Investigating the Period of Practice Needed to Acquire Expertise in Great Britain 2012 Track and Field Olympic Athletes

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Abstract
Deliberate practice theory argues that expertise can be acquired only after 10 years of domain-specific deliberate practice. To assess this prediction, we examined data from track (*n* = 57) and field (*n* = 15) athletes representing Great Britain Track and Field team (Team GB) at the 2012 Olympics. We defined the period to excellence as the difference in age between achieving expertise (the first selection for an international senior outdoor athletic championship) and starting age (joining a club, being coached, or engaging in competition). Results indicated that elite track (75.4%) and field (93.3%) athletes acquired expertise in significantly less than 10 years (*M* = 7.20, *SD* = 3.20, *p* < .001). Expertise mostly relying on the anaerobic pathway (*n* = 51) was acquired significantly faster than expertise mostly utilizing the aerobic pathway (*n* = 21), 6.15 ± 2.84 years vs. 9.78 ± 2.52 years (*p* < .001). Those who did not specialize early (*n* = 40) were faster in acquiring expertise in a new sport than those who specialized early (*n* = 32), 6.27 ± 2.78 vs. 8.38 ± 3.34 years (*p* = .005), contrary to deliberate-practice contention that early specialization is critical.

Keywords
deliberate practice, expertise, period to excellence, sports-specific practice, energy pathway

Introduction

How long does it take to become an Olympian? Why do some athletes achieve top performance levels while others do not? More generally, what are the differences between individuals that attain expert performance in domains such as science, the professions, the arts, and sports, and those who do not?

Three main approaches have aimed at answering these questions. The first emphasizes innate potential and talent (Gardner, 1983). This approach has recently received strong support from research in genetics and genomics showing that some abilities – both physical and psychological – depend on innate factors (Ahmetov & Fedotovskaya, 2012; Tucker & Collins, 2012). The second approach focuses on the role of environment and practice (Bloom, 1985; Simon & Chase, 1973). It emphasizes the role of teachers, family and wider environment, practice, and feedback. The third approach considers aspects linked both to talent and practice, and highlights the interactions between them (Gobet, 2015; Simonton, 1999; Ullén, Hambrick, & Mosing, 2016). It also highlights the time-dependent dynamics of the acquisition of expertise, such as the possibility that small initial variations might lead to large difference years later.

Over the last two decades, the deliberate practice approach has been particularly influential. It states that domain-specific expert levels of performance can only be attained through sustained investment in activities deliberately designed to improve performance (Ericsson, Krampe, & Tesch-Romer, 1993). Irrespective of initial individual differences in talent or experience, the right kind of practice will produce expertise. Although individually focused, deliberate practice requires teachers, training material, and facilities. The practice is domain specific, effortful, and not inherently motivating or enjoyable, and can only be sustained for limited periods so that the exhaustion point is not reached. Only those hours spent practicing alone count as deliberate practice; team practice and competition are explicitly excluded. It is assumed that talent and previous experience do not accelerate the speed of acquiring expertise performance and that performance is a monotonic function of the amount of time devoted to deliberate practice: "[T]he adult elite performance, even among individuals with more than 10 years of practice, is related to the amount of deliberate practice" (Ericsson et al., 1993, p. 373).

Practice is optimal when tailored to a specific domain; therefore, expertise in one sport is not useful in another sport, and early specialization is a requirement for success. Building on Simon and Chase's (1973) estimate, Ericsson et al. (1993) state that an important prediction of the deliberate practice framework is that "… expert performance is not reached with less than 10 years of deliberate practice" (p. 372); this period to excellence of 10 years (or 10,000 hours) is a minimum that applies across all domains. Thus, they consider the period of expert attainment in mathematics, sport, and teaching to be the same, given appropriate levels of deliberate practice. This prediction has been repeated in many publications about deliberate practice. For example, Ericsson, Prietula, and Cokely (2007, p. 119) write "… our research shows that even the most gifted performers need a minimum of ten years (or 10,000 hours) of intense training before they win international competitions" and, specifically in relation to competing in the Olympics, that (i) "…. it is almost impossible to beat the ten-year rule" plus (ii) "…it would be virtually impossible for anyone to win an individual medal without a training history comparable with that of today's elite performers, nearly all of whom started very early" (2007, p. 119).

The deliberate practice hypothesis was originally formulated in the field of music. It has then been applied to many domains of expertise, including sports (Hyllegard & Yamamoto, 2007), chess (Gobet & Campitelli, 2007) and mathematics teaching (Han & Paine, 2010). Most domains show a correlation between the amount of practice and the level of expertise (Baker, Horton, Robertson-Wilson, & Wall, 2003; Ford & Williams, 2012). However, the amount of variance accounted for differs considerably between domains (Hambrick et al., 2014) with, for example, 26% accounted for in chess and only 4% accounted for in education. There is also substantial variability of practice, even between individuals performing at the same level (Gobet & Campitelli, 2007; Hambrick et al., 2014).

Research into deliberate practice has been particularly extensive in sports, where the correlation between the amount of domain-specific practice and skill level has been an area of debate. Many researchers have shown this correlation to be a robust phenomenon. For example, in soccer, over a career period of 18 years, international players accumulated more deliberate practice (M = 9,332 hr) than national players (M = 7,449 hr) and provincial players (M = 5,079 hr) (Helsen, Starkes, & Hodges, 1998). However, differences between sports have also been identified. Compared to soccer, Baker, Côté, and Abernethy (2003a) reported shorter periods to excellence in basketball (M = 5,908 hr of deliberate practice), netball (M = 2,260 hr). and field hockey (M = 3,583 hr). Furthermore, Baker, Côté, and Deakin (2005) reported that the period to excellence is fairly long in Ultra Distance Triathlon, requiring a mean of 12,558 hr, with considerable variability (range: from 8,004 hr to 19,630 hr). This result is not totally unexpected, as high levels of specialization are required in three different activities: swimming

(*M* = 3,472 hr), cycling (*M* = 5,039 hr), and running (*M* = 3,457 hr), although results do identify the likely performance benefits of practice of the other two sports (i.e., conditioning achieved by swimming and cycling may be beneficial in running). Analyzing the careers of 15 Olympic sprint champions and of the 20 fastest male American sprinters, Lombardo and Deaner (2014) found that these athletes were considered as exceptional already before starting training and that they reached world-class level in fewer than 10 years of deliberate practice (a median of 3 years for the Olympic champions, and 7.5 years for the fastest American sprinters). Ericsson (2006) acknowledges that "people are able to reach world-class levels in fewer than ten years in activities that lack a history of organized international competition" (p. 692). However, as noted by Hambrick, Burgoyne, Macnamara, and Ullén (2018), activities such as running and chess, where individuals have reached expert level in much less than 10 years, do enjoy a long history of organized international competition.

In contrast, research comparing the sporting history of elite athletes across sports has focused on prior sport engagement that cast doubts on the robustness of the relationship between domain-specific practice and skill. Studies comparing medalist and non-medalist elite performers found that medalists were more likely to have engaged in coach-led practice and competitive opportunities not associated with their medal winning sport; in addition, they started to engage in the medal-winning activity later than non-medalists (Güllich & Emrich, 2014; Güllich, 2017). This demonstrates that, when sub-elite levels of expertise are compared with elite levels, the monotonic relationship between practice and skill is not confirmed.

Williams and Ericsson (2008) note that the sports domain has particular difficulties in identifying and measuring particular components of deliberate practice, leading to loose definitions of the term and thus variable estimates of the amount of deliberate practice needed to reach expertise. Furthermore, Ericsson et al.'s (1993) data rely upon professional musicians with a mean age of 50.5 years recalling what practice they did at ten years of age, thus leading to the likelihood of recall bias. Contrary to theory, deliberate practice activities have been found enjoyable in several sports (Helsen et al., 1998; Hodges & Starkes, 1996). Not only individual, but also team practice is essential in many sports (Helsen et al., 1998; Ward, Hodges, Williams & Starkes, 2007). In addition, several athletes use techniques such as mental concentration and imagery in addition to deliberate practice (Starkes, Deakin, Allard, Hodges, & Hayes, 1996).

As noted above, deliberate practice predicts that the best way to reach excellence is through early specialization, as this optimizes the number of hours engaged practicing. However, while some studies support early specialization in sports such as soccer and rhythmic gymnastics (Law, Côté, & Ericsson, 2007; Ward, Hodges, Williams, & Starkes, 2007) others support the opposite approach, namely early diversification (Barynina, & Vaitsekhovskii, 1992; Carlson, 1997; Güllich, 2014; Güllich, 2018b) in sports such as swimming, baseball, tennis, field hockey, netball, and basketball.

The aim of this article is to understand the role played by the demands of the sport chosen, including its relation to motor skill and energy pathway, the role of early practice and the role of individual versus team practice in attaining top-level athletic performance. To do so, we researched the participants selected to compete for Team GB in the London 2012 Olympics in athletics. The domain of track and field athletics offers a range of events where features such as motor skill and the energy pathway utilized are clearly determined. In particular, we attempted to ascertain whether 10 years of deliberate practice to expertise, early specialization (domain-specific practice), and individual practice (compared with team practice) are necessary conditions for acquiring expertise within the domain of track and field athletics. Our hypothesis was that the period to excellence in track and field athletics is affected by the following variables: (a) motor skill, classified using Magill's one dimensional system (Magill, 2001) and operationalized in our study as track (gross, continuous, open), field (gross, discrete, open), and multi-events (gross, continuous/discrete, open) (International Olympic Committee, 2012), (b) the energy pathway (dominant aerobic or dominant anaerobic) (Kenney, Wilmore, & Costill, 2012) using Fox, Bowers, and Foss's (1993) sports classification; and (c) previous sporting experience with three aspects: diversification vs. specialization, energy pathway (dominant anaerobic vs. dominant aerobic), and sport type (individual vs. team).

Method

Participants

The sample consisted of all participants in athletics selected for Team GB in the London 2012 Olympics (*N* = 72). Participants were 44 men and 28 women aged 18 to 32 years (Men: *M* = 22.8, *SD* = 3.1; Women: *M* = 23.6, *SD* = 3.3). Multi-event athletes (*n* = 4) were not included, nor were two women field athletes due to the unavailability of data on their deliberate practice starting point. Table 1 displays the numbers of Great Britain track and field medal winners at London 2012 Olympics.

The sample was partitioned in four ways: (a) type of current sport, sub-divided into track-running events (*n* = 57) and field events (*n* = 15); (b) energy pathway of current sport, sub-divided into dominant aerobic (*n* = 21) and dominant anaerobic (*n* = 51); (c) energy pathway of previous sports, sub-divided into dominant aerobic (*n* = 21), equal contribution from aerobic and anaerobic pathways (*n* = 19), and no previous sport (*n* = 32); and (d) composition of previous sports: team sports (*n* = 25), individual sports (*n* = 15), and no previous sport (*n* = 32).

Table 1. Great Britain medal winners at London 2012 Olympics

Team GB London 2012 Track and Field results			
Medal	Gold	Silver	Bronze
Quantity	4	1	1

Data Collection

We identified all Team GB track and field athletes selected for the London 2012 Olympics. In the literature, this is characterized as a hard-to-reach population (King, O'Rourke, & DeLongis, 2014; Rhodes, Bowie, & Hergenrather, 2003). The following online sources were drawn upon. First, the search engine Google (https://www.google.co.uk/search) was used as a general source of information. Second, the BBC (B.B.C., n.d.) media website provided the following information: (a) identification of participants, (b) date of birth, and (c) some social networking information, such as Twitter, Facebook, and personal website addresses, where further biographical data may be sought. Third, the Telegraph (Telegraph, n.d.) newspaper website provided basic biographical information such as when the athlete started in their sport, whether they had competed in other sports, and when they joined a club and focused on their sport. Fourth, the search for further biographical information was enhanced by a Google search based on athletes' names and identifying their personal website, which often linked to personal agents and promotional companies. Finally, we used the website Power of 10 (Power of 10, n.d.), which is the official statistical tool of UK Athletics. This site offers a complete list of registered performances in UK meetings, plus notable participations in national meetings and selections for international meetings. In addition, information was sought via personal management companies and agents, who often represented more than one Team GB athlete. This involved simple questions for them to obtain answers from the athlete, such as (a) When did you start to focus on your sport? (b) At what age were you coached for your sport? (c) Did you train for any other sport prior to focusing on your main sport? If yes, which sport?

Measures

As seen above, the period to excellence from novice to expert is hypothesized to be at least 10 years. To operationalize this variable, we used the difference between the finishing point (expert) and starting point (novice), as suggested by Ericsson et al. (1993). All durations < 10 years were considered in disagreement with the deliberate practice framework. All durations ≥ 10 years were considered in agreement with the deliberate practice framework.

The start of deliberate practice was operationalized in accordance with Ericsson et al. (1993). We took the point at which athletes initiated a motivated attempt to enhance performance, using the criteria specified by Ericsson et al., such as joining a club, being coached, or engaging in competition within the sport of choice. The end of the period to excellence coincides with the mastery of existing techniques and knowledge, which is often exemplified by the individual earning an income from performances within the domain. In our sample, the finishing point was operationalized as the first selection for an international senior outdoor athletic championship (for full detailed results from Team GB 2012, see Table 2). The term "senior" is defined by UK Athletics as representing athletes who are 20 years or older on the 31st o December in the year of competition; under-17 men and women (school years 10 and 11) may compete against seniors in events less than 3000 meters (see UK Athletics Rule Book, http://uka.org.uk/competitions/rules/).

The first author collected the athletes' date of birth, starting point of deliberate practice, previous sporting experience, and date of acquiring expertise. The second author independently coded the starting point of deliberate practice and the date of acquiring expertise. The two coders were in agreement in 91% of the cases. The points of disagreement (3 starting dates and 10 finishing points) were all resolved through discussion.

Table 2. Championships in which expertise was first achieved

First competitive senior championships				
Championships	World	Commonwealth	Olympics	European
Quantity	22	13	21	16

Two types of sports were identified (International Olympic Committee, 2012; Magill, 2001). *Track events* consisted of gross, continuous, and open skills; and *field events* consisted of gross, discrete, and open skills. The track, marathon, and race-walking athletes represented the track group, and the jumps; and throws athletes represented the field group. In addition, in line with the sport-science literature (Kenney et al., 2012), two energy pathways were selected based on the dominant use of either the *anaerobic pathway* or the *aerobic pathway* in performance (Fox et al., 1993). The dominant anaerobic group consisted of athletes where performance energy was obtained from two systems, either the anaerobic alactic (ATP-CP) or the anaerobic lactic (Bompa & Carrera, 2005). The track athletes from sprints up to 800 meters and field event athletes represented this group (Fox et al., 1993). The dominant aerobic group consisted of those athletes where the main determinant of performance was aerobic energy (Bompa & Carrera, 2005)**;** this group was represented by the events further than 800 meters (Fox et al., 1993).

The question on previous sport participation made it possible to pinpoint the sports in which the participant trained prior to focusing on their Olympic event. However, the extent to which this was deliberate practice could not be ascertained. The influence of previous sport involvement was studied from two perspectives. The energy pathway perspective subdivided sports into (a) dominant aerobic, (b) combination of both aerobic and anaerobic (no participants identified exclusively a dominant anaerobic sport) and (c) no previous sporting experience. The sports composition perspective subdivided sports into (a) team, (b) individual performance, and (c) no previous sporting experience.

Results

Descriptive Statistics

Table 3 displays the descriptive statistics of our sample, and Figure 1 shows the frequency histogram of the period to excellence. Table A1 in the appendix provides the data for each individual.

Table 3. Descriptive statistics of the period to excellence (in years)

	N	Minimum	Maximum	Mean	Std. Deviation	Median
Period to Excellence	72	0.67	13.30	7.21	3.20	7.20
Starting Age	72	8.01	26.02	15.92	2.92	16.01
Expertise Age	72	18.34	31.99	23.33	3.27	22.59

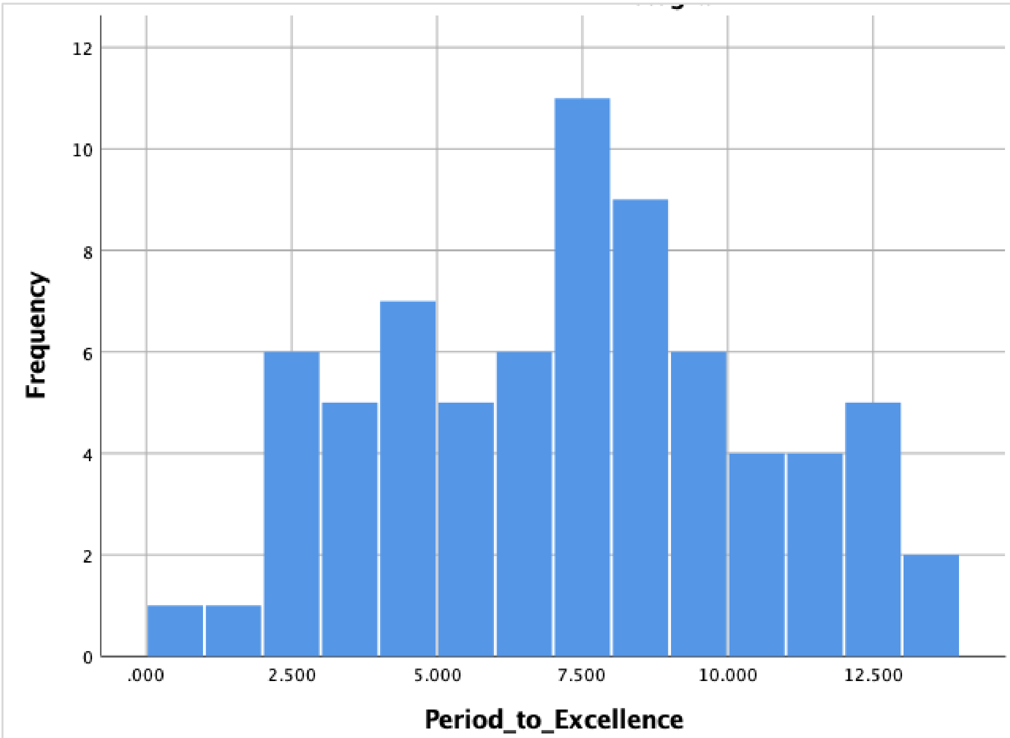

Figure 1. Frequency histogram of period to excellence

The Period to Excellence Measured from the Entire Sample (*n* = 72)

To become an expert took on average 7.20 years (*SD* = 3.20). There was no reliable difference between female (*M* = 7.41 years, *SD* = 3.13, *n* = 28) and male athletes (*M* = 7.08, *SD* = 3.27, *n* = 44), F (1, 70) = 0.18, p = .676, η_p^2 = .003. Fifty-seven athletes (i.e., 79.2% of the sample) needed less than 10 years to reach expert level. A t-test revealed a statistically significant difference between the observed mean period to excellence and the hypothesized 10 years, t (71) = -7.41, p < .001, 95% CI of mean difference [-3.54, -2.04].

The Period to Excellence and Its Association with Event Type

The mean period to excellence for track athletes was 7.43 years (*SD* = 3.37, *n* = 57, range = 0.67–13.30 years). Forty-three athletes reached expertise before 10 years, representing 75.4% of all track athletes irrespective of event. The mean period to excellence for field athletes was 6.36 years (*SD* = 2.38, *n* = 15, range = 1.82–10.49 years). Fourteen athletes reached expertise before 10 years, representing 93.3% of all field athletes irrespective of event. The difference between track athletes and field athletes (1.07 years) was not statistically significant, F (1, 70) = 1.33, p = .253, η_p^2 = .019.

The Period to Excellence and Components Associated with the Energy Pathway

The mean period to excellence of the dominant anaerobic group was 6.15 years (*SD* = 2.84, *n* = 51, range = 0.67–12.72 years). Forty-seven athletes reached expertise before 10 years, representing 92.1% of all athletes using predominantly the anaerobic system, irrespective of event. A t-test revealed a statistically significant difference between period to excellence and the hypothesized 10 years, t (50) = -9.70, $p < .001$. The mean period to excellence of the dominant aerobic group was 9.78 years (SD = 2.52, n = 21, range = 3.69–13.30 years). A t-test revealed that the observed mean period to excellence did not differ significantly from the hypothesized 10 years, t (20) = -0.4, $p >.05$. Ten athletes reached expertise before 10 years, representing 47.6% of all athletes using predominantly the aerobic system, irrespective of event. The dominant anaerobic group was 3.63 years faster than the dominant aerobic group to reach expert level, a difference that is statistically significant, F (1, 70) = 25.97, $p < .001$, $\eta_p^2 = .27$ (see Figure 2).

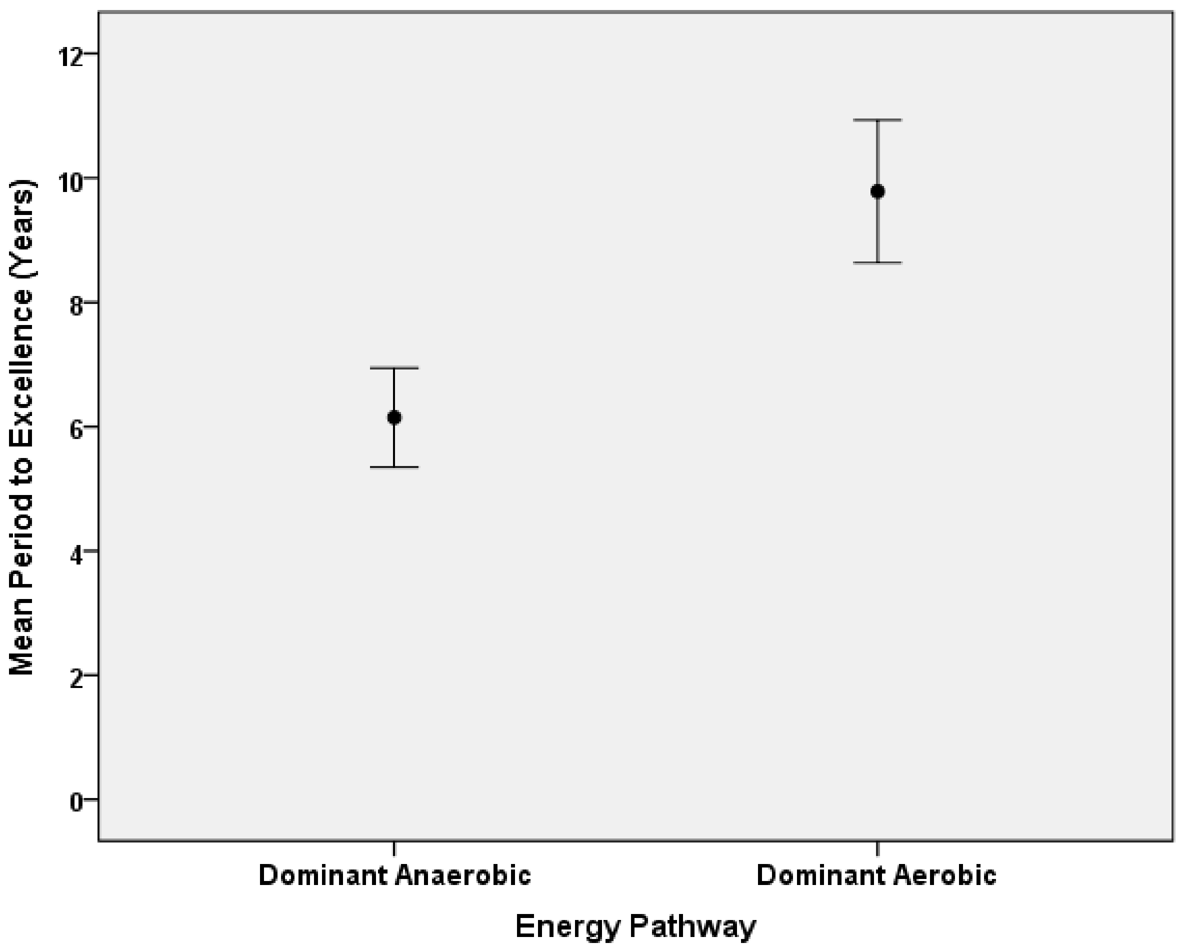

Figure 2. Period to excellence as a function of energy pathway; errors bars indicate 95% confidence intervals

The Period to Excellence and Previous Sporting Experience

Investigating the influence of an athlete's previous sporting experience showed that those who did not specialize early (n = 40) were significantly faster in acquiring expertise in a new sport than those who specialized early (n = 32), 6.27 ± 2.78 vs. 8.38 ± 3.34 years, F (1,70) = 8.53, p = .005, $\eta_p^2 = .109$**.** This suggests a contribution to performance from other sports and is inconsistent with the hypothesis that practice should be deliberate early on. However, even those who specialized early achieved expertise significantly quicker than 10 years, t (31) = -2.74, p = .01, 95% CI of mean difference [-2.82, -0.41].

The Period to Excellence and the Energy Pathway with Reference to Previous Sporting Experience

In this and the following analysis, we consider only those athletes who engaged in previous sports. The first group (the dominant anaerobic group) consisted of those athletes who had participated in previous sports such as cricket, gymnastics, and squash. For this group, the mean period to excellence was 5.99 years (SD = 2.34, n = 21). The second group combined anaerobic and aerobic group, where the energy systems were both engaged, and was represented by football, rugby, and ice hockey. Its mean period to excellence was 6.27 years (SD = 2.78, n = 19). An analysis of variance showed no significant difference between these two groups, F (1, 38) = 0.445, *ns*, p = .51, $\eta_p^2 = .012$.

The Period to Excellence and Previous Sporting Experience (Team vs. Individual)

The team group consisted of those athletes who had previously participated in sports such as cricket, football, and hockey. The period to excellence was 6.22 years (SD = 3.14, n = 25). The individual group consisted of those athletes who had previously participated in sports such as swimming, athletics, and tennis. The mean period to excellence was 6.34 years (SD = 2.14, n = 15). An analysis of variance found no significant difference between the two groups, F (1,38) = .019, p = .892, $\eta_p^2 = .000$.

Discussion

The framework of deliberate practice (Ericsson et al., 1993; Ericsson, 2016), which emphasizes the role of intensive goal-directed practice in becoming an expert while denying the contributions of talent (other than size and personality) and type of skill, has been highly influential in the last two decades. Previous investigators have utilized different roles within a sport to assess expertise, studying both single sports (Ford & Williams, 2008; Güllich, 2014; Güllich, 2018a; Helsen, Hodges, Van Winckel, & Starkes, 2000) and multiple sports (Baker et al., 2003; Güllich & Emrich, 2014; Güllich, 2017; Memmert, Baker, & Bertsch, 2010). Thus, typically, the speed in acquiring expertise in soccer is represented by a mean value of goalkeepers and outfield players, wingers, and defenders. However, the individual skill components that make up overall sports performance have largely been ignored. Particularly, investigators have focused on domain-specific enquiry to the detriment of understanding those talents and general skills of constituents that comprise individual differences. An exception is offered by Güllich and colleagues, who have made significant advances in understanding the interaction between previous sports training and domain practice in elite performance, critically concluding that it is organized practice in other sports, and not the main sport, that specifically contributes to elite performance (Güllich, 2014; Güllich & Emrich, 2014; Güllich, 2017; Güllich, 2018a; Güllich, 2018b). This research has concentrated on the characteristics of the current sport event (type of event and dominant energy pathway) and the characteristics of the previous sports (dominant energy pathway and individual versus team practice), affording an opportunity for investigating particular influences in acquiring specific athletic expertise.

The methodology utilized by Ericsson et al. (1993) identified the starting and finishing point for the measures of the period to excellence. The criteria of joining a club, being coached, and performing competitively within a sport-specific domain define different potential starting points and potentially can produce conflicting results. The concept of performing competitively is introduced as a catalyst for further competition and a precursor for joining a club or seeking a coach. We contend that competitive performance would normally satisfy these criteria. We identified each measure and utilized the earliest date identified. The finishing point of expertise was defined as competition in a senior international outdoor championship (note that we intentionally omitted junior competitions and senior indoor championships). International senior championships have strict selection criteria, which are usually based on two factors: (a) winning a national championship or (b) achieving a qualifying mark (e.g., distance, time). A junior who achieves these standards and has the requisite minimum age can compete at a senior level subject to several limitations, as there are age group differences (e.g., field implements are heavier, hurdles are higher, and juniors are not allowed to compete against seniors over 3000 meters or longer). Furthermore, indoor championships tend not to follow such exacting qualification standards as outdoor championships. In total, our strict criteria mean that it is possible that the actual finishing point of expertise is shorter than our chosen value. The consequence would be that the period to excellence is further reduced, thus strengthening our conclusions.

We considered using only participants who had achieved medal status as those who had achieved expertise. This methodology has been used previously in team sports (Barreiros, Côté, & Fonseca; Güllich, 2014; Güllich, 2017) as well as in individual (Barreiros, Côté, & Fonseca, 2013; Güllich, 2017; Moesch, Elbe, Hauge, & Wikman, 2011). However, the overall objective of our research was to investigate, across a wide range of events, if the energy pathway influenced the speed at which expertise was acquired. We would expect expertise to be achieved before elite medal status is acquired, and thus limiting our research to medalists was not necessary.

Using data from Team GB at the London Olympics in 2012, the current study tested a key prediction of the deliberate-practice framework – that it takes 10 years of deliberate practice to become an expert in any domain – and examined its boundary conditions. Consistent with Gobet and Ereku (2014), Baker et al. (2003a) and others, this prediction was not supported by the data, as the average number of deliberate-practice years in our sample was 7.20 years (*SD* = 3.20). Importantly, four-fifths of the athletes in our sample required less than 10 years. Although there was a tendency for track athletes who utilize gross, continuous, and open skills to take longer (7.43 years) than field athletes (6.36 years) using gross, discrete, and open skills, sport type was not significantly associated with the number of years to reach expertise. By contrast, energy pathway was associated with the mean period to excellence, with athletes in the dominant anaerobic group being significantly quicker (6.15 years) than athletes in the dominant aerobic group (9.78 years). Finally, the presence of a previous sport was reliably associated with the period to excellence, with athletes who specialized early taking longer (8.38 years) than athletes who did not specialize early (6.27 years). However, within the group of athletes who had previously engaged in different sports, neither the practice of team or individual sports nor the energy pathways of the previous sport(s) predicted the period to excellence.

As mentioned earlier, previous research had noted specific exceptions to the "10-year rule," for example in chess (Gobet & Ereku, 2014) and team ball sport (Baker et al., 2003). However, our data indicate systematic violations across a broad spectrum of track and field events. The current research suggests that the shorter dominant anaerobic events result in a reduced time to excellence compared to longer dominant aerobic events. This is in line with previous research (Hodges, Kerr, Starkes, & Weir, 2004) showing that practice results were event specific in swimming. Furthermore, the dominant anaerobic group consisted of many field athletes whose mean period to excellence was shorter than that in the dominant aerobic group. We suggest that the considerable time for physiological adaptations to occur in aerobic capacity inevitably leads to a longer period to acquire expertise.

Our results also shed light on the question of early specialization vs. diversification in sports, which has previously produced contradictory results (e.g., Gobet, 2015). Our data clearly support the importance of doing a variety of sports before specializing on the target sport. But what is the motivation for individuals to practice multiple sports? The results predominantly identify the teenage years as the initial period of acquiring expertise; variety is important, and we hypothesize that at this period it is the enjoyment of practice that leads to multiple sports activity (Gould & Petlickhoff, 1988). Both are contrary to Ericsson et al.'s (1993) claims that deliberate practice is not enjoyable and that diversification does not contribute to expertise.

Limitations

The study has a number of limitations. As is common with studies on world-class experts, the size of our sample was somewhat limited. In addition, we did not operationalize deliberate practice in the usual way, using retrospective protocols. In this respect, we note that the reliability of retrospective verbal protocol has been criticized in general (Ericsson & Simon, 1993) and in particular within the context of researching the topic of deliberate practice. For example, Macnamara, Hambrick, and Oswald (2014) note that the exact method of collecting measures of deliberate practice leads to substantial differences: With retrospective interviews, 20% of the variance in performance is explained; with retrospective questionnaires, 12% of the variance is explained; finally, with a log method, which presumably offers the best estimate as the amount of practice is recorded concurrently, only 5% of the variance is accounted for. Furthermore, we overcame potential recall bias by using online data collection methods which are considered at least as good as in-person data (Casler, Bickel, & Hackett, 2013; Gosling, Gaddis, & Vazire, 2007; Vazire & Gosling, 2004). Thus, our method, while not perfect, reflects recommended methodology in hard-to-reach populations such as elite athletes.

Our measure of the period to excellence calls for two comments. First, the cut-off we chose for achieving expertise – first selection for a senior outdoor international championship – was likely to extend this period. Importantly, by omitting junior and senior indoor championships, we selected an assessment of expertise made by an independent third party (the UK Athletics). Second, the way we estimated the age at which expertise was started has limitations, particularly with respect to the media data. For example, practice activities before the start year as defined in this article may have contributed towards expertise, resulting in longer period to expertise than we have calculated. However, we have rigorously followed Ericsson et al. (1993) to ensure that comparisons between deliberate practice and period to excellence are valid. Although other starting points are possible – e.g., prior coaching in a sport different from that in which expert performance was achieved (Güllich, 2014) – we considered it best practice for comparative purposes to utilize the definition provided by Ericsson et al. (1993). In addition, and importantly, even though the use of our method might include some time that is not optimal and thus might overestimate our measure of the period to excellence, the conclusions of this paper are not affected: If there is overestimation, the true amount of deliberate practice necessary for reaching expertise is even less than what we have reported.

Finally, the way we collected our data did not enable us to calculate a mean period of daily practice and compare it with the often-quoted 10,000 hours of deliberate practice applied over 10 years (Ericsson et al., 1993; Ericsson et al., 2007; Ericsson, 2016; Gladwell 2009). The period to excellence can be directly compared with the overall practice period (10 years) that takes into account practice, rest, recuperation, and rehabilitation after injury but not the hourly measures of practice. The application of daily practice to achieve expertise is influenced by individual differences and the many different periods to expertise reported in sport are most likely a representation of sports differences (Baker et al., 2003; Baker et al., 2005; Helsen et al., 1998; Hoare & Warr, 2000; Hodges & Starkes, 1996; Lombardo & Deaner, 2014; Ward, Hodges, Williams, & Starkes, 2007).

Conclusion

Altogether, our results add to a growing body of evidence questioning the deliberate practice framework (Hambrick et al., 2014; Macnamara, Hambrick, & Oswald, 2014). The amount of deliberate practice necessary for becoming an expert varies considerably between fields, and the fact that, in some sports, individuals can reach expert level in a couple of years, as shown in our data, suggests that other factors are important beyond domain-specific deliberate practice.

The deliberate practice hypothesis suggests that talent and previously acquired general skill do not directly contribute to the acquisition of expertise, which can instead be attained only after 10 years of deliberate, motivated practice. Our results suggest that expertise can be attained quicker than 10 years and that trying multiple sports before specializing in a new sport has a positive influence on the speed of acquiring expertise.

Authors' Declarations

The authors declare that there are no personal or financial conflicts of interest regarding the research in this article.

The authors declare that they conducted the research reported in this article in accordance with the Ethical Principles of the Journal of Expertise.

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Appendix

Table A1

ID	Gender	Type	Skill type	Energy Pathway	Age (years)	Period to excellence (Years)	Previous sporting influence (Physiological)	Previous sporting influence (team/individual)	Sport
1	1	100 & 4x100	1	1	18.8329	0.668	2	1	Soccer
2	1	100 & 4x100	1	1	20.3370	4.326	3	3	
3	1	100 & 4x100	1	1	22.9205	4.260	2	1	Soccer
4	1	200 & 4x100	1	1	19.1753	2.011	3	3	
5	1	200 & 4x100	1	1	25.9178	11.995	3	3	
6	1	400 & 4x400	1	1	18.3425	2.323	1	2	800m runner
7	1	400 & 4x400	1	1	27.3863	6.263	3	3	
8	1	400 & 4x400	1	1	22.2685	8.260	3	3	
9	1	800	1	1	22.4630	7.452	2	1	Soccer/Karate
10	1	800	1	1	27.2932	9.279	2	1	Rugby
11	1	800	1	1	20.5041	12.499	3	3	
12	1	1500	1	2	21.8301	9.175	3	3	
13	1	1500	1	2	24.1315	10.121	3	3	
14	1	5000	1	2	24.9041	8.893	1	2	Squash
15	1	5000 & 10000	1	2	23.3753	12.367	2	1	Soccer
16	1	10000	1	2	25.3068	13.299	3	3	
17	1	3000SC	1	2	25.6712	7.145	3	3	
18	1	110H	1	1	20.4027	2.389	3	3	
19	1	110H	1	1	20.2274	5.219	2	1	Range of sports @ 10
20	1	110H	1	1	25.9068	8.893	2	1	Soccer/Rugby
21	1	400H & 4x400	1	1	20.3205	2.307	2	1	Soccer
22	1	400H & 4x400	1	1	19.8329	4.855	3	3	
23	1	400H	1	1	22.4411	8.436	1	2	Swimming
24	1	High Jump	3	1	24.8466	8.255	3	3	
25	1	Pole Vault	3	1	20.2137	7.997	1	2	Began as hurdler
26	1	Long Jump	3	1	19.7178	3.707	1	1	Rugby, Soccer, badminton

ID	Gender	Type	Skill type	Energy Pathway	Age (years)	Period to excellence (Years)	Previous sporting influence (Physiological)	Previous sporting influence (team/individual)	Sport
27	1	Long Jump	3	1	20.8904	6.058	1	2	100/200m runner
28	1	Triple Jump	3	1	21.6027	6.592	1	1	Basketball, american football
29	1	Javelin	3	1	24.6877	8.677	3	3	
30	1	Discus	3	1	20.8356	1.822	2	1	Rugby
31	1	Discus	3	1	21.4822	4.874	2	1	Soccer and Rugby
32	1	Discus	3	1	27.1178	7.104	1	2	Sprints and Jumps
33	1	Shot Put	3	1	23.7945	7.110	3	3	
34	1	Hammer	3	1	22.4192	10.490	3	3	
36	1	50K Walk	1	2	23.1890	8.178	1	2	Tried all athletic events.
37	1	4x100	1	1	20.2658	5.255	2	1	Soccer
38	1	4x100	1	1	22.5562	3.162	2	1	Soccer
39	1	4x100	1	1	18.9205	6.912	3	3	
40	1	4x400	1	1	20.7260	4.208	1	1	Basketball
41	1	4x400	1	1	23.2575	6.912	2	1	Ice Hockey
42	1	4x400	1	1	22.6301	7.252	2	1	Soccer
43	1	Marathon	1	2	29.4959	13.074	3	3	
44	1	Marathon	1	2	30.3973	10.167	3	3	
45	1	Marathon	1	2	31.2877	11.274	2	1	Soccer
46	2	100 & 200	1	1	21.6027	3.077	3	3	
47	2	100 & 200	1	1	21.7726	5.071	3	3	
48	2	200	1	1	27.2959	6.282	3	3	
49	2	400 & 4x400	1	1	20.2219	2.211	1	1	U17/19 England Netball
50	2	400 & 4x400	1	1	27.5425	8.474	2	1	All sports
51	2	400 & 4x400	1	1	22.8274	2.814	1	2	High Jumper
52	2	800	1	1	22.0740	9.233	3	3	

ID	Gender	Type	Skill type	Energy Pathway	Age (years)	Period to excellence (Years)	Previous sporting influence (Physiological)	Previous sporting influence (team/individual)	Sport
53	2	1500	1	2	21.1014	8.189	2	2	Cross country
54	2	1500	1	2	23.6219	11.249	3	3	
55	2	1500	1	2	24.4219	9.263	1	1	Cricket
56	2	5000 & 10000	1	2	23.8795	9.068	1	1	Soccer,hockey,netball, swimming, tennis.
57	2	5000 & 10000	1	2	30.9151	11.959	3	3	
58	2	5000 & 3000SC	1	2	25.7479	10.112	2	1	Soccer
59	2	3000SC	1	2	21.6986	3.685	1	1	Hockey, swimming,netball, tennis
60	2	20K Walk	1	2	22.5507	5.732	3	3	
61	2	100H	1	1	23.7315	12.723	3	3	
62	2	400H	1	1	20.6247	4.200	3	3	
63	2	400H	1	1	24.4603	7.082	1	2	Swimming
64	2	Pole Vault	3	1	20.7616	3.748	1	2	Gymnast
65	2	Pole Vault	3	1	23.2493	5.879	1	2	Gymnast
68	2	Hammer	3	1	20.0712	4.060	1	2	Netball/Ballet/Trampoline
69	2	Javelin	3	1	22.0603	9.041	3	3	
73	2	4x400	1	1	22.8685	7.260	2	1	Lacrosse
74	2	4x400	1	1	23.1233	7.447	1	2	Hurdler
75	2	4x400	1	1	21.1562	7.030	1	2	Tennis
76	2	Marathon	1	2	28.8849	12.956	3	3	
77	2	Marathon	1	2	31.9890	7.504	3	3	
78	2	Marathon	1	2	29.3973	12.033	3	3	

Key.
Skill. Type 1 = Track, running, walking. 3 = Field events.
Energy Pathway. Type 1 = anaerobic pathway. 2 = aerobic pathway.
Previous sporting experience (Phys) Type 1 = aerobic and anaerobic. 2 = aerobic. 3 = none.
Previous sporting experience (Team/Ind) Type 1 = individual. 2 = team. 3 = none.