

Training history, deliberate practice and elite sports performance: an analysis in response to Tucker and Collins review—what makes champions?

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With the recent advances in genome-wide mapping studies and the emerging findings on the relation between athletes' training histories and their performance, this should be a time for integrating these two bodies of knowledge for a more complete understanding of the complex development of elite performance.¹ In their recent article, Tucker and Collins² criticised a popularised but simplistic view of our work circulated on the internet, which suggests that anyone who has accumulated sufficient number of hours of practice in a given domain will automatically become an expert and a champion. Unfortunately they incorrectly attributed this view to me and my colleagues and criticised our research on deliberate practice.

TUCKER AND COLLINS' MISUNDERSTANDING OF OUR CLAIMS FOR THE ROLE OF DELIBERATE PRACTICE

I agree with Tucker's and Collins' claim about the current failure 'to discover a candidate gene that can be conclusively linked to performance'.² However, they incorrectly state that I described this failure 'as evidence that genetics play only a minimal, or even no role, in the attainment of elite performance'.² There is a fundamental difference between claiming that there is evidence for the complete absence of genetic influences on elite performance in sport and claiming that *no current evidence exists* for such genetic influences. From the beginning of my research on expert performance I have made a point of distinguishing between empirical evidence collected on expert performers from beliefs or inferences from research on the general population.

In one of my first publications³ on expert performance I reviewed the compelling evidence for the absence of training effects on height and body size. I concluded that in many sports elite athletes are either systematically taller or shorter than the general population and these differences in height were virtually completely determined by genetic factors. In most of my subsequent publications I have simply referred to this review, and in doing so the importance I place on it may have been overlooked by others. My recent reviews^{1 4 5} have focused on the rich body of evidence that virtually every other aspect of the human body and nervous system can be modified by intense training, sustained for months and years, and that the degree of modifiability interacted with the childhood and adolescence developmental phase of athletes.^{1 4} These reviews found numerous studies documenting how engagement in intense physical training was associated with changes in muscle fibres, capillaries and size and structure of hearts. Some of these attributes were directly linked to the current level of training and receded back towards normal levels after reduction of intense training. For example, the heart size of athletes was dramatically reduced from when they competed at the Olympic Games to when they were tested again 10 years later.⁶ Furthermore, I have reviewed heritability estimates obtained with sedentary adults and non-athletes^{1 4} and questioned whether they can be generalised to expert athletes, who have engaged in several thousands of hours of training and attained qualitatively different physiological adaptations. I also reviewed studies of the genetic influence on the size of the training effect (trainability) and noted that only sedentary adults had been tested, which raises similar issues about valid generalisability to elite athletes—a similar concern was raised by Bouchard⁷ in his recent review. Finally these reviews also argued 'that heritable individual differences might influence

processes related to motivation and the original enjoyment of the activities in the domain and, even more important, may affect the inevitable differences in the capacity to engage in hard work (deliberate practice)'.^{1 4} In sum, my published reviews^{1 4 5} are mainly in agreement with those of Tucker and Collins² and together they show errors and omissions in the popularised internet views.

In their paper Tucker and Collins criticise a version of 'the 10000 h rule', namely 'that a specific volume of 10000 h of training *must be* accumulated over a period of approximately 10 years of structured training and involvement in an activity in order to achieve expert levels'.² They incorrectly attribute the 10 000 h rule to me and further state that I have claimed that deliberate practice is *sufficient* to explain the acquisition of all aspects of expert performance—a claim that I have never made.

THE RELATIONSHIP BETWEEN 'THE 10 000 HOUR RULE' AND THE DELIBERATE PRACTICE FRAMEWORK

Given the recent popularity of '10 000 h rule' it might be useful to trace its emergence. In a chapter with the title 'the 10 000-hour rule', Malcolm Gladwell⁸ described our research on expert violinists⁴ in considerable detail and then immediately afterwards offered the following generalisation: 'that excellence at performing a complex task requires a critical minimum level of practice surfaces again and again in studies of expertise. In fact, researchers have settled on what they believe is the magic number for true expertise: 10 000 h'. He then goes on to cite Levitin,⁹ who had written that 10 000 h of practice is necessary for world-class performance after citing our research. The popular internet version of the 10 000 h rule suggests that attaining expert performance is all about getting more and more practice and experience in a given domain of activity and then reaching an expert status at 10 000 h.

The distinctions between being an 'expert', reaching fame, and performing at a world-class level have disappeared suggesting that all experts have a similar development.

Given that this is my first opportunity to comment on 'the 10 000 h rule'—a term that I do not use in my own papers—it is important to point out the differences and inconsistencies with our research findings and the popular internet view. Our research on expert music performance focused on objectively measurable performance and claimed that this

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type performance is improved gradually by deliberate practice (defined as the engagement with full concentration in a training activity designed to improve a particular aspect of performance with immediate feedback, opportunities for gradual refinement by repetition and problem solving) and by maturation (responsible for increases in height and body size). In direct violation of the alleged necessity of 10 000 h in 10 years for becoming an expert, our original study estimated that one of our four groups of expert violinists had only *averaged* around 5000 h of solitary practice (the activity most closely matching the criteria for deliberate practice) at age 20⁴—as a consequence more than half of them had actually accumulated less than 5000 h. The best group of violinists with estimated prospects for an international solo career had accumulated an *average* of over 10 000 h at age 20. In fact, even Malcolm Gladwell misconstrued this and claimed that ‘the elite performers had *each totaled* ten thousand hours of practice’.⁸ Our main point was that the best group of violinists had spent significantly more hours practising than the two groups of less accomplished groups of expert violinists, and vastly more time than amateur musicians. There is nothing magical about exactly 10 000 h. Winners of international piano competitions continued full-time practice for many years beyond age 20 and thus accumulated around 25 000 h at the time of their success. In other domains, especially less competitive ones, it is possible to reach an international level in much less time. In the early 1980s my colleagues and I demonstrated that college students could reach a world-class performance for memorising digits after 500–1000 h of training.^{10 11}

More importantly, our research has never been about counting hours of any type of practice. In fact, it is now quite clear that the number of hours of merely engaging in activities, such as playing music, chess and soccer, or engaging in professional work activities has a much lower benefit for improving performance than deliberate practice.¹²

THE CHALLENGE OF COLLECTING VALID REPORTS OF PAST ENGAGEMENT IN DELIBERATE PRACTICE

Tucker and Collins reject the claim that the retrospective measures of practice history explains all of the variance in elite performance—a claim that I have never

made. They are correct about the difficulties of collecting valid estimates for past practice, especially if we want to distinguish deliberate practice from playing and unstructured practice. The approach in the original study was to search for types of training activities which were hypothesised to contain a higher proportion of deliberate practice than other music-related activities, yet would be sufficiently distinct that individuals could estimate, many years later, its average weekly duration. For example, most music students typically set aside time each day to work alone on assignments given by their music teachers at their lessons, and diary studies showed that this duration was quite stable from day to day. When we asked them to recall and estimate the weekly hours of practice for each year of their entire career we found that there was a significant correlation ($r(28)=0.74$)⁴ between their estimates for most recent year and their diaries—but obviously not perfect. The collected reliability of cumulated life-time practice at different test occasions in large samples has typically been found to range between 0.7 and 0.8¹³ implying that estimates of training history could never account for more than 49–64% of variance in measures of performance—even less for measures of performance that are not perfectly reliable. With these measures of the total duration of solitary practice activities reflecting a higher probability of deliberate practice summed over a decade, we can at most realise a significant correlation between our measures of training history and final adult performance.

These limited estimates of practice during the complete development of expert performance were viewed as composites and only a first step toward more detailed mechanisms of how specific types of deliberate practice and particular aspects of performance. The acquisition of expert performance is viewed^{1 4 13} as an extended sequence of successively attained levels of measureable performance. For example, music students have a curriculum, where they work on increasingly difficult techniques, such as complex chords and polyrhythms. By focusing on the mastery of a particular intermediate skill, we will be able to identify more specific types of deliberate practice and collect more recent reports on practice, perhaps even concurrent diaries, to build models of the amount, quality and type of practice and their association with measurable improvements related to that particular skill.

THE NEED TO COLLECT DETAILED DATA ON ATHLETES’ TRAINING HISTORIES

By collecting detailed knowledge on current goals for improvement of some measureable aspect of performance and concurrent practice we will be able to uncover more detailed mechanisms that account for previously demonstrated relations between training history and performance. For example, starting serious practice at a young age has been found to be associated with attaining elite adult performance and that early deliberate training in sports, ballet and music has been found to be beneficial.^{1 4 5} Early engagement in deliberate practice has been found to change neuronal myelination of particular regions of the brain in children and adolescents. Researchers have demonstrated brain changes in children that are linked to training in mental calculation, reading and practising music.¹⁴ A large number of studies have now demonstrated systematic differences in the structure of the brain for adult experts in basketball, golf, judo and diving compared to the general population.¹⁵ In a recent study,¹⁶ black belt Karate experts produced a punch with maximal force and, compared to controls, showed associated differences in the white matter of the cerebellum. Also, the experts showed correlations between brain differences and timing control, starting age and length of training.

In sports it has been less common to distinguish deliberate practice from other types of practice, but when this distinction has been made relations between some types of specific practice and elite performance has been amplified. For example, national middle-distance runners were found to differ from regional runners by their higher number of accumulated hours of weight and technical training¹⁷ (training with particular goals and immediate feedback), whereas the overall accumulated amount of training hours did not differentiate the two groups. Information about deliberate practice is more likely to emerge when we analyse the characteristics of athletes’ training at the time they actually improve their performance in a longitudinal design. For example, a recent review of longitudinal studies of long-distance runners and other endurance athletes concluded that the largest training effects for elite athletes required attaining the best balance of engaging in practice activities with both lower and very high training intensities.¹⁸ Other longitudinal studies of

performance and training^{19–21} have identified at which point during development there are reliable differences in aspects of performance between elite and subelite adult athletes, so future research can focus on the factors accounting for these particular differences.

TOWARDS A COMPLETE ACCOUNT OF THE INTERACTION BETWEEN GENES AND TRAINING ACTIVITIES

A full understanding of the complex extended development of performance of elite athletes requires detailed accounts of how current and past training activities and maturation change the body and nervous system. The expert performance approach suggests that we first identify aspects of objective performance that change during development and then assess which genetic and training factors and their interactions that best predict the improvement and attainment of that aspect of performance. It is possible to describe the whole genome and also describe the transcriptome in particular tissues²²—except perhaps highly complex changes in the brain tissue of athletes²³—so we should be able to identify the critical factors influencing particular performance improvements in future studies. As long as we agree that the information about training and genetic factors are important, there is nothing to be gained by prejudging the issue of how many genetic factors will be unique to particular individuals' innate endowment (such as height and body size) and how much reflects genes that healthy individuals have as part of their genomes. An important step towards this goal would be attained if the current genome-wide mapping studies of elite athletes also collected data on the athletes' training histories. In the future we should be able to develop statistical

models integrating genetic and training factors along with their interactions to account for the attained performance level of elite athletes, which in turn will inform coaches, athletes and sponsors about how to change selection and training to help future athletes reach their highest performance.

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