©Journal of Sports Science and Medicine (2003) **2**, 1-9
http://www.jssm.org

Review article

NURTURING SPORT EXPERTISE: FACTORS INFLUENCING THE DEVELOPMENT OF ELITE ATHLETE

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Received: 16 September 2002 / Accepted: 21 November 2002 / Published (online): 01 March 2003

ABSTRACT
The development of expertise in sport is the result of successful interaction of biological, psychological, and sociological constraints. This review examines the training and environmental factors that influence the acquisition of sport expertise. Research examining the quality and quantity of training indicate that these two elements are crucial predictors of attainment. In addition, the possession of resources such as parental support and adequate coaching are essential. Social factors such as cultural influences and the relative age effect are also considered as determinants of sport expertise. Although it is evident that environmental factors are essential to the acquisition of high levels of sport development, further research is clearly required.

KEY WORDS: Parents, coaching, practice, skill-acquisition.

INTRODUCTION

Researchers interested in identifying the factors that distinguish the exceptional from the ordinary performer have created numerous theories to explain the development of expertise. Since Francis Galton wrote the phrase 'nature and nurture' in 1874 scientists have used (and overused) this phrase to describe factors that interact to promote high levels of human achievement (i.e., expertise). Our current understanding of the relative contributions of genetic (nature) and environmental (nurture) factors suggests that a significant portion of the variation among individuals can be accounted for by 'heritability'. For instance, research from the HERITAGE family study has linked genetic factors to physical characteristics such as heart rate and blood pressure (Wilmore et al., 2001), as well as measures of aerobic performance (Pérusse et al., 2001). Perhaps more importantly, these findings suggest that the level of improvement due to training (i.e., trainability) is constrained by genetic factors. Lewontin (2000) uses the metaphor of the empty bucket to describe this approach to the relative contribution of genes and environment on development; specifically that genes determine the size of the bucket while the environment determines the contents.

Regardless of whether one completely supports this position or not (cf. Ericsson et al., 1993; Lewontin, 2000), environmental factors clearly play important roles in accounting for inter-individual variation. The purpose of this review is to examine the training and environmental factors related to acquiring high levels of sport proficiency.

Training Factors

It is perhaps not surprising that high levels of training or practice are required to attain expertise. Research on skill development clearly supports the relationship between training/practice and skill acquisition. Moreover, previous research has identified general rules that outline the progression from novice to expert in a given domain. These include the "10-year rule" (Simon and Chase, 1973) and the power law of practice (Newell and Rosenbloom, 1981).

The 10-year rule.

In a study of expertise in chess, Simon and Chase (1973) indicated that differences between the expert level players (grandmaster player) and lesser skilled players (master and novice players) were attributable to the ability to organize information in more meaningful "chunks" rather than the possession of a superior memory capacity. Based on this finding, the authors suggested that inter-individual variation in performance could be explained by quantity and quality of training. Since then, there have been no reliable differences found between expert and novice performers on static, physical capacities such as visual acuity, reaction time, or memory. However, consistent differences for domain-specific information-processing strategies have been identified, thus suggesting that these differences were the result of training or experience. Singer and Janelle (1999) summarized the characteristics that distinguish the expert as follows:

1. Experts have greater task-specific knowledge.
2. Experts interpret greater meaning from available information.
3. Experts store and access information more effectively.
4. Experts can better detect and recognize structured patterns of play.
5. Experts use situational probability data better.
6. Experts make decisions that are more rapid and more appropriate.

Evidence from perceptual/cognitive sports examined to date implies that in domains where experts and non-experts are distinguished by domain-specific, information-processing abilities, these skill differences are better accounted for by intense training rather than innate abilities. The logic behind this position is that while certain gross, general traits have been linked to genetic endowment (e.g., intelligence; Bouchard, 1997), the refinement of these traits into domain specific abilities (e.g., pattern recognition, strategic thinking) only occurs after years of intense training. Furthermore, there is no empirical support for the idea that there is a gene that predisposes an athlete to superior information processing that is only manifested in a single domain (e.g., a gene for soccer processing).

According to the "10-year rule," a 10-year commitment to high levels of training is the minimum requirement to reach the expert level. This "rule" has been supported in music (Ericsson et al., 1993; Hayes, 1981; Sosniak, 1985), mathematics (Gustin, 1985), swimming (Kalinowski, 1985), distance running (Wallingford, 1975), and tennis (Monsaas, 1985). The theory of deliberate practice (Ericsson et al., 1993) extends Simon and Chase's work by suggesting that it was not simply training of any type, but engagement in 'deliberate practice' that was necessary for the attainment of expertise. According to Ericsson et al. (1993), deliberate practice activities are forms of training that are not intrinsically motivating, require high levels of effort and attention, and do not lead to immediate social or financial rewards. Under deliberate practice conditions, experts develop specific skills that are required by their domain under conditions of high effort and concentration. The authors suggest that by continually modifying training activities so that optimal amounts of effort and concentration are required, future experts maximize physiological and cognitive adaptations.

The Power Law of Practice.

Research examining the accumulated effects of prolonged practice and the rate of learning indicates that performance increases monotonically (i.e., along a straight line) according to a power function. The power law of practice (Newell and Rosenbloom, 1981) states that learning occurs at a rapid rate after the onset of practice but that this rate of learning decreases over time as practice continues. An example of the power law of practice is presented in Figure 1, illustrating the data from a single subject in Koler's (1975) study on learning to read inverted text. In this study participants were required to read up to 165 pages of inverted text. The data indicate that learning of this task follows a power function. Further, researchers have indicated that this 'law' is present in all learning behaviors, from general tasks such as choosing the correct response in an array of choices (e.g., Seibel, 1963) to more particular activities such as rolling cigars (Crossman, 1959).

Central to the theory of deliberate practice suggested by Ericsson et al. (1993) is the *monotonic benefits assumption*. According to this assumption and in concordance with the power law of practice, a monotonic relationship exists between the number of hours of deliberate practice performed and the performance level achieved. However, Ericsson et al. (1993) argued that it was not simply the accumulation of training hours that lead to superior levels of performance. Training quality was also important. In a review of studies on skill acquisition and learning, Ericsson (1996) concluded that level of performance was determined by the amount of time spent performing a "well defined task with an appropriate difficulty level for the particular individual, informative feedback, and opportunities for repetition and corrections of errors" (pp. 20-21). Future experts create opportunities to prevent learning plateaus and perpetuate adaptation to higher amounts of training stress by continually modifying task difficulty.

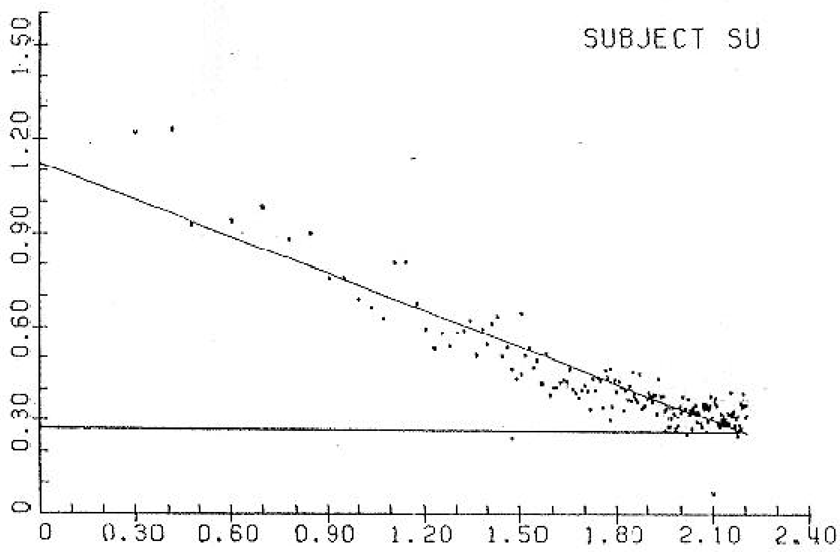

Figure 1. Log-transformed data from Kolers' (1975) study of learning to read inverted text. Copyright © 1975 by the American Psychological Association. Adapted with permission.

Data from the Ericsson et al. (1993) study of expert musicians supports the relationship between number of hours of deliberate practice and level of performance. Specifically, they found that expert level musicians spent in excess of 25 hours per week in deliberate practice activities (i.e., training alone) whereas less successful musicians spent considerably less time in deliberate practice (e.g., amateurs < 2 hours per week). These notable differences in weekly training accumulate to mark enormous divisions in practice after years of training. Experts accumulated over 10 000 hours in deliberate practice by age 20 while amateurs accumulated about 2000 hours at the same age. Similar relationships have also been found in chess (Charness et al., 1996).

Ericsson and colleagues have indicated that the theory also applies to expertise in sport (Ericsson et al., 1993; Ericsson, 1996). Researchers examining the application of the theory of deliberate practice to the domain of sport have investigated figure skating (Starkes et al., 1996), karate (Hodge and Deakin, 1998), wrestling (Hodges and Starkes, 1996), soccer (Helsen et al., 2000; Helsen et al., 1998), middle distance running (Young and Salmela, 2002), field hockey (Baker et al, in press-a; Helsen et al., 1998), basketball and netball (Baker et al., in press-a). Typically, the relationship between hours spent in sport-specific practice and level of attainment is consistent with the tenets of deliberate practice theory; expert athletes accumulated more hours of training than non-experts (Helsen et al., 1998; Starkes et al., 1996; Hodge and Deakin, 1998). Moreover, not only do experts spend more time overall in practice they also devote more time to participating in the specific activities deemed to be the most relevant to developing the essential component skills for expert performance (Baker et al., in press-b). For example, Baker et al. (in press-b) found that expert athletes from basketball, netball, and field hockey accumulated significantly more hours in video training, competition, organized team practices, and one-on-one coach instruction than non-expert athletes. In sum, differences between experts and non-experts on both quantity and quality of training are strongly supported in sport and other domains.

Environmental Factors Associated with the Attainment of Sport Expertise

While empirical evidence indicates that sheer quantity and quality of training are important variables in understanding how one attains the status of 'expert' in any field, there are significant environmental factors that also contribute to the development of exceptional performance.

Maturational Factors: The Relative Age Effect

The availability of essential resources, such as coaching and parental support, can significantly influence the ability to engage in the required amounts of high quality training. Another factor that appears to influence the acquisition of expertise is the relative age phenomenon. First demonstrated in the academic domain, the relative age effect refers to differences in age among children born in the same calendar year (Barnsley & Thompson, 1985). As in school, many sports group children by age to equalize evaluation and competition (Barrow & McGee, 1971). However, the presence of the relative age effect suggests that categorizing children by age can create training inequalities and reduced opportunities for younger children.

In sport the relative age effect was first discussed in ice-hockey where children are organized into leagues according to the calendar year. Barnsley, Thompson, and Barnsley (1985) conducted analyses of birth dates for players in the Ontario Hockey League (OHL), Western Hockey League (WHL), and National Hockey League (NHL) during the 1982-83 season. Month of birth for all players was then compared to the frequency of male births in Canada and data was arranged by birth quarter (Quarter 1: January-March, Quarter 2: April-June, Quarter 3: July-September, Quarter 4: October-December). Results revealed that the majority of players were born earlier in the year; NHL players were twice as likely and WHL and OHL players four times more likely to be born within the first quarter of the year than the last.

The prevalence of older players at the elite levels of hockey led to a follow-up study (Barnsley and Thompson, 1988) to examine minor hockey participation patterns and level of hockey participation at representative or house levels. Researchers compared birth quarters of players with the hockey league as a Mite (under 10), Peewee (ages 11-12), Bantom (ages 13-14), Midget (ages 15-16), Juvenile (ages 17-18), or Junior (ages 19-20) player. Findings showed that from Peewee through Juvenile, more players involved in hockey were born in the first quarter of the year. Moreover, players born earlier in the year were more likely to participate in hockey at the top tier levels compared to players born during the later months of the year. The relative age effect has been supported in other sports including Major League baseball (Thompson et al., 1991), Junior football (Barnsley et al., 1992), tennis and swimming (Baxter-Jones and Helms, 1994), and soccer (Dudink, 1994; Helsen et al., 1998; Verhulst, 1992).

Two main explanations have been offered to account for the relative age effect. Barnsley and colleagues (Barnsley and Thompson, 1988; Barnsley et al., 1985) hypothesized that older players were bigger, stronger, faster, and better coordinated than the younger players and thus experienced more success and rewards in hockey and were more likely to remain involved. Younger peers were thought to experience failure and frustration and withdraw from hockey. A second hypothesis proposed that older players were more likely to be selected to higher competitive representational teams where they would receive improved coaching, facilities, and ice-time when compared with their peers.

This second hypothesis has clear implications for the development of elite athletes given the necessity of resources in the attainment of expertise (Ericsson et al., 1993). Unfortunately, the organization of many sports and the disparity in skill level amongst same-aged youth facilitates the selection of older players to high-level training and resources while the potential of younger athletes can be overlooked. Research on the relative age effect suggests that the development of elite athletes is based in part on age differences and unequal access to training opportunities. Alternative methods of grouping children for competition and advancement in sport require examination.

The Role of Coaching and Instruction

As indicated above, one important consequence of the relative age effect is that targeted athletes often get access to better resources, including better instruction. Research is starting to show the distinct advantages of having access to an expert coach. A coach normally constructs a high percentage - in some cases 100 percent - of an athlete's practice time. The ability of the coach to devise an environment that fosters optimal learning thus becomes one of the most significant keys to athlete development.

Meticulous planning of practice is one hallmark of coaching expertise. Voss et al. (1983) found that expert coaches spent more time planning practices and were more precise in their goals and objectives for the practice session than their non-expert counterparts. This was a notable feature of legendary UCLA basketball coach John Wooden. Wooden spent more than an hour preparing for each practice, meticulously planning each detail so that players were always active, either engaged in drills or shooting free throws. No one was permitted to stand around watching (Wooden, 1988).

The emphasis that deliberate practice theory places on the quality of training led to examinations of the microstructure of practice in sport. Recent studies have used time-motion analysis and practice evaluation questionnaires to analyze practice environments in wrestling, figure skating and field hockey (e.g., Starkes, 2000; Deakin and Cobley, 2001). Recently, a time-motion analysis was completed on hockey players of three different levels: Junior A, Junior C, and Midget AAA. The structure of practices was comparable across all three levels: 22% of time was spent on instruction, 30% active in drills, and 48% not active (Starkes, 2000). The fact that virtually one-half of practice time can be considered "not active" is telling.

Videotaped practices of Olympic, club, and high school wrestlers revealed that all three groups were active for 77% of the scheduled practice time. One surprising result was the rather limited amount of time wrestlers spent sparing. Full sparing was regarded by each group as being the most important activity for improvement, yet only 8.06% of practice time for Olympic wrestlers, 8.48% for club wrestlers, and 2.2% for high school wrestlers was spent sparring (Starkes, 2000).

Time-motion analysis of figure skating practices revealed that elite skaters made better use of time on the ice than less accomplished skaters (Starkes, 2000). However, even the elite skaters, like all the athletes surveyed, spent more time working on well-learned elements rather than on the development of new skills. Although skaters saw the acquisition and mastery of new jumps as critical for future performance success, the bulk of practice time was spent on jumps that were already well established in their repertoire. Starkes (2000) concluded that coaches trying to increase time in deliberate practice activities were well advised to maximize the time they already had rather than look for more practice hours.

In a study of coaching expertise in volleyball, Cobley (2001) found that athletes were active in drills over 92 percent of the scheduled practice time and the intensity level was equivalent to that faced in matches. The emphasis in practice was to engage the players in drills that closely simulated game conditions and that had a high probability of occurring against a future opponent. Cobley (2001) concluded that the expert volleyball coach played a critical role in structuring an optimal practice environment that exemplified the tenets of deliberate practice. This corresponds with Wooden's philosophy of an optimal practice environment: "In every facet of basketball, we work on pressure. The opponent provides that during the game. I tried to provide it in practice with drills that recreated game conditions" (Wooden, 1988, p. 113).

In addition to a coach's ability to maximize practice time, the expert coach also possesses domain specific knowledge that is essential to fostering improvement, particularly as the athlete advances in skill level. Rutt-Leas and Chi's (1993) examination of novice and expert swimming coaches supported these assertions. The coaches observed underwater video recordings of four swimmers of different skill levels and were then asked to analyze the strokes and to provide instruction. While novice coaches offered a somewhat superficial analysis using vague descriptions, expert coaches were very precise in their assessment and specific in their recommendations for improvement. Expert coaches had the ability to extract more from the information presented and were able to provide fundamentally better solutions to perceived problems. Rutt-Leas and Chi (1993) concluded that the expert coach displayed the same kind of domain specific expertise that has been documented in other fields.

Bloom et al. (1999) hypothesized that in high-strategy team sports, this domain specific expertise of the coach manifests itself in tactical knowledge. Bloom et al. (1999) extended earlier work by Tharp and Gallimore (1976) by creating the Revised Coaching Behavior Recording Form and using it to analyze the practices of Fresno State basketball coach Jerry Tarkanian over the course of the 1996-1997 season. Most significantly, the "instruction" category utilized by Tharp and Gallimore (1976) was divided into three separate categories- tactical, technical and general instruction. Bloom et al. (1999) found that 29 percent of Tarkanian's observed behaviors consisted of tactical instruction-more than twice that of technical instruction. They hypothesized that at the elite level, players already had a sound grasp of the fundamentals, or were expected to develop them in their own time, which freed Tarkanian to focus on preparing for upcoming opponents. Bloom et al. (1999) concluded that coaches at the elite level spend most of their time on the cognitive or tactical elements while coaches of beginners and intermediates focus more on the fundamentals of the sport. They also suggested that non-expert coaches might not be able to impart a large amount of tactical knowledge because of their own limitations in this regard.

An important question to consider is at what age should athletes seek out expert coaching. Early studies focussing on the specific requirements of working with younger and less technically proficient athletes (e.g., Bloom, 1985; Smith et al., 1979) proposed that in the early stages of development athletes require primarily technical instruction to develop proper fundamentals, along with a high degree of support and praise to encourage continuing participation in the sport. They described an important part of the coach's role in the early years as being kind, cheerful, and caring. Only when athletes were older and more highly skilled would a coach require sophisticated knowledge and advanced qualifications.

Recent work by Côté and Hay (2002) supported these assertions and suggested that while advanced coaching qualifications were deemed necessary in the later stages of development, coaches working with children at the initial involvement stage needed enthusiasm and facilitation skills above and beyond any technical expertise in the sport. Clearly, both the practice structure and the domain-specific knowledge of coaches are highly relevant to the progression and development of athletes in sport.

Parental Influences

Retrospective research with elite performers over the last 30 years has revealed the importance of parental support for the development of expertise. Bloom and colleagues (1985) interviewed talented performers and their families in the fields of music, art, science, mathematics, and athletics and created a model of talent development with three stages: the early years, the middle years, and the later years. Each stage is characterized by shifting demands on the child and parents. In the early years parents were found to take a leadership role where they provided their child with the initial opportunity to participate in the domain and sought out their child's first formal teacher. Here parents also encouraged and supported their child's learning and were often involved directly in lessons and practice. For the child athlete, the emphasis in these years was on having fun and enjoying learning the basics skills. The transition to the middle years was characterized by a greater commitment of both parents and the athletes to the athletic domain. Parents were found to assume a leadership role, seeking more accomplished teachers for their child while also devoting more time and resources to the activity. It was also during these years that the child's talent often dominated the family's routine. During the later years, parental involvement decreased as the performer took greater control of the decision-making process with regards to their future career. Yet, parents continued to provide support in a background role, as providers of not only financial support but also emotional support. According to Sloane (1985) of greatest importance was that parents offered a "nurturant, understanding environment for their child to retreat to, if necessary" (p. 470). Sloane's (1985) analysis revealed how parents can ease the demands imposed on their child by the demands of training (e.g., reduction of psychological stress by providing a supportive atmosphere).

Côté (1999) furthered the work of Bloom (1985) by developing a sport-specific model of talent development. Côté's work with families of elite Canadian rowers and tennis players lead to the idea that talent development in sport is encompassed by sampling years (ages 6-12), specializing years (ages 13-15), and investment years (ages 16+). Similar to Bloom's model, parental roles changed with the differing demands of each stage. During the sampling years parents provided their children with the opportunity to sample a wide variety of sports. Côté noted that while parents encouraged participation in sport, the choice of sport was not important. In essence, parents played a leadership role during the sampling years by initiating sport involvement. The specializing years saw parents in a facilitative role where they made financial and time commitments to their child's sport, supporting access to better coaches, equipment, and training facilities. Finally, in the investment years parents played strictly an advisory and supportive role as the athlete committed to a higher level of training and competition. Parents maintained a high interest in their child's sport and were essential in providing emotional support to help their child overcome setbacks, such as injuries, pressure and fatigue as well as financial support for training. This high level of emotional support during stressful times is a central characteristic of the investment years.

The research of Bloom (1985) and Côté (1999) demonstrates how parental support helps expert performers and elite athletes deal with the demands of the sustained deliberate practice necessary to reach an expert level of performance. The two models demonstrate the evolving role of parents from that of a leadership role, to that of a general supportive role. Athletes unable to access certain emotional and financial resources face a qualitatively different road in order to accumulate the high levels of practice necessary for expert performance.

Cultural Factors

Cultural factors are a significant and often overlooked component of the environmental equation and development of expertise. The importance that a country or society places on a particular sport can have a dramatic influence on any success achieved. For instance, in Canada, where there is a long and storied history of ice hockey, the game has become an integral component of the national identity (Russell, 2000). Ice hockey has been featured on the national television network each Saturday evening for more than 50 years. A large number of the nation's heroes, both past and present, are ice hockey players. The northern climate and numerous lakes and rivers provide opportunity to play outdoors for considerable portions of the year, and public money has been used to build a large network of ice hockey arenas throughout the country. An extensive club system allows children to get involved in the game at a very young age, and to continue playing right through adolescence into adulthood. In fact, Canada has 3.5 times more children playing ice hockey than Russia, Sweden, Finland, the Czech Republic, and Slovakia combined (Robinson, 1998). Given these factors, it seems hardly surprising that Canada has enjoyed success internationally in the sport and produced a great number of the game's stars.

In Austria we can find the same factors at work, but for alpine skiing (Coakley, 2000). Similarly, the sporting culture in Nordic countries places a high value on cross-country skiing. The natural environment in these nations, combined with the public interest and adulation that is given to ski heroes, provides fertile ground for developing skiing expertise. The notion that Canadians have a genetic predisposition for hockey, or that there exists a Nordic ski gene is not supported empirically; yet the search for genetic answers is often what occurs when certain groups start to dominate a sport. For example, the dominance of American basketball by Black athletes, and the recent pre-eminence of Kenyans in middle and long-distance running events has sparked the belief in a genetic advantage, which often ignores the various cultural and psychological factors at work (Hamilton, 2000).

In addition, the sports that Black America have come to dominate, consisting primarily of basketball, football, and track and field, reflect a cultural emphasis made evident by the support these sports receive through the public school system. Black athletes have access to coaching, facilities, and competition in publicly funded school sports to a much greater extent than for traditionally more exclusionary endeavors. Sports taught primarily in a country club setting, like golf and tennis, provide a significant barrier to entry for Blacks, as private clubs have historically denied membership to certain minority groups for economic and social reasons (Wiggins, 1997). While the social factors that influence the acquisition of high levels of sport proficiency are only briefly presented here, it is vitally important to acknowledge that environmental constraints on expertise can be broad (e.g., cultural factors) and/or narrow (e.g., family or coaching factors).

CONCLUSION

Although there is a wealth of information regarding the environmental and training factors that influence the acquisition and maintenance of expert performance, our understanding is far from complete. Future research is needed to address areas of limitation, such as the interaction between training and genetic predispositions or the balance between training stress and recovery. Further examinations of the resources that constrain the development of expertise are also essential. Current examinations from our laboratory with triathletes, ice-hockey players, soccer players and expert coaches are examining these and other issues.

ACKNOWLEDGEMENTS

Support for the writing of this manuscript was given by a doctoral fellowship to the first author from the Social Sciences and Humanities Research Council of Canada (SSHRC Fellowship # 752-2001-1491).

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