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20 years later: deliberate practice and the development of expertise in sport

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Twenty-one years ago, Ericsson, Krampe and Tesch-Romer published their seminal work expounding the notion of deliberate practice in explaining the development of expertise. This concept has since become extremely influential in the fields of sport psychology and motor learning. This review evaluates current understanding of deliberate practice in sport skill acquisition with an emphasis on the role of deliberate practice in distinguishing expert athletes from non-experts. In particular, we re-examine the original tenets of Ericsson et al.'s framework to (a) evaluate the sport-related research supporting their claims and (b) identify remaining research questions in this area. The review highlights the overall importance of deliberate practice in the development of expert sport performers; however, our understanding is far from complete. Several directions for future research are highlighted, including the need for more rigorous research designs and statistical models that can evaluate changes in developmental and contextual factors across development. Finally, we advocate for a more thorough understanding of the implications of a 'deliberate practice approach' for coaching science.

Keywords: expertise; skill-acquisition; practice

Researchers continue to debate the elements essential for developing expertise (e.g. Baker & Davids, 2006; Tucker & Collins, 2012). However, most agree that expert-level performance is not possible without a long-term commitment to training and practice (e.g. Howe, Davidson, & Sloboda, 1998; Starkes, 2000). Twenty-one years ago, psychologist Anders Ericsson introduced the concept of deliberate practice (Ericsson, Krampe, & Tesch-Römer, 1993), proposing that it was not simply training of any type, but a prolonged engagement in 'deliberate practice' that was necessary for the attainment of expertise. Deliberate practice refers to activities that require cognitive or physical effort, do not lead to immediate personal, social or financial rewards, and are done with the purpose of improving performance. Although the concept of deliberate practice was advanced using data from musicians, Ericsson and his colleagues have indicated that it applies to the acquisition of expertise in all areas of human endeavor, with the domain of sport often used to exemplify the relationship between types of practice and attainment. In particular, they proposed that between-group differences in skilled performance (e.g. expert compared to less-expert groups) are predominantly related to differences in the amount of deliberate practice accumulated over long periods of time.

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The Ericsson et al. (1993) study has been extremely influential. Current citation counts list 3812 citations on Google Scholar and 1376 on Web of Science (as of 20 September 2013). Moreover, and perhaps more significantly, the deliberate practice concept has been widely embraced by the lay public, as reflected in the recent international bestselling non-fiction books *Outliers* (Gladwell, 2008), *Talent is Over-Rated* (Colvin, 2008), *The Talent Code* (Coyle, 2009) and *Bounce* (Syed, 2010), among others (however, see Epstein, 2013) for a contrary position. Prior to the emergence of such popular texts, researchers in sport psychology and motor learning had been quick to embrace the concept, testing its tenets in a range of sports (see Table 1). While these studies have had varying degrees of success in establishing the fundamental principles underpinning the concept of deliberate practice, a consistent finding has been the relationship between cumulative training and expertise.

In light of two decades of psychomotor research on the deliberate practice framework, the purpose of this review is to provide a summary of current evidence concerning this concept as it applies to sport and to identify gaps in our understanding that can serve as stimuli for future research.

A brief synopsis of the Deliberate Practice Framework (DPF)

In essence, deliberate practice is a highly effortful and structured activity with the explicit goal of improving performance (as compared to work or play) through specific tasks designed to overcome current levels of weakness. The acquisition of sufficient deliberate practice to achieve expertise in any domain requires the developing performer to navigate through three types of constraints.

(1) *Motivation*. Since the acquisition of expertise requires an extended time (typically > 10 years), the DPF notes that developing performers must establish methods to sustain and maximize motivation for long periods. Given the goal of deliberate practice (i.e. improving current levels of performance), performers must be primarily motivated to engage in practice to improve performance and not for some other reason (e.g. enjoyment, social interaction). Ericsson et al. (1993) noted that during early phases of development, practice initiation and the establishment of regular patterns of practice in young athletes may be driven by their parents, but over time, individuals internalize these practices to the point that 'motivation to practice becomes so closely connected to the goal of becoming an expert performer and so integrated with the individual's daily life that motivation to practice, per se, cannot be easily assessed' (p. 372).

(2) *Resources*. As noted above, parents and guardians are seen as essential resources for the progression of aspiring individuals in the DPF, having a key role in encouraging and promoting practice and monitoring performance during early phases of development. Moreover, the parents' interest is important for aiding the transition from initial forms of playful involvement to more structured forms of deliberate practice. Perhaps most importantly, parents provide much of the financial resources to secure facilities for practice (e.g. access to tennis courts for tennis players or ice rinks for skaters and ice-hockey players). Incredibly, a recent examination of development of elite adolescent ice hockey players put the financial cost as high as $30,000 per year (Campbell & Parcels, 2013), highlighting how access to resources (financial and otherwise) can have a limiting role on opportunities for expertise development.

Table 1. Summary of studies examining quantities of cumulative deliberate practice in sport.

Source	Skill/Sport Examined	Groups (*n*)	Hours of Deliberate Practice ± SD	Reporting Period	Methodological Notations*	Statistical Notations
Baker et al. (2003a)	Decision-making in basketball, netball, field hockey	Expert (15)	3939 ± 1770	Childhood to national team	All sport-specific training consider DP; no non-expert comparison	No comparison to non-experts
Baker et al. (2003b)	Decision-making in basketball, netball, field hockey	Expert (15) Non-expert (13)	4885 ± NR 3168 ± NR	Career to 20 years of age	Sum of organized training, video training, individual instruction with coach, practice alone, weight training and aerobic training	Experts had more organized training and individual instruction with coach than non-experts
Baker et al. (2005)	Ironman Triathlon	Front of pack (9) Middle of pack (9) Back of pack (9)	12,558 ± 3581 6196 ± 3425 4123 ± 2288	Career to date	All sport-specific training considered DP	Front of the pack reported more training than middle and back of the pack athletes
Berry et al. (2008)	Decision-making in AFL Football	Expert (17) Near-expert (15)	4185 ± 1461 3223 ± 927	Before entering AFL	Structured activities considered DP	Experts differed from near-experts
Catteeuw, Helsen, Gilis, and Wagemans (2009)	Soccer Refereeing	Int. Referees (7) Nat. Referees (20) Int. Assistant Referees (9) Nat. Assistant Referees (18)	5325 ± 1926 5277 ± 2155 4987 ± 1439 5417 ± 1695	Career to date	All referee training considered DP	No differences between referees and assistant referees. Skill was predicted by accumulated hours in DP

Table 1. (*Continued*)

Source	Skill/Sport Examined	Groups (*n*)	Hours of Deliberate Practice ± SD	Reporting Period	Methodological Notations*	Statistical Notations
Duffy et al. (2004)	Darts	Professional – men (12) Amateur – men (12) Professional – women (6) Amateur – women (6)	12,839 ± 7780 3270 ± 2916 6491 ± 3299 1612 ± 1430	15 years into career	DP is solitary practice and practice with a partner combined	Professional players reported more DP than amateurs. No gender differences
Ford and Williams (2008)	Soccer	Soccer (NR)	4645 ± 2146	Career up to signing pro contract	All soccer activity considered DP	No between group comparison
Helsen et al. (1998)	Soccer	International (17) National (21) Provincial (35)	9332 ± NR 7449 ± NR 5079 ± NR	18 years into career	All sport-specific training considered DP	Significant differences between skill groups
	Field Hockey	International (16) National (18) Provincial (17)	10,237 ± NR 9147 ± NR 6048 ± NR	18 years into career	All sport-specific training considered DP	Significant differences between skill groups
Hodges and Starkes (1996)	Wrestling	International (24) Club (17)	5882 ± NR 3571 ± NR	10 years into career	All sport-specific training considered DP	
Hodges et al. (2004)	Triathlon	Females – Young (17) Males – Young (15)	5776 ± 4484 7260 ± 4259	Career to date	Six sport-specific activities considered DP; no expert comparison groups	No between group tests

Table 1. (*Continued*)

Source	Skill/Sport Examined	Groups (*n*)	Hours of Deliberate Practice ± SD	Reporting Period	Methodological Notations*	Statistical Notations
	Swimmers	Females – Young (28) Males – Young (20)	6001 ± 2659 7516 ± 3739	Career to date	Six sport-specific activities considered DP; no expert comparison groups	No between group tests
Law et al. (2007)	Gymnastics	Olympic (6) International (6)	18,835 ± 2936 6686 ± 2198	At 16 years of age	All sport-specific training considered DP	Olympic gymnasts performed more DP than international group
Moesch et al. (2011)	Varied	Elite (99) Near-elite (76)	6334 ± NR 5205 ± NR	Up to 21 years of age	Sport-specific practice hours	Elites performed more DP than near-elites
Roca, Williams, and Ford (2012)	Soccer	High-performing (16) Low-performing (16) Recreational (16)	5947 ± 1470 4564 ± 769 2670 ± 1075	Up to 18 years of age	All soccer-activity considered DP	Group differences at all levels
Soberlak and Côté (2003)	Ice Hockey	Elite (4)	3072 ± NR	Career to 20 years of age	DP defined as training designed to improve performance	No comparison group
Weissensteiner et al. (2008)	Cricket	Skilled-U15 (21) Skilled-U20 (18) Skilled-adult (13) Unskilled-U15 (20) Unskilled-U20 (20) Unskilled-adult (10)	2045 ± 1620 3402 ± 2505 7273 ± 3585 656 ± 316 1856 ± 1982 3140 ± 1657	Career to date	DP defined as organized cricket-specific activities	Skilled greater than unskilled for all levels of development

Table 1. (*Continued*)

Source	Skill/Sport Examined	Groups (*n*)	Hours of Deliberate Practice ± SD	Reporting Period	Methodological Notations*	Statistical Notations
Young, Jemczyk, Brophy, and Côté (2009)	Athletics Coaching	National (18) Provincial (10) Senior club (19) Local (24)	12736 ± 6504 9116 ± 9096 3875 ± 3642 2105 ± 1903	Career to date	All coaching-specific interactions considered DP	National coaches engaged in more DP than senior, local coaches; provincial engaged in more DP than senior and local.
Young and Salmela (2010)	Middle Distance Track	National (10) Provincial (24) Club (14) National (10) Provincial (24) Club (14)	3113 ± NR 2965 ± NR 2445 ± NR 638 ± NR 663 ± NR 577 ± NR	7 years into career	(a) All sport-specific training considered DP	No significant differences between groups
					(b) Used DP metric based on Young and Salmela (2002)	No significant differences between groups

Note: Summary was limited to studies published in peer-reviewed English language journals. *= the variables used by the authors to calculate DP for comparison to other studies in the table. NR = not reported.

(3) *Effort*. Effort constraints focused on two elements: the first dealt with the need for attention during practice; the second with the need to balance effortful training with appropriate time for rest and recuperation. In the first instance, Ericsson et al. (1993) discussed the benefits of maintaining attention during practice, advocating that it had a crucial role in promoting continued adaptations and improved performance. Nonetheless, because deliberate practice requires high levels of cognitive and physical effort, optimal training adaptations require a balance between training effort required to move the performer to the next level of skill and the rest required to recuperate from this high level of training effort. Ericsson et al. argued that there was a threshold to the amount of deliberate practice an individual could perform, after which additional time led to decreasing benefits such as increased risk of injury or burnout. Importantly, they also argued that the optimal daily level of deliberate practice could be increased over time as the developing performer became more capable of handling training stress.

In the following section, we consider the specific predictions made by the DPF as first outlined by Ericsson and colleagues in 1993.

Predictions of the DPF

Ultimately, Ericsson et al. held a central position, which was that 'adult elite performance, even among individuals with more than 10 years of practice, is related to the amount of deliberate practice' (1993, p. 373). This notion will be revisited later in the review, but at this point we explore a series of supporting predictions about various elements of expertise acquisition that are helpful for exploring the subtleties of the DPF. Below we consider each of these predictions and their evidence base, with particular focus on sport and psycho-motor expertise studies since 1993.

Developmental history 1: past amount of deliberate practice is directly related to current performance

For over a century, researchers (e.g. Bryan & Harter, 1897; Newell & Rosenbloom, 1981) have emphasized the strong, positive relationship between time spent in practice/training and level of skill development. Although researchers have debated the most appropriate mathematical representation of this relationship (c.f. Newell, Liu, & Mayer-Kress, 2001; Newell & Rosenbloom, 1981), few would argue the primacy of training to the development of elite performers. The DPF is grounded in the *monotonic benefits assumption*, a proposition whereby the 'the amount of time an individual is engaged in deliberate practice activities in monotonically related to that individual's acquired performance' (Ericsson et al., 1993, p. 368).[1]

Ericsson (1996) concluded that by continually modifying the level of task difficulty through deliberate practice, experts can prevent learning plateaus and perpetuate adaptation to higher amounts of training stress, and, therefore, higher levels of performance. Having access to informative feedback from coaches (Côté, Erickson, & Duffy, 2013) and opportunities for repetition allow the performer to master skills more easily and progress more quickly.

Deliberate practice studies in sport have consistently revealed that experts spend more time overall in training. For example, of the 17 sport studies summarized in Table 1 that have performed between-group analyses to compare expert and less-expert performance groups, only one study (Young & Salmela, 2010) failed to demonstrate significant group differences for global totals of practice. Not only do experts typically invest in greater amounts of deliberate training overall, but studies have demonstrated that they devote more time to participating in the specific activities most relevant to developing the essential component skills for expert performance (Baker, Côté, & Abernethy, 2003b; Deakin & Cobley, 2003; Ericsson et al., 1993). For example, Deakin and Cobley (2003) reported that elite figure skaters spent more time practicing the more advanced technical aspects of performance such as complex jumps and spins than competitive or test skaters. Similarly, Baker et al. (2003b) found that expert athletes from basketball, netball and field hockey accumulated significantly more hours in video training, organized team practices and one-on-one coach instruction than non-expert athletes. Interestingly, Young and Salmela (2010) found no significant differences between national, provincial and club level middle-distance runners across the first seven years of a career using measures representing overall sport training. However, analyses for cumulative measures in specific activities proved significant, with large effect sizes attributed to 'weights for endurance', and medium effects attributed to 'technique training' and 'work with a coach'. Runners who eventually attained higher performance accumulated more technique training and work with a coach after year one, year three and year five, and amassed more endurance weights after three years and onwards, compared to runners who attained lower performance groups. These findings, along with others (e.g. Soberlak & Côté, 2003), suggest that specific types of training may be important at particular periods of development. Young and Salmela (2010) commented that, compared to less-experts, experts may not always do more of everything, rather, they may reliably 'do a lot more of the little things' (p. 86) which might be dismissed as peripheral or add-on training by less-expert athletes.

Developmental history 2: deliberate practice starts at low levels and increases slowly over time

Sport studies that have reported practice hours over time have indicated a gradual increase in the hours of deliberate practice per week as the athlete develops (Starkes, 2000). On the one hand, this trend is predictable, reflecting the developing performer's adaptation to previous training stress (see Selye, 1956). On the other hand, however, these data consistently suggest a constant pattern of increase over time (e.g., see Figure 1 in Starkes, 2000), which may represent a 'hard limit' to the human body's ability to adapt to higher levels of training stress. For the purpose of the current manuscript, we attempted to update Starkes' (2000) figure which plotted increases in weekly practice as a function of years into one's career. Unfortunately, we found this exercise of comparing across studies difficult since some have reported weekly training hours by years into career (e.g., Baker, Côté, & Abernethy, 2003a; Hodges & Starkes, 1996), while others have reported them by age (Law, Côté, & Ericsson, 2007), while still others have reported cumulative practice by age (e.g., Berry, Abernethy, & Côté, 2008; Moesch, Elbe, Hauge, & Wikman, 2011) or career stage (e.g., Hodges, Kerr, Starkes, Weir, & Nananidou, 2004; Weissensteiner, Abernethy, Farrow, & Muller, 2008). Comparing across studies is also challenging because hours of training per week (or per year) have typically been presented as mean values without corresponding measures of variability (e.g. Hodges & Starkes, 1996; Starkes, 2000). Overcoming these limitations will be important for understanding the rate at which high quality training can be increased across development, information that would be invaluable for coaching practice.

Habits of elite performers 1: the highest improvement in performance is associated with largest amounts of deliberate practice

Surprisingly, even though the proposition above seems most readily examined in an experimental setting, there have been few examinations of its validity. To be sure, there have been examinations of level of attainment relative to amount of deliberate practice, which have been very consistent in indicating that total amount of deliberate practice is highly correlated with attainment. However, these correlative studies, which have exclusively been based on retrospective-longitudinal designs, do not necessarily support the conclusion that deliberate practice results in the greatest improvement. A hallmark of the DPF is that deliberate practice is the most effective form of training/involvement, and that participation in this form of training should be explicitly linked to performance improvement. This premise can be studied by examining how present performance markers regress upon amounts of current deliberate practice, while statistically controlling for earlier career performance (Plant, Ericsson, Hill, & Asberg, 2005). Such an approach, however, has not yet been adopted in sport research, nor have prospective experimental research designs been employed to exact the effects of deliberate practice (DP) on performance improvements.

Habits of elite performers 2: periods of deliberate practice should be of limited duration with rest periods in between

Due to the increased physical and mental stress associated with deliberate practice, an adequate balance must be maintained with the rest and recuperation necessary for system adaptation. With this in mind, instructors, coaches and educators, either consciously or implicitly through trial and error, have developed sophisticated models to reflect this need for balance between training stress and recovery. In sport, for example, the concept of periodization has become the principal model for managing training stress and recovery in sport. The central aim of this approach is to maximize athlete adaptation to training stress while reducing the likelihood of burnout or plateaus in performance (e.g. Bompa, 1999). Although there has been limited work in this area in the sport domain, Baker, Côté, and Deakin's (2005) examination of training design among expert and non-expert triathletes showed that the design of experts' training suggested a more optimal balance between periods of high training stress and decreased periods of reduced stress to facilitate adaptation and recovery (i.e., the ratio between training stress and rest was more balanced as reflected in high periods of training stress followed by low periods).

Quality of various activities: deliberate practice would be rated very high on relevance for performance, high on effort and comparatively low on inherent enjoyment

According to the DPF, deliberate practice represents a very select class of practice activities that are most effective for performance acquisition. Ericsson et al. (1993) defined these select activities as being 'very high on *relevance* for performance, high on *effort*, and comparatively low on inherent *enjoyment*' (p. 373, emphasis added), especially relative to other domain-related activities, and relative to active leisure or sleep. They surveyed musicians' perceptions according to these dimensions – relevance, effort and enjoyment – and found that 'solo practice' best captured the qualities of deliberate practice according to these dimensions among instrumental musicians. Sport researchers followed suit, asking athletes to rate a repertoire of training activities to define an exclusive set of deliberate practice activities (Helsen, Starkes, & Hodges, 1998; Hodges & Starkes, 1996; Kallio & Salmela, 1998; Starkes, 2000; Starkes, Deakin, Allard, Hodges, & Hayes, 1996; Young & Salmela, 2002). Results using this retrospective rating protocol have shown that, in sport, it has proven important to separate 'effort' into 'physical effort' and 'mental concentration', resulting in four activity rating dimensions. Furthermore, athletes' retrospective ratings of deliberate practice show that the most relevant and effortful activities are perceived as the most enjoyable in which to participate, a finding that does not fit well with the original definition of deliberate practice for music.

Ericsson's (1996) explanation of this discrepancy with enjoyment is that sport practice is inherently social and it is this social aspect that individuals find enjoyable, as opposed to the practice itself. In response, Starkes (2000) pointed out that the social argument may be flawed for it fails to explain why ball sport players, wrestlers and figure skaters working entirely alone on technical skills continued to rate this activity as highly enjoyable. Ericsson has also expressed concerns that athletes tend to rate the consequences (e.g. increased fitness, improved performance, bio-psychological states such as the 'runner's high'), rather than the actual enjoyment they perceive while doing the activity. Athletes may also be inflating their enjoyment ratings because they have come to internalize and integrate the discomforts of intense training to valued aspects of the self (e.g. outcomes such as improved fitness/performance).

Confidence in using participants' ratings to determine deliberate practice is important, considering that Ericsson et al. (1993) and others (e.g. Young & Salmela, 2010) advocated using these ratings in an *a priori* fashion to determine the activities that would subsequently comprise the deliberate practice 'metric' for enumerating career-span training amounts. Yet it appears that the construct validity of the enjoyment dimension does not hold equally in sport and music. Moreover, there are concerns about the reliability of these dimensions (Young & Starkes, 2003) and that enjoyment level is influenced by when ratings data are collected (i.e. time since practice). For example, Hodges et al. (2004) showed that although practice is 'generally' viewed as enjoyable, specific practice activity ratings sampled immediately following practice are less so. If the quality of deliberate practice is to be judged based on dimensions of relevance, enjoyment and physical/mental effort, more research is needed to understand the reliability and validity of activity ratings.

In the academic domain, Plant et al. (2005) found that 'solo study' represented the highest-quality deliberate practice among college students. Discussions of quality deliberate practice in this case were not tied to students' ratings, but were characterized according to the operational definition of one particular study time measure – students' choice of a quiet, solitary environment with few distractions. Investigators proposed that time spent in such an environment would optimize learning. Analyses indicated that solo study had predictive validity, proving to be most significantly associated with students' grade point averages, after controlling for prior performance conditions and quantity of study time. In fact, sheer quantity of weekly study time was a non-significant predictor of academic performance, lending support to the notion that higher-quality metrics be used when explaining the influence of deliberate practice on performance. Although higher-quality metrics for deliberate practice are more individual in music and academia, solo practice is unlikely to be the plausible discriminating metric in many sports, particularly sports where ultimate performance is enacted in a team setting.

Future research in sport should seek to define and isolate metrics of higher-quality deliberate practice that are relevant to the performance domain before submitting practice data to between-group analyses. In an effort to remedy concerns about the reliability of retrospective DP activity ratings, Coughlan, Williams, McRobert, and Ford (2013) recently employed a novel paradigm where they collected *in situ* ratings of Gaelic football players' practice activity. In a laboratory setting, investigators first confirmed that the practice trials in which experts and intermediates engaged had indeed improved performance (i.e., they ensured relevance of the practice using pre-to-post analyses and retention tests). When offered free choice of what they wished to work on, expert players selected a practice schedule whereby they more frequently trained a skill in which they were personally weaker, than a skill in which they were stronger; the opposite was true for intermediate-level players. Furthermore, experts more frequently self-selected a schedule comprising random practice trials (indicative of heightened investiture of mental effort as one shifted between different skills during training) than intermediates. Importantly, while they spent relatively more time working on their weaknesses, experts' in situ ratings for their practice were less enjoyable and more effortful than intermediates' reports, results that are in line with Ericsson's early definition of DP. This novel test paradigm may prove to be a complementary if not critical methodological advance for resolving debates over the defining dimensions and high-quality conditions of DP in sport.

In the following sections we highlight remaining general questions for researchers in this area and propose several directions for future research.

Remaining questions

Q1. Does practice need to be deliberate?

As noted earlier, the notion that time spent in structured forms of training is effective in promoting skill development is almost universally accepted. However, there is debate about the value of other forms of training (c.f. Abernethy, Farrow, & Berry, 2003; Ericsson, 2003). Below we examine evidence regarding the value of other forms of training, besides deliberate practice, on the acquisition of expertise.

Play and unstructured training

Although play is often described as having no readily observable immediate benefits (Ericsson et al., 1993), it has been defended as having an important function in children's development (Pellegrini & Smith, 1998). According to Bjorklund and Pellegrini (2002), the apparent lack of immediate benefits associated with play reveals either a benefit that is delayed in development and/or an immediate benefit that the participant (or the observer) may be unaware of. For example, unstructured play in sport, termed 'deliberate play' by Côté and colleagues (Côté, Baker, & Abernethy, 2003; Côté & Hay, 2002) may influence an athlete's motivation to stay involved in sport or their later ability to process information in various sporting situations. The sense of personal control associated with children's involvement in deliberate play, or a sense of enjoyment endemic to sporting play that becomes internalized and integrated to the self, may result in increased enthusiasm for sport, which in turn could afford greater opportunities for learning specific skills.

An area where deliberate play and structured practice are appreciably different is in the amount of time that youth spend actively engaged in the activity. Deliberate play activities involve an engagement that is difficult to match with any kind of structured practice. When youth play street basketball two-on-two for one hour, there are few periods of waiting or 'off task' time such as one would find in a structured practice. Athletes' 'time on task' or actual engagement in physical activities in practices has been investigated in a range of youth sports (Boudreau & Tousignant, 1991; Brunelle, Spallanzani, Tousignant, Martel, & Gagnon, 1989; Trudel & Brunelle, 1985; Wuest, Mancini, Van der Mars, & Terrillion, 1986) and data indicated athletes' time on task rates varied between 25 and 54% of the total practice time. Time 'off task' during practices usually includes athletes waiting around to perform the next drill, coaches setting up equipment, or athletes transitioning from one drill to another. Although there are obvious advantages to having a coach provide athletes with feedback about their performance, monitor success and provide immediate instruction, it is unclear, at least during early stages of development, whether the benefits of this structured environment are superior to the benefits one gains from engagement in deliberate play activities (e.g. a higher relative portion of active time using motor skills for play versus practice). It is also plausible that deliberate play activities during early development establish a range of cognitive and motor experiences that become beneficial for sport-specific performance and later involvement in deliberate practice activities (see Baker, 2003).

Performance and competition

There is little value ascribed to time spent in performance or competition in the DPF. According to Ericsson et al. (1993), competition and performance do not qualify as deliberate practice because they are not purposefully designed to improve specific aspects of performance. In point of fact, although competition and performance require high amounts of physical and cognitive effort, the purpose of competition is to win and the purpose of performance is to demonstrate the highest level of functioning possible.

However, the unique demands inherent in competition and performance may make them extremely valuable training activities. For instance, the demands of competition are not easily recreated during practice or training. In team sports, such as basketball or soccer, individuals are under unique time constraints during competition and although these types of constraints can be attempted in training through scrimmages, they are not completely reconstructed. Moreover, studies have shown that competition can be an extremely stressful and emotional experience (Hanin, 2000; Wiggins, 1998). These factors can have a significant effect on performance (Hanin, 2000; Jokela & Hanin, 1999) and are difficult (if not impossible) to recreate during training. As a result, time spent in competition may be the only method of developing the skills and capabilities to deal with these factors. Janelle and Hillman (2003) claimed that the relative contribution of competitive experiences has been de-emphasized in favor of general descriptions of the requirements of deliberate practice. They argued that competitive experiences that are strategically included in the training setting equip athletes with requisite self-regulatory capabilities that otherwise would not be acquired. Based on the premise that the 'capability to compete has to be learned' (p. 27), they encouraged sport expertise researchers to document the formative nature of competitive experiences in a training forum. To date, however, competitive simulations and competitive trials have not been considered consistently in the DPF as it pertains to sport.

When they have been considered, sport performers rate competition as being extremely important for their development (Baker et al., 2003b; Young & Salmela, 2002). Among expert decision-makers from team ball sports, athletes' ratings of their training activities showed that time spent in competition was the most valuable training activity for developing essential elements of performance (i.e. perceptual/cognitive abilities and physical fitness; Baker et al., 2003b). In a sample of national-level middle distance runners, races/time trials were judged to be the second-highest activity for improving performance in a taxonomy of 12 sport-specific activities (Young & Salmela, 2002). When competitive data have been submitted to between-group analyses, results have been equivocal. Amount of time spent in competition clearly distinguished expert decision-makers from non-experts (Baker et al., 2003b). However, data from other sports have been contradictory (e.g. distance running; Young & Salmela, 2010). Continued work is needed to validly assess the learned aspects of competition as a form of practice, and to examine how such measures discriminate performance groups in different sports and at different ages.

Q2. Is 10,000 hours a good estimate of the time necessary to become an expert?

One of the most widely cited elements of the DPF, certainly among the popular science press, is the notion that 10,000 hours is a good representation of the amount of deliberate practice required to become an expert. Data from the Ericsson et al. (1993) study of expert musicians noted 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 < two hours per week). These notable differences in weekly training accumulate to become enormous differences after years of training. Expert musicians accumulated over 10,000 hours in deliberate practice by age 20 while amateurs had accumulated only 2000 hours at the same age.

Although researchers examining the DPF in sport have supported the relationship between hours of deliberate practice and level of attainment (e.g. Baker et al., 2003a; Helsen et al., 1998; Starkes et al., 1996), there is conflicting evidence that 10,000 hours of involvement is necessary for all domains. For instance, the data in Table 1 indicate that while some experts required over 10,000 hours of training to obtain expert-level performance (e.g. triathletes, Baker et al., 2005; dart players, Duffy, Baluch, & Ericsson, 2004; gymnastics, Law et al., 2007), others required less than 4000 hours (expert decision-makers in team sports, Baker et al. 2003a; ice-hockey players, Soberlak & Côté, 2003).

In addition to the wide range in total hours required to attain expertise, there is alarming variability in these totals. For instance, Duffy et al.'s (2004) examination of professional dart players found an average of 12,839 hours of deliberate practice but with a standard deviation of 7780 hours. These across-study discrepancies and the high degrees of variability may stem from inconsistent operationalization of who experts are because of the very difficult challenge of equating experts across domains (i.e. across studies). Importantly, there are significant limitations to the 'bean counting' of hours of deliberate practice, including group assignment (valid groups, multiple groups showing correspondence in trends), ensuring that the metric being recalled is in fact deliberate practice (and not simply experience), and the use of appropriate time-based statistics (e.g.

interpreting group by time interactions derived from repeated measures ANOVAs). These limitations call into question the empirical value of our knowledge regarding 10,000 hours of deliberate practice as a threshold for understanding the development of expert athletes.

Q3. How does someone maintain and regulate their involvement for this length of time?

Twenty-one years on, the examination of long-term sport expertise development remains somewhat divorced from studies that explain how people propel themselves, repeatedly over time, to engage in the voluminous practice and training necessary to become an expert. In 1993, Ericsson et al. identified effort and motivation as two constraints on expert development, yet there was no indication within the DP framework of how individuals successfully circumvent or negotiate these constraints across many practices and over time. Choosing not to focus on it explicitly, Ericsson et al. noted that '[w]ithin our framework we would expect that several "personality" factors, such as individual differences in activity levels and emotionality may differentially predispose individuals toward deliberate practice as well as allow these individuals to sustain very high levels of it for extended periods' (1993, p. 393). However, despite its prominence in the DPF, questions remain about the personal attributes that enable maximal levels of deliberate practice over extended periods. For instance, how do aspiring athletes consistently muster the fortitude to engage in such inherently unenjoyable training? How do aspiring athletes make strategic scheduling decisions to effectively balance their hard work with necessary rest/recovery to help optimize their training? How do they accurately prioritize certain activities or strategies that are most beneficial to their improvement at distinct points in time, given a vast repertoire of possible training activities/strategies? While the first question refers to motivation in general, the latter questions relate to metacognition, or the decision-making processes that regulate the selection and use of various forms of knowledge. Together, these questions relate to self-regulated learning (Zimmerman, 1989), which describes processes in which 'learners are meta-cognitively, motivationally, and behaviorally active participants in their own learning process' (p. 329).

Sport researchers (Toering, Elferink-Gemser, Jordet, & Visscher, 2009; Young & Medic, 2008; Young & Starkes, 2006) have contended that aspiring athletes who enact self-motivational processes more frequently and who make effective/accurate decisions that consistently help to optimize training bouts should get more out of their training and thus acquire higher levels of sport performance. As such, the individual differences to which Ericsson et al. alluded may be differences in self-regulated learning processes as applied to the sport training context. 'Getting the most out of one's training' is necessary to negotiate the effort constraint within Ericsson et al.'s (1993) DPF; if one is limited by how much training one can do, then the training must be smarter (i.e. more deliberately in tune with one's goals or weaknesses), must involve shrewd selection of activities or resources, and training behaviors must be reflected upon to inform an understanding of subsequent competitive outcomes or to inform future practice planning.

Twenty-one years ago, Ericsson et al. (1993) asked readers to consider individual differences in factors that predispose individuals toward sustained DP. They went further and suggested that 'heritable differences might influence processes related to motivation and the original enjoyment of the activities in the domain and, even more important, affect the inevitable differences in the capacity to engage in hard work (deliberate practice)' (p. 399). Little research has since explored heritable individual differences relating to expertise motivation in sport. Elsewhere, discussions of motivation in domains that require an emphasis on acquisition over the long term through dedicated practice have focused on the social-cognitive origins (Schunk & Zimmerman, 1998; Zimmerman, 1989, 2000, 2006) of processes that serve to optimize/maximize goal-oriented practice behaviors, which suggests that these processes are better aligned with the nurturistic perspective of the DP framework than inherited factors. Borrowing Zimmerman's conceptualization, Toering, Elferink-Gemser, Jonker, van Heuvelen, and Visscher (2012) recently summarized their work validating self-report measures that capture aspects of self-regulated sport training in young athletes. In sum, it is plausible that future research may help us better understand the long-term pursuit of DP by reconciling motivational and metacognitive measures for self-regulated sport training with cumulative measures for DP. In particular, researchers might seek to determine whether individual differences in identifiable self-regulatory variables moderate the effects of DP and the explanation of expert–novice group differences.

Q4. Is time spent in deliberate practice sufficient to explain expertise?

Certainly the most controversial element of the DPF (unquestionably the one most focused upon in the popular press) has been the notion that time spent in deliberate practice is sufficient to explain a performer's level of attainment in most endeavors (c.f. Ericsson, 2007, 2013; Tucker & Collins, 2012). Critics of this position argue that it devalues the contribution of genetic and biological factors to the acquisition of exceptional skill. For instance, Tucker and Collins (2012) argued that 'deliberate practice alone fails to account for the wide range of individual performance levels and responses to training observed in sport and skill-based activities like chess and darts' (p. 556). They highlight the emerging evidence (e.g. Kraus et al., 2001; Morss et al., 2004) indicating that a meaningful amount of variability in athlete development *must* be explained by genetic factors. Similarly, research highlighting the consistent predictive ability of stable biological factors such as digit ratio (2D:4D; e.g. Baker et al., 2013; Hönekopp & Schuster, 2010) reinforces the conclusion that the acquisition of expertise is not simply a matter of accumulating DP. As we note in the following section, the designs that have been used in prior research of this phenomenon are insufficient to make conclusions regarding whether DP is sufficient for expertise. They merely demonstrate that it is necessary. Undoubtedly, some of the strongest evidence for the sufficiency of DP for explaining skill attainment comes from longitudinal studies of the acquisition of memory skill conducted by Ericsson and his colleagues (e.g. the SF studies described in Chase & Ericsson, 1981; Ericsson, Chase, & Faloon, 1980). However, sport performance requires a considerable range of skills beyond memory and similar studies exploring the acquisition of sport skills would be valuable for determining the 'sufficiency versus necessity question' with regard to DP.

Additionally, research on the DPF has focused almost exclusively on how (and how much) practice facilitates expert performance acquisition. However, there was significant attention paid to the interspersing of practice activity with rest, recovery and sleep/napping patterns in the original Ericsson et al. (1993) treatise. In particular, the investigators chose to document these patterns to legitimize the notion of an effort constraint, and the idea that those individuals who did more intensive practice would need to spread it out more and engage in lengthier rest periods to compensate. Little research has pursued this notion since, which is especially surprising in the sport domain, considering how principles of sport training inextricably prescribe physical 'work' as a ratio of 'rest'. An exception is Young and Salmela's (2001) examination of deliberate recovery activities between elite versus intermediate-level distance runners. Based on data derived from a seven-day diary study, analyses showed no significant group differences for activities comprising body care (e.g. massage therapy), sleeping and napping, and non-active leisure. However, contemporary methods now exist to more validly assess time invested in a broader range of dedicated regenerative activities, possibly uncovering reliable group differences. The notion of *deliberate recovery* appears to be a ripe area for research, and is in keeping with recent calls to understand the mechanisms of off-line motor learning during restful states (Korman et al., 2007; Walker & Stickgold, 2004). Studies of deliberate recovery may help us better understand the effort constraint, and perhaps more importantly, account for variance in performance above and beyond deliberate practice alone.

Theoretical and methodological considerations for future research

The strong relationship between training and skill development ensures that models detailing the path to expertise will continue to highlight the necessity of proper training. However, factors that continue to be raised (e.g. Abernethy et al., 2003; Sternberg, 1996; Tucker & Collins, 2012) preclude the adoption of 'training only' models as fully representing the range of factors influencing the acquisition of expertise. In the previous sections, we have highlighted several areas of future research. However, we encourage researchers to consider the methodological and theoretical limitations of previous work. Below we highlight some of these concerns.

Need for better theoretical models

The specifics of the DPF outlined in the earlier sections of this review have not been examined with the type of experimental rigor necessary to make firm conclusions regarding the value of this framework. The development of superior theoretical models will undoubtedly lead to clearer hypotheses that can be tested experimentally and longitudinally. Importantly, better theory produces stronger evidence, which could ultimately 'rule out' or 'confirm' the fundamental importance of training and/or heredity factors. In his criticism of one of the earliest reviews of deliberate practice (Ericsson & Charness, 1994), Gardner (1995) proposed that understanding the acquisition of expertise requires resolving 'who starts and why, who continues and why, and in what ways do those who continue successfully differ from all others' (p. 803). To date, there has been considerable research devoted to the latter question, almost to the exclusion of the former questions, at least in studies using the DPF. Comparatively, there has been little research to understand the conditions that allow individuals to circumvent motivational and effort constraints in the DPF. However, there has been much greater focus on quantitative aspects relating to patterns of long-term performance acquisition through deliberate practice and on the conditions that afford (are correlated with ultimately higher levels of performance acquisition) certain individuals access to deliberate practice. For instance, there has been considerable attention devoted to the 'Relative Age Effect' (see Cobley, Wattie, Baker, & McKenna, 2009; Wattie, Cobley & Baker, 2008) whereby those born closer to a sport's cutoff date (the date used to group athletes into age bands) are more likely to attain elite levels of performance. One hypothesis of this pervasive effect relates to the ease with which relatively older athletes are able to access higher levels of competition, superior coaching and opportunities for deliberate practice (Helsen, Hodges, van Winckel, & Starkes, 2000). While this effect is certainly interesting, conditions that afford individuals preferential access to deliberate practice opportunities are not the same as conditions of self-motivation and self-regulation. Greater attention to questions regarding how athletes maintain motivation and effort for extensive periods of time would be invaluable.

Need for better study designs

A related issue concerns the need for better study designs in deliberate practice research. Most of the work in this area has necessarily been limited to using retrospective techniques. While these investigations have been quite useful in identifying the quantity and quality of training performed by experts, they do not provide evidence of a causal relationship due to the absence of control groups and/or lack of follow-up of those who drop out of the development pathway/system (Abernethy et al., 2003; Sternberg, 1996). The addition of systematic, experimental and longitudinal evidence (although unattractive due to logistical and financial factors) would add considerable support for training-specific approaches to expertise development. An intriguing and novel approach was taken by Ward, Hodges, Starkes, and Williams (2007), who used a retrospective cross-sectional approach to compare soccer players ranging in age from nine to 18 years. Their innovative approach compared elite and sub-elite players at each age to the data reported by adult players for the same age (i.e. cross-sectional data compared to retrospective data). This type of creativity in study design provides one method of circumventing the logistical and administrative barriers of longitudinal research.

In addition, it will be important for researchers to explore different methods of examining the relationships between training/practice-related variables and developmental outcomes. For instance, many of the statistical approaches used in DP research are based on assumed linearity between practice and performance improvement over time. Given the complex interaction suggested by advocates of deliberate play during early phases of development (see Côté, Baker, & Abernethy, 2007), or functions associated with a phenomenon such as the Matthew effect (Rigney, 2010), it is possible that the relationship between deliberate practice and performance improvement is better captured through regressions using quadratic or exponential functions. Matthew effects, although not yet studied with respect to sport expertise, would posit that those who enjoy early success in sport development (e.g. because of early training) may increasingly benefit from subsequent affordances, rewards and/or opportunities, which cause their amounts of deliberate practice to increasingly accelerate (curvilinear; e.g. Hancock, Adler, & Côté, 2013). Other young athletes in the same cohort who were not as successful early on would not be afforded the same subsequent catalysts to deliberate practice and their skill acquisition pathway may look more linear.

A final concern for coaching science

Although a definitive answer to whether nature or nurture is the ultimate constraint on elite athlete development appears unlikely without much additional research, it is critical to consider the effects of training methods and coaching philosophies firmly grounded in each perspective. How one conceptualizes their skills and abilities affects learning of new information (Mangels, Butterfield, Lamb, Good, & Dweck, 2006) as well as motivation for training and practice (Cimpian, Arce, Markham, & Dweck, 2007; Jourden, Bandura, & Banfield, 1991). Although much of the research from motor learning indicates that having the belief that ability is something that can be developed through hard work is more beneficial to learning and motivation, others (e.g. Pinker, 2002) have suggested that messages de-emphasizing the role of biological factors may have considerable long-term effects on development and psychological health. Coaching researchers may be particularly interested in the consequences of uninformed and poorly considered messages, and the timing of messages to developing athletes, as properly timed messages can serve to encourage hard work toward future excellence, and poorly delivered messages can de-motivate cohorts as well (e.g. Lockwood & Kunda, 1997).

Concluding remarks

Twenty-one years ago, the publication of Ericsson and colleagues' (1993) study of DP in musicians marked an important milestone in research on the acquisition of expertise. Since that time, the concept of deliberate practice has increased in prominence as a research topic and as a foundational consideration for those involved with coaching and training. However, it would seem that the 'riches' identified in the Ericsson et al. paper have not been adequately mined by the academic community, which instead has focused on a relatively narrow set of conclusions from this study. In the sections above, we have argued for continued examination of the subtleties of this framework in order to determine its value for explaining the process and constraints associated with sport skill acquisition. Developing superior theory, research designs, and asking slightly different questions, will be important steps to determine the ultimate value of Ericsson and colleagues' DPF to expert sport development.

Note

1. There is some confusion regarding what the 'monotonic benefits assumption' means. By definition, a monotonic function is an ordered system of sets, whereby each subsequent set contains the preceding set. This could be interpreted as meaning that gains at each subsequent career stage in a developing athlete's pathway are supported by accrued benefits at prior stages. However, the actual career-span pattern of sport performance as a function of practice has not been plotted in sport expertise research on young, developing athletes. Several studies on developing young athletes have, however, consistently shown that increases in deliberate practice are monotonic (i.e. constant increases at each subsequent career stage in sequence) for expert/elite samples.

References

Abernethy, B., Farrow, D., & Berry, J. (2003). Constraints and issues in the development of a general theory of expert perceptual-motor performance: A critique of the deliberate practice framework. In J. L. Starkes & K. A. Ericsson (Eds.), *Expert performance in sports: Advances in research on sport expertise* (pp. 349–370). Champaign, IL: Human Kinetics.

Baker, J. (2003). Early specialization in youth sport: A requirement for adult expertise?. *High Ability Studies*, *14*, 85–94. doi:10.1080/13598130304091

Baker, J., Cote, J., & Abernethy, B. (2003a). Sport specific practice and the development of expert decision-making in team ball sports. *Journal of Applied Sport Psychology*, *15*, 12–25. doi:10.1080/10413200305400

Baker, J., Côté, J., & Abernethy, B. (2003b). Learning from the experts: Practice activities of expert decision-makers in sport. *Research Quarterly for Exercise and Sport*, *74*, 342–347. doi:10.1080/02701367.2003.10609101

Baker, J., Côté, J., & Deakin, J. (2005). Expertise in ultra-endurance triathletes early sport involvement, training structure, and the theory of deliberate practice. *Journal of Applied Sport Psychology*, *17*, 64–78. doi:10.1080/10413200590907577

Baker, J., & Davids, K. (2006). Genetic and environmental constraints on variability in sport performance. In K. Davids, S. J. Bennett, & K. M. Newell (Eds.), *Movement system variability* (pp. 109–132). Champaign, IL: Human Kinetics.

Baker, J., Kungl, A. M., Pabst, J., Strauss, B., Büsch, D., & Schorer, J. (2013). Your fate is in your hands? Handedness, digit ratio, (2D:4D) and selection to a national talent development system. *Laterality*, *18*, 710–718. doi:10.1080/1357650X.2012.755992

Berry, J., Abernethy, B., & Côté, J. (2008). The contribution of structure activity and deliberate play to the development of expert perceptual and decision-making skill. *Journal of Sport and Exercise Psychology*, *30*, 685–708.

Bjorklund, D. F., & Pellegrini, A. D. (2002). *The origins of human nature: Evolutionary developmental psychology*. Washington, DC: American Psychological Association.

Bompa, T. O. (1999). *Periodization: Theory and methodology of training* (4th ed.). Champaign, IL: Human Kinetics.

Boudreau, P., & Tousignant, M. (1991). L'efficacite de l'intervention d'entraineurs benevoles en formation [Effectiveness of an intervention to train volunteer coaches]. *Canadian Journal of Sport Sciences*, *16*, 134–141.

Brunelle, J., Spallanzani, C., Tousignant, M., Martel, D., & Gagnon, J. (1989). Effets d'une strategie d'auto-supervision sur les composantes du temps d'apprentissage dans l'enseignement de deux sports [Effects of a strategy of self-supervision on components of learning time in the teaching of two sports]. *Revue Canadienne de l'Education*, *14*, 182–201. doi:10.2307/1495350

Bryan, W. L., & Harter, N. (1897). Studies in the physiology and psychology of the telegraphic language. *Psychological Review*, *4*, 27–53. doi:10.1037/h0073806

Campbell, K., & Parcels, J. (2013). *Selling the dream: How hockey parents and their kids are paying the price for our national obsession*. New York, NY: Penguin.

Catteeuw, P., Helsen, W., Gilis, B., & Wagemans, J. (2009). Decision-making skills, role specificity, and deliberate practice in association football refereeing. *Journal of Sports Sciences*, *27*, 1125–1136. doi:10.1080/02640410903079179

Chase, W. G., & Ericsson, K. A. (1981). Skilled memory. In J. R. Anderson (Ed.). *Cognitive skills and their acquisition* (pp. 141–189). Hillsdale, NJ: Erlbaum.

Cimpian, A., Arce, H. M., Markham, E. M., & Dweck, C. S. (2007). Subtle linguistic cues affect children's motivation. *Psychological Science*, *18*, 314–316. doi:10.1111/j.1467-9280.2007.01896.x

Cobley, S., Wattie, N., Baker, J., & McKenna, J. (2009). A meta-analytical review of relative age effects in sport: The emerging picture. *Sports Medicine*, *39*, 235–256. doi:10.2165/00007256-200939030-00005

Colvin, G. (2008). *Talent is overrated: What really separates world-class performers from everybody else*. New York, NY: Portfolio.

Côté, J., Baker, J., & Abernethy, B. (2003). From play to practice: A developmental framework for the acquisition of expertise in team sports. In J. Starkes & K. A. Ericsson (Eds.), *Expert performance in sports: Advances in research on sport expertise* (pp. 89–110). Champaign, IL: Human Kinetics.

Côté, J., Baker, J., & Abernethy, B. (2007). Practice and play in the development of sport expertise. In R. Eklund & G. Tenenbaum (Eds.), *Handbook of sport psychology* (3rd ed., pp. 184–202). Hoboken, NJ: Wiley.

Côté, J., Erickson, K., & Duffy, P. (2013). Developing the expert performance coach. In D. Farrow, J. Baker, & C. MacMahon (Eds.), *Developing sport expertise* (2nd ed., pp. 96–109). London: Routledge.

Côté, J., & Hay, J. (2002). Children's involvement in sport: A developmental analysis. In J. M. Silva & D. Stevens (Eds.), *Psychological foundations of sport* (pp. 484–502). Boston, MA: Allyn and Bacon.

Coughlan, E. K., Williams, A. M., McRobert, A. P., & Ford, P. R. (2013). How experts practice: A novel test of deliberate practice theory. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *40*, 449–458. doi:10.1037/a0034302

Coyle, D. (2009). *The talent code*. New York, NY: Bantam.

Deakin, J. M., & Cobley, S. (2003). An examination of the practice environments in figure skating and volleyball: A search for deliberate practice. In J. Starkes & K. A. Ericsson (Eds.), *Expert performance in sports: Advances in research on sport expertise* (pp. 90–113). Champaign, IL: Human Kinetics.

Duffy, L. J., Baluch, B., & Ericsson, K. A. (2004). Dart performance as a function of facets of practice amongst professional and amateur men and women players. *International Journal of Sport Psychology*, *35*, 232–245.

Epstein, D. (2013). *The sports gene*. New York, NY: Penguin.

Ericsson, K. A. (1996). *The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games*. Mahwah, NJ: Erlbaum.

Ericsson, K. A. (2003). How the expert performance approach differs from traditional approaches to expertise in sport: In search of a shared theoretical framework for studying expert performance. In J. L. Starkes & K. A. Ericsson (Eds.), *Expert performance in sports: Advances in research on sport expertise* (pp. 371–402), Champaign, IL: Human Kinetics.

Ericsson, K. A. (2007). Deliberate practice and the modifiability of body and mind: Toward a science of the structure and acquisition of expert and elite performance. *International Journal of Sport Psychology*, *38*, 4–34.

Ericsson, K.A. (2013). Training history, deliberate practice and elite sports performance: an analysis in response to Tucker and Collins review—what makes champions? *British Journal of Sports Medicine*, *47*, 533–535. doi:10.1136/bjsports-2012-091767

Ericsson, K. A., & Charness, N. (1994). Expert performance: Its structure and acquisition. *American Psychologist*, *49*, 725–747. doi:10.1037/0003-066X.49.8.725

Ericsson, K. A., Chase, W. G., & Faloon, S. (1980). Acquisition of a memory skill. *Science*, *208*, 1181–1182. doi:10.1126/science.7375930

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, *100*, 363–406. doi:10.1037/0033-295X.100.3.363

Ford, P. R., & Williams, A. M. (2008). The effect of participation in Gaelic football on the development of Irish professional soccer players. *Journal of Sport & Exercise Psychology*, *30*, 709–722.

Gardner, H. (1995). Why would anyone become an expert?. *American Psychologist*, *50*, 802–803. doi:10.1037/0003-066X.50.9.802

Gladwell, M. (2008). *Outliers: The story of success*. Boston, MA: Little, Brown and Company.

Hancock, D., Adler, A. L., & Côté, J. (2013). A proposed theoretical model to explain relative age effects in sport. *European Journal of Sport Science*, *13*, 630–637. http://dx.doi.org/10.1080/17461391.2013.775352

Hanin, Y. L. (2000). *Emotions in sport*. Champaign, IL: Human Kinetics.

Helsen, W. F., Hodges, N. J., Van Winckel, J., & Starkes, J. L. (2000). The roles of talent, physical precocity and practice in the development of soccer expertise. *Journal of Sports Sciences*, *18*, 727–736. doi:10.1080/02640410050120104

Helsen, W. F., Starkes, J. L., & Hodges, N. J. (1998). Team sports and the theory of deliberate practice. *Journal of Sport & Exercise Psychology*, *20*, 12–34.

Hodges, N. J., Kerr, T., Starkes, J. L., Weir, P. L., & Nananidou, A. (2004). Predicting performance times from deliberate practice hours for triathletes and swimmers: What, when, and where is practice important? *Journal of Experimental Psychology: Applied*, *10*, 219–237. doi:10.1037/1076-898X.10.4.219

Hodges, N. J., & Starkes, J. L. (1996). Wrestling with the nature of expertise: A sport specific test of Ericsson, Krampe, and Tesch-Römer's (1993) theory of deliberate practice. *International Journal of Sport Psychology*, *27*, 400–424.

Hönekopp, J., & Schuster, M. (2010). A meta-analysis on 2D:4D and athletic prowess: Substantial relationships but neither hand out-predicts the other. *Personality and Individual Differences*, *48*, 4–10. doi:10.1016/j.paid.2009.08.009

Howe, M. J. A., Davidson, J. W., & Sloboda, J. (1998). Innate talents: Reality or myth?. *Behavior and Brain Sciences*, *21*, 399–442. doi:10.1017/S0140525X9800123X

Janelle, C. M., & Hillman, C. H. (2003). Expert performance in sport: Current perspectives and critical issues. In J. L. Starkes & K. A. Ericsson (Eds.), *Expert performance in sport* (pp. 19–48). Champaign, IL: Human Kinetics.

Jokela, M., & Hanin, I. L. (1999). Does the individual zones of optimal functioning model discriminate between successful and less successful athletes: A meta-analysis. *Journal of Sport Sciences*, *17*, 873–887. doi:10.1080/026404199365434

Jourden, F. J., Bandura, A., & Banfield, J. T. (1991). The impact of conceptions of ability on self-regulatory factors and motor skill acquisition. *Journal of Sport & Exercise Psychology*, *13*, 213–226.

Kallio, J., & Salmela, J. H. (1998). Development of expert performance in biathlon. *Journal of Applied Sport Psychology*, *10*, s90.

Korman, M., Doyon, J., Doljansky, J., Carrier, J., Dagan, Y., & Karni, A. (2007). Daytime sleep condenses the time course of motor memory consolidation. *Nature Neuroscience*, *10*, 1206–1213. doi:10.1038/nn1959

Kraus, W. E., Torgan, C. E., Duscha, B. D., Norris, J., Brown, S. A., Cobb, F. R., … Slentz, C. A. (2001). Studies of a targeted risk reduction intervention through defined exercise (STRRIDE). *Medicine and Science in Sports and Exercise*, *33*, 1774–1784. doi:10.1097/00005768-200110000-00025

Law, M. P., Côté, J., & Ericsson, K. A. (2007). Characteristics of expert development in rhythmic gymnastics: A retrospective study. *International Journal of Exercise and Sport Psychology*, *5*, 82–103. doi:10.1080/1612197X.2008.9671814

Lockwood, P., & Kunda, Z. (1997). Superstars and me: Predicting the impact of role models on the self. *Journal of Personality and Social Psychology*, *73*, 91–103. doi:10.1037/0022-3514.73.1.91

Mangels, J. A., Butterfield, B., Lamb, J., Good, C., & Dweck, C. S. (2006). Why do beliefs about intelligence influence learning success? A social cognitive neuroscience model. *Social Cognitive and Affective Neuroscience*, *1*, 75–86. doi:10.1093/scan/nsl013

Moesch, K., Elbe, A. M., Hauge, M. L., & Wikman, J. M. (2011). Late specialization: The key to success in centimeters, grams, or seconds (cgs) sports. *Scandinavian Journal of Medicine and Science in Sports*, *21*, e282–e290. doi:10.1111/j.1600-0838.2010.01280.x

Morss, G. M., Jordan, A. N., Skinner, J. S., Dunn, A. L., Church, T. S., Earnest, C. P., … Blair, S. N. (2004). Dose response to exercise in women aged 45–75yr (DREW): Design and rationale. *Medicine and Science in Sports and Exercise*, *36*, 336–344. doi:10.1249/01.MSS.0000113738.06267.E5

Newell, K. M., Liu, Y.-T., & Mayer-Kress, G. (2001). Time scales in motor learning and development. *Psychological Review*, *108*, 57–82. doi:10.1037/0033-295X.108.1.57

Newell, A., & Rosenbloom, P. S. (1981). Mechanisms of skill acquisition and the law of practice. In J. R. Anderson (Ed.). *Cognitive skills and their acquisition* (pp. 1–55). Hillsdale, NJ: Erlbaum.

Pellegrini, A. D., & Smith, P. K. (1998). Physical activity play: The nature and function of a neglected aspect of playing. *Child Development*, *69*, 577–598.

Pinker, S. (2002). *The blank slate: The modern denial of human nature*. New York, NY: Penguin.

Plant, E. A., Ericsson, K. A., Hill, L., & Asberg, K. (2005). Why study time does not predict grade point average across college students: Implications of deliberate practice for academic performance. *Contemporary Educational Psychology*, *30*, 96–116. doi:10.1016/j.cedpsych.2004.06.001

Rigney, D. (2010). *The Matthew effect: How advantage begets further advantage*. New York, NY: Columbia University Press.

Roca, A., Williams, A. M., & Ford, P. R. (2012). Developmental activities and the acquisition of superior anticipation and decision making in soccer players. *Journal of Sports Sciences*, *30*, 1643–1652. doi:10.1080/02640414.2012.701761

Schunk, D. H., & Zimmerman, B. J. (1998). *Self-regulated learning: From teaching to self-reflective practice*. New York, NY: Guilford Press.

Selye, H. (1956). *The stress of life*. New York, NY: McGraw-Hill

Soberlak, P., & Côté, J. (2003). The developmental activities of elite ice-hockey players. *Journal of Applied Sport Psychology*, *15*, 41–49. doi:10.1080/10413200305401

Starkes, J. L. (2000). The road to expertise: Is practice the only determinant? *International Journal of Sport Psychology*, *31*, 431–451.

Starkes, J. L., Deakin, J. M., Allard, F., Hodges, N. J., and Hayes, A. (1996). Deliberate practice in sports: What is it anyway?. In K. A. Ericsson (Ed.), *The road to excellence: The acquisition of expert performance in the arts, sciences, sports and games* (pp. 81–106). Mahwah, NJ: Erlbaum.
Sternberg, R. J. (1996). Costs of expertise. In K. A. Ericsson (Ed.), *The road to excellence: The acquisition of expert performance in the arts and sciences, sports, and games* (pp. 347–354). Mahwah, NJ: Erlbaum.
Syed, M. (2010). *Bounce: Mozart, Federer, Picasso, Beckham and the science of success*. New York, NY: Harper.
Toering, T., Elferink-Gemser, M. T., Jonker, L., van Heuvelen, M. J. G., & Visscher, C. (2012). Measuring self-regulation in a learning context: Reliability and validity of the Self-Regulation of Learning Self-Report Scale (SRL-SRS). *International Journal of Sport and Exercise Psychology*, *10*, 24–38. doi:10.1080/1612197X.2012.645132
Toering, T. T., Elferink-Gemser, M. T., Jordet, G., & Visscher, C. (2009). Self-regulation and performance level of elite and non-elite youth soccer players. *Journal of Sports Sciences*, *27*, 1509–1517. doi:10.1080/02640410903369919
Trudel, P., & Brunelle, J. (1985). Les situations d'apprentissage offertes aux joueurs inscrits dans des ligues de hockey mineur [Learning situations available to minor hockey players]. *L'Association Canadienne pour la Sante, l'Education Physique et le Loisir*, *51*, 18–25.
Tucker, R., & Collins, M. (2012). What makes champions? A review of the relative contribution of genes and training to sporting success. *British Journal of Sports Medicine*, *46*, 555–561. doi:10.1136/bjsports-2011-090548
Walker, M. P., & Stickgold, R. (2004). Sleep-dependent learning and memory consolidation. *Neuron*, *44*, 121–133. doi:10.1016/j.neuron.2004.08.031
Ward, P., Hodges, N. J., Starkes, J. L., & Williams, A. M. (2007). The road to excellence: Deliberate practice and the development of expertise. *High Ability Studies*, *18*, 119–153. doi:10.1080/13598130701709715
Wattie, N., Cobley, S., & Baker, J. (2008). Toward a unified understanding of relative age effects in sport. *Journal of Sports Sciences*, *26*, 1403–1409. doi:10.1080/02640410802233034
Weissensteiner, J., Abernethy, B., Farrow, D., & Muller, S. (2008). The development of anticipation: A cross-sectional examination of the practice experiences contributing to skill in cricket batting. *Journal of Sport & Exercise Psychology*, *30*, 663–684.
Wiggins, M. S. (1998). Anxiety intensity and direction: Preperformance temporal patterns and expectations in athletes. *Journal of Applied Sport Psychology*, *10*, 201–211. doi:10.1080/10413209808406388
Wuest, D. A., Mancini, V. H., van der Mars, H., & Terrillion, K. (1986). The academic learning time-physical education of high-, medium-, and low-skilled female intercollegiate volleyball players. In M. Pieron & G. Graham (Eds.), *Olympic Scientific Congress Proceedings*, Volume 6 (pp. 123–130). Champaign, IL: Human Kinetics Publishers.
Young, B. W., Jemczyk, K., Brophy, K., & Côté, J. (2009). Discriminating skilled coaching groups: Quantitative examination of developmental experiences and activities. *International Journal of Sports Science and Coaching*, *4*, 397–414. doi:10.1260/174795409789623937
Young, B. W., & Medic, N. (2008). The motivation to become an expert athlete: How coaches can promote long-term commitment. In Farrow, D., Baker, J., & MacMahon, C. (Eds.), *Developing elite sports performers: Lessons from theory and practice* (pp.43–59). New York, NY: Routledge.
Young, B. W., & Salmela, J. H. (2001). *Diary analyses of practice and recovery activities for elite and intermediate middle distance runners*. Conference proceedings for the 10th meeting of the International Society of Sport Psychology, vol. 4, p.19. Skiathos, Greece.
Young, B. W., & Salmela, J. H. (2002). Perceptions of training and deliberate practice of middle distance runners. *International Journal of Sport Psychology*, *33*, 167–181.
Young, B. W., & Salmela, J. H. (2010). Examination of practice activities related to the acquisition of elite performance in Canadian middle distance running. *International Journal of Sport Psychology*, *41*, 73–90.
Young, B. W., & Starkes, J. L., (2003). Test-retest reliability of the deliberate practice activity ratings questionnaire. *Journal of Sport & Exercise Psychology*, *25*, S143.
Young, B. W., & Starkes, J. L. (2006). Coaches' perceptions of non-regulated training behaviors in competitive swimmers. *International Journal of Sports Science and Coaching*, *1*, 53–68. doi:10.1260/174795406776338427

Zimmerman, B. J. (1989). A social cognitive view of self-regulated academic learning. *Journal ofEducational Psychology*, *81*, 329–339. doi:10.1037/0022-0663.81.3.329

Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13–41). San Diego, CA: Academic Press.

Zimmerman, B. J. (2006). Development and adaptation of expertise: The role of self-regulatory processes and beliefs. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 705–722). New York, NY: Cambridge University Press.