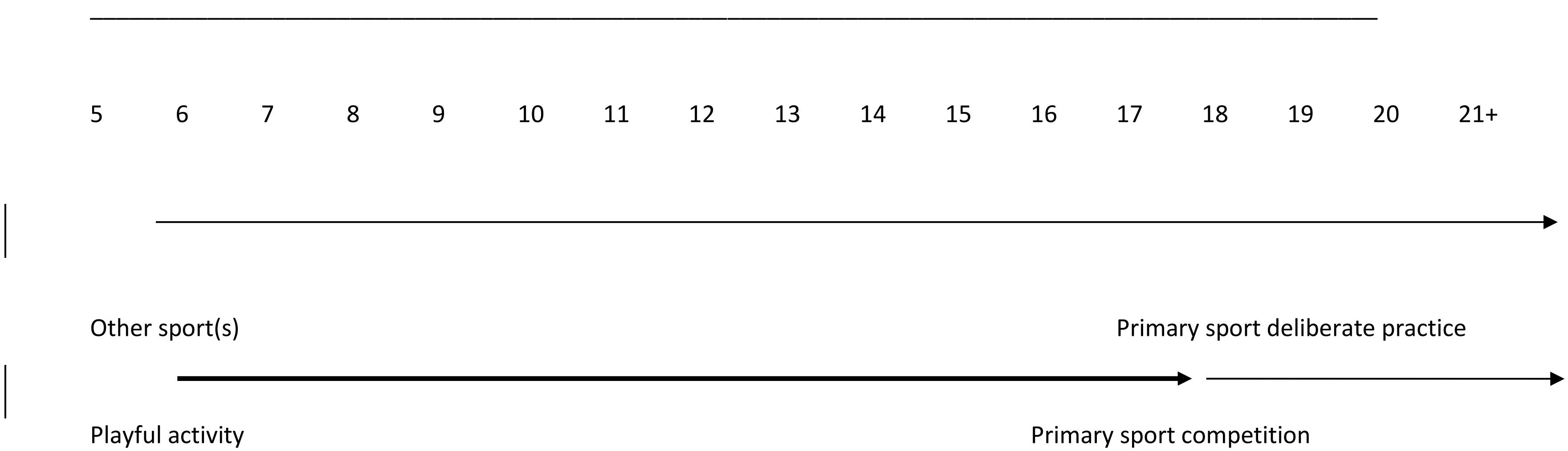

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Table 18.1.

Eight environmental factors that influence the development of expert performance in sport, whose occurrence can vary across time depending on the sport and country

1.	Start age in the primary sport
2.	Start age in sport-specific deliberate practice
3.	Start age in adult-orientated competition (e.g., matches, leagues, tournaments)
4.	Athlete's main intention during the activity (i.e., to improve performance or have fun)
5.	Coach's main intention during the activity (i.e., to improve performance or facilitate fun)
6.	Amount of primary sport-specific activity compared to activity in other sports
7.	Amount of non-coach-led activity compared to coach-led activity
8.	Age when access to "elite" coaching is sought