Centro Interdipartimentale di Scienze e Cultura dello Sport
Osservatorio Nazionale del Talento

Physical activity and health promotion master degree

An overview on Talent

The scientific state of the art and some considerations.

Prof. Bruno RUSCELLO, Ph.D

Bruno RUSCELLO, PhD
biodata

Researcher and lecturer at the School of Sport and Exercise Sciences, Faculty of Medicine and Surgery, “Tor Vergata” University of Rome, Italy, since 2008 (http://www.scienzemotorie.uniroma2.it/) and at the Faculty of Sports and Motor Sciences, “San Raffaele” University of Rome (http://sms.unisanraffaele.gov.it/), since 2012. Professor of Team Sports Theory, Techniques and Didactics; professor of Principles of Match Analysis (basic module – Bachelor’s Degree) and Match Analysis (advanced module – Master’s Degree in Sport Sciences).

Professor of applied Biomechanics in Sports (Master’s Degree in Sport Sciences) at the “Tor Vergata” University of Rome. Professor of Statistics (applied statistics in sports) at the “San Raffaele” University of Rome. Referee for many international journal of Sport Sciences (impact factor >1). Currently (2017) publishing scientific paper on the field of Biomechanics, Match Analysis and Exercise Physiology.

Former Senior Coach of the National Men’s Field Hockey Team and Technical Director of all the National Teams of the Italian Field Hockey Federation (2004 to 2011), Project Manager of the Italian Field Hockey National Teams (2013-2014) and the Director of the Centre for the Research and Studies of the Italian Field Hockey Federation.
Appointed as the Technical Director and Team Manager of the National Men's Field Hockey team (2014-2015).

Talent

- the “Talent" is a subject with a greater potential to excel in a particular activity (i.e. sport).
- He/She can provide a 10% higher performance compared to others of his/her age group

Williams and Reilly

RISKS

- The risk relating to the definition of TALENT is the series of reactions that stem from the very definition of a subject as a Talent:
- raising of motivations, expectations, investment and pressure;
- exclusion of individuals with similar characteristics.

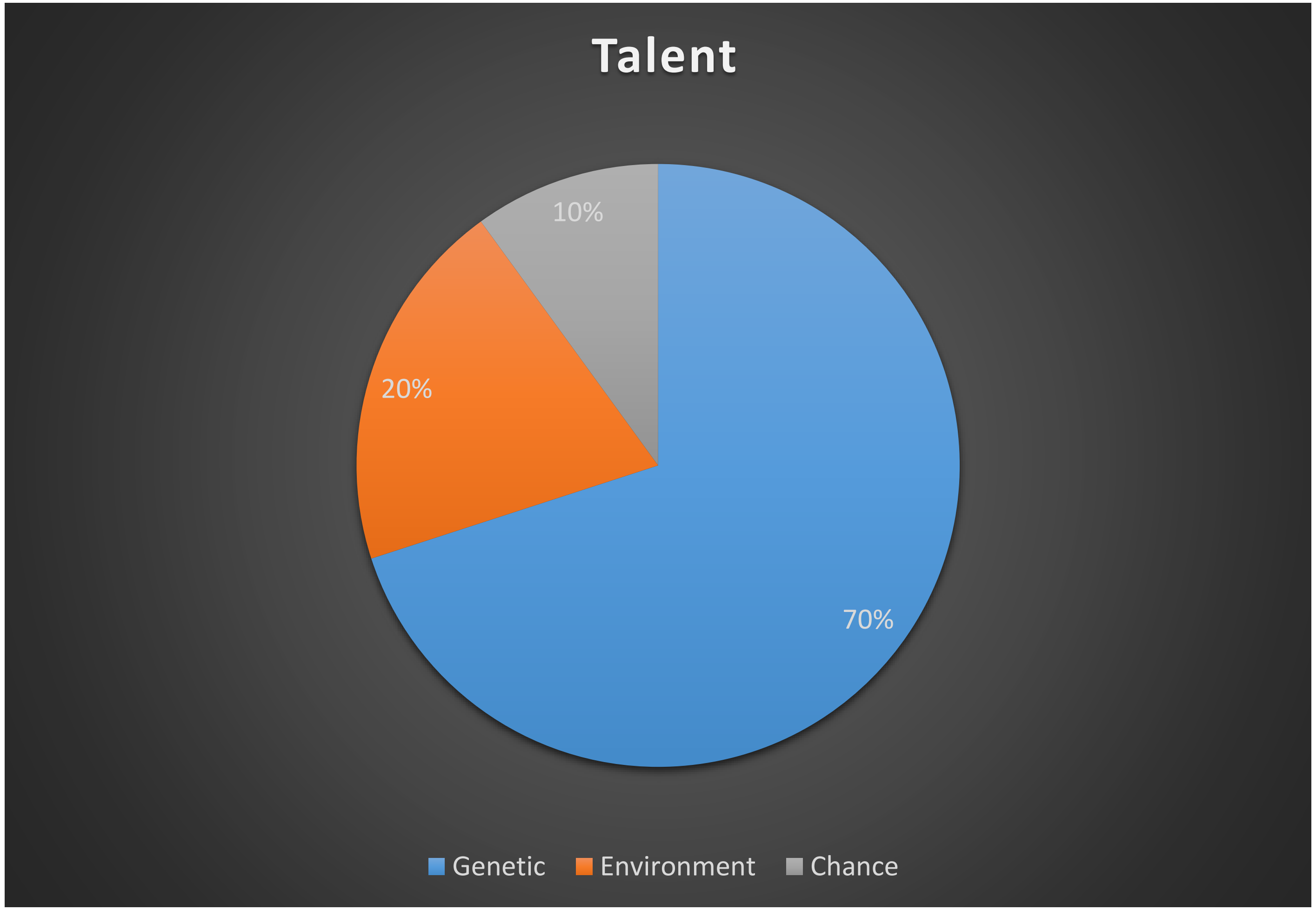
WHY ANTICIPATE?

- **MAKING PREDICTIONS**: means to say something verifiable in a intersubjective way with a specific content and an acceptable margin of error.

- But with humans and especially in sports this enterprise becomes almost impossible.

The Talent's formula

$T_e = 0,7G+0,2E+0,1C$



Talent and Genetic

- Understanding
- Orientation
- Guidance
- Doping
- …….

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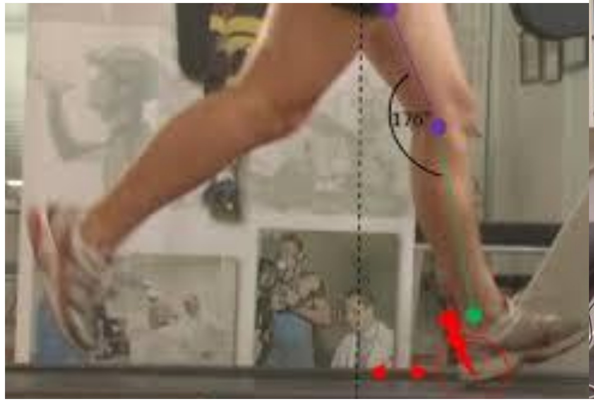
Talent and Environment

- Education
- Programming
- Planning
- Control
- Designing scenarios



Talent and Chance

- Fate (the cards I received…)
- Destiny (the game I play…)

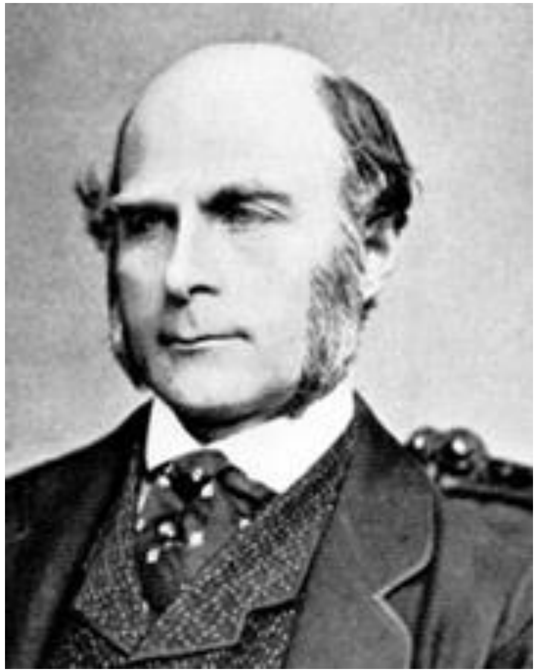
Br J Sports Med 2012;46:555–561. doi:10.1136/bjsports-2011-090548

What makes champions? A review of the relative contribution of genes and training to sporting success

Ross Tucker, Malcolm Collins

Considerable research exists on the roles played by both genetic factors and training in determining elite sporting performance.

The dismissal of either genetic or training factors to performance is a sort of anathema in sports science, since **considerable evidence exists to distinguish elite athletes from less well-performing athletes with respect to both genetic factors and training histories**.



Sir Francis Dalton

The ‘born versus bred’ question dates back to the 1800s, and the theory of Sir Francis Galton which posited that mental capacities are limited **by hereditary factors** (Galton 1869).

The Galtonian model proposed that practice and training would lead to improvements in performance, but that a ceiling existed for each person, influenced by heritable characteristics.

In contrast, **K. Anders Ericsson and others (1993)** have suggested that performance is constrained not by genetic or innate factors, but by engagement in deliberate practice and training during optimal periods of development.

According to this model, practice is both necessary and sufficient for the attainment of deliberate performance, and is effective because it "selectively activates dormant genes that are contained within all healthy individuals' DNA".

Ericsson has however, neither produced any evidence of **which genes these may be**, nor has he established that training **activates genes to the same extent** when comparing individuals.

Rather, his model is based on studies using **retrospective questionnaires** of training history, in skill-based activities including **darts and violin playing**, and overlooks a body of scientific literature which strongly disproves his model.

K. Anders Ericsson

Within the sports sciences, elite performance is understood to be the result of both training and genetic factors, as illustrated by models such as those proposed by Vaeyens et al. (2009) and Schneider (1997).

However, whether champions are **born** or **made** is a question that remains of considerable interest in the exercise sciences, since it has implications **for talent identification and management**, as well as for how sporting federations allocate scarce resources towards the optimization of **high-performance programmes**.

Psychological Review
1993, Vol. 100. No. 3, 363-406

OO33-295X/93/S3.OO

The Role of Deliberate Practice in the Acquisition of Expert Performance

K. Anders Ericsson, Ralf Th. Krampe, and Clemens Tesch-Romer

The theoretical framework presented in this article explains expert performance as the end result of individuals' prolonged efforts to improve performance while negotiating motivational and external constraints. In most domains of expertise, individuals begin in their childhood a regimen of effortful activities (deliberate practice) designed to optimize improvement. Individual differences, even among elite performers, are closely related to assessed amounts of deliberate practice. Many characteristics once believed to reflect innate talent are actually the result of intense practice extended for a minimum of 10 years. Analysis of expert performance provides unique evidence on the potential and limits of extreme environmental adaptation and learning.

THE DELIBERATE PRACTICE MODEL FOR EXPERT PERFORMANCE

The model for deliberate practice, as proposed by Ericsson et al. (1993) holds that "the distinctive characteristics of exceptional performers are the result of adaptations to extended and intense practice activities that selectively activate **dormant genes** that are contained within all healthy individuals' DNA".

Central to this theory is that **elite performance is achievable for any individual**, and is constrained primarily by the "**engagement in deliberate practice and the quality of the available training resources**"

Ericsson has further developed this model to propose that a specific volume **of 10 000 hours 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.

The fundamental study that led to the development of the deliberate practice framework and the 10 000 hours concept was conducted on violinists in Berlin, where it was found that the subjectively judged skill level of the violinists was associated with accumulated training time during the first 20 years of their lives.

That is, the best expert performers had accumulated just over 10 000 hours by the age of 20.

In contrast, those violinists judged to be good or average had accumulated only approximately 7800 and 4600 hours, respectively.

Ericsson concluded that there was “complete correspondence between the skill level of the group and their average accumulation of practice time alone with the violin”.

Crucially, however, Ericsson presented **no measures of variance** in the results in this study.

That is, no Standard Deviation (SD) or ranges were provided, and as such, it is unclear whether the association between training and performance applies to every individual.

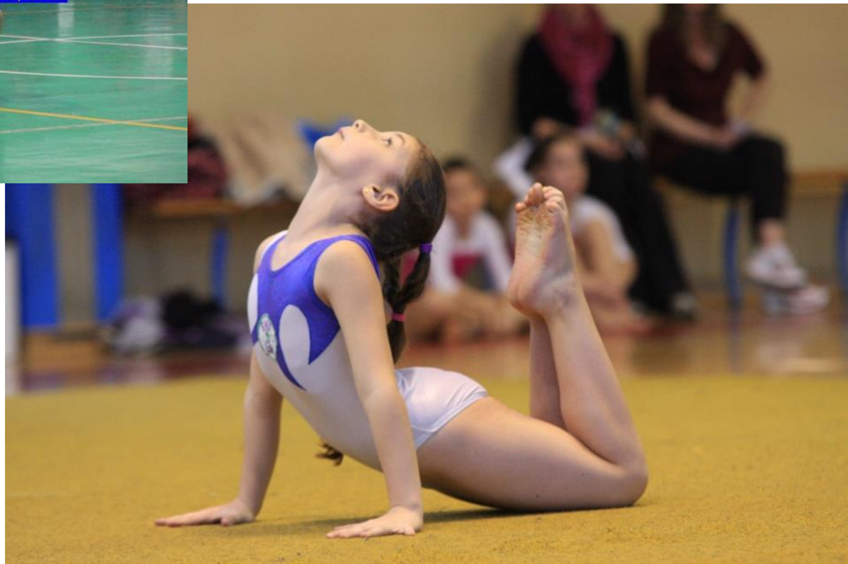
It must be emphasized that individual variation within groups is of crucial significance.

An individual who is able to achieve best expert levels can, according to this model, do so only if they engage in sufficient deliberate practice.
Similarly, the theory predicts that an individual who fails to attain expert levels must fail because they have not accumulated the required training time.

Any individual who violates either of these conditions, either by achieving best expertise with less time or by failing to achieve expert levels despite exceeding the training volume of peers, call into question the theory that posits that performance is the result of selective activation of DNA possessed by all individuals.

As such, studies of sporting performance that have examined variability are of considerable value.

The **Gronigen talent studies** on soccer, hockey, basketball, tennis and gymnastics have clearly shown **that talent identification requires an individualised approach**, since individual development curves differ so significantly from one another.



This is further shown in studies of chess performance

In one study, accumulated training time to reach master level in a group of 104 chess players was 11 053±5538 hours (mean±SD), in close agreement with the average time in the violin study.

However, enormous differences existed between individuals, as indicated by the SD and coefficient of variation (50%).

The fastest player to reach master level had done so after only 3016 h, while another had taken 23 608 h. Other players in the sample had failed to achieve master level despite accumulating over 25 000 h of practice.

Variables including practice time could account for only 34% of the variance in performance rating, and it was concluded that practice, while important for performance, was not sufficient for becoming a master.

Similarly, darts performance has been found to be poorly related to deliberate practice time, with only 28% of the variance in performance explained by accumulated practice time despite the accumulation of 12 839 h of practice over 15 years.

What does really means «deliberate practice»?

Ericsson has spoken of and defined “deliberate practice” as “practice activities with full concentration on improving some specific aspect of performance”.

For sport in particular, the wide scope of training activities may not be easily quantifiable, and there will be dispute over whether an hour of practice on one aspect of performance (for example, strength training) is as effective as another (tactical or skill training), or whether the individual is using ‘full concentration’ during practice.

However, it must also be noted that this theory, in its current form, is unfalsifiable, since the quality of practice can always be questioned to explain why the quantity of practice does not conform to some requisite number, in this case, 10 000 h.

However, the chess and darts studies clearly reveal a large range of required hours, and sports examples discussed subsequently show the role of **genetic factors in moderating both the response to training and the ultimate performance level reached**.

Studies of sport reveal that elite athletes rarely complete 10 000 h before reaching international levels.

For example, 28% of elite Australian athletes reached elite status within 4 years of taking up the sport for the very first time, while international level wrestlers, field hockey players and footballers had accumulated only 6000 h 4000 h and 5000 h of training, respectively.

Also of note is the finding that the best performing young footballers who will go on to play the sport professionally display superior dribbling skills, endurance capacity and tactical awareness compared to their peers, from as early as 14 years of age.

These differences appear well before it is possible to accumulate 10 000 h of practice, but allow predictions of which players will go on to achieve best performances in adulthood, **suggesting that the effectiveness of and response to training, rather than simply training, determines success.**

The factors responsible for differences in training adaptability are not known, but genetic factors seem likely.

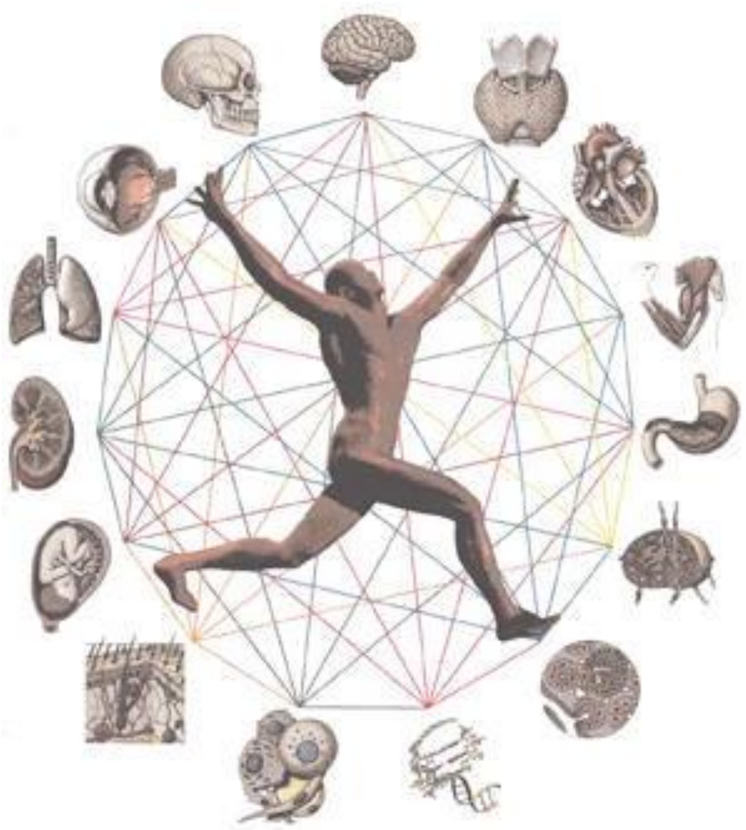
It is clear that the theory that expert level performance is the result of deliberate practice alone fails to account for the wide range of individual performance levels and responses to training observed in sport and skill-based activities like chess and darts and other sports.

In conclusion, the deliberate practice model for performance has contributed to our understanding that skill and certain aspects of physiological performance can be significantly improved as a result of deliberate practice.

However, this model has failed to demonstrate that expert performance levels are achievable for any and every individual, since large individual differences in performances achieved through training have been documented.

THE GENETIC INFLUENCE ON PERFORMANCE

At the biological level, numerous physiological and biochemical systems and pathways must interact and function optimally to enable elite performances. These include physiological and biochemical processes within the musculoskeletal, cardiovascular, central nervous and respiratory systems.



The optimal biological characteristics are sport-specific – the advantageous properties of skeletal muscle are very different for an endurance athlete compared with a sprint or power athlete, for example

When considered individually, each biological system is in its own right complex, consisting of different cell types, proteins and other macromolecules.

Multiple protein-coding and non-coding genes located throughout the entire human genome determine the genetic blueprint for each individual biological system.

With these layers of complexity from the whole body right down to the genetic material in each cell, **it is highly unlikely that a single or even a few genetic elements are associated with superior athletic performance.**

GENETIC COMPLEXITY AND GENETIC DETERMINANTS OF PERFORMANCE

Elite performance is a polygenic trait.

The genes that have been associated with performance or performance-related phenotypes to date have been extensively reviewed.

Generally speaking, different sets of genetic sequence variants have been associated with endurance performance and sprint/power events.

Although, investigators have primarily investigated the association of common variants with performance, the role of rare and other DNA variants, such as copy-number variants (CNV), also need to be considered when investigating performance or performance-related phenotypes.

Rather than merely listing and describing specific genes that have been associated with performance and performance-related traits, we will discuss the current knowledge of the role that genes play in determining four of the many intrinsic traits known to contributes to elite performance phenotypes.

These are
- sex,
- height,
- skeletal muscle properties and
- VO2max

Sex

While inherently obvious, biological sex is a key predictor of absolute levels of performance, and is the most fundamental biological characteristic where genes influence performance

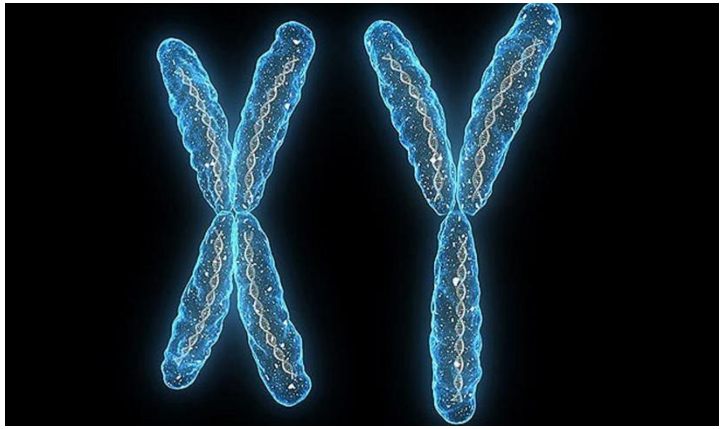
An analysis of world record performances in the track and road running events, ranging from the 100 m to a 90 km ultramarathon, highlights that the best males out perform the best females by between 9% and 14%.

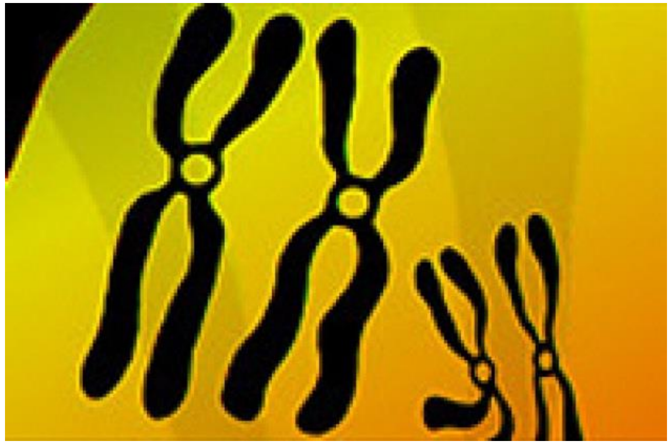
The current women's marathon world best time, for example, lies outside the top 3000 performances in the marathon's history.

Sex therefore plays a significant role in determining elite performance and is the reason that athletes compete in separate male and female categories for most sporting codes.

Sex is determined entirely genetically during development, and unless an athlete presents with one of the rare disorders of sex development, there is no difference between genetic and anatomical sex.

Although several genes are probably involved in sex development and more specifically involved in ovarian development, the SRY, SOX9 and DHTR genes are the best understood genes involved in the development of the male phenotype.





Height

Unlike sex, height is determined by both genetic and environmental factors such as nutrition, and is the result of several growth and developmental processes. Numerous studies report that height is highly heritable with 80% of its variance controlled by multiple genes (polygenic).

The influence of height on performance is of course sport specific – it is a prerequisite for success in sports such as volleyball, basketball and netball, whereas large body size and stature may be deleterious for endurance running, for example.

It has however been documented that athletes in many sports have been getting taller, heavier and more slender over time, even when corrected for changes in height and size within the general population.

Some talent identification programs, such as the UK's Tall and Talented program, adopt height as an initial screening variable for prospective Olympic athletes (http://www.uksport. gov.uk/pages/talent-2016-tall-and-talented/).

A discussion of the genetic determinants of height is thus relevant, for it illustrates:

(a) the genetic complexity of a relatively simple phenotype like height, further highlighting the complexity of identifying a performance gene, and

(b) how genetic factors may predispose an individual for success or mitigate against it based on their stature.

Meta-analysis of genome-wide association studies (GWAS) has identified 47 common genetic variants, which only explain 5% of height in Caucasians.

Recently, Yang et al 30 estimated that approximately 295 000 common Single Nucleotide Polymorphisms (SNPs) explained 45% of the variance in height within 3925 unrelated individuals using linear model analysis.

They also suggested that the remaining 35% of the variance determined by genetics could be explained by the incomplete linkage disequilibrium between the causal variants and the genotyped SNPs.

Rare genetic variants may however also account for a significant fraction of the 'missing heritability' in height

The implication of this finding is that height, a relatively easily measurable trait, is the outcome of small contributions of thousands of sequence variants within genes involved in the growth and developmental processes, which ultimately determine height.

Significantly, athletic performance is undoubtedly more complex than height, and if such a large population and almost 300 000 SNPs are able to account for only 45% of the variance in height, then the concept that a single gene, or even a few thousand genes, can explain athletic performance is grossly oversimplified and may ultimately be futile.

VO2max

Recently, Ericsson challenged the contribution made by genetic factors to the attainment of elite athletic performance by specifically focusing on VO2max and muscle fibre type heritability, and concluded that neither is a good trait that may be 'constrained by heredity'.

However, this conclusion fails to acknowledge a vast body of research that has established relationships between genetic factors and these two exercise related phenotypes.

For example, studies in which a large cross-section of individuals has been exposed to a standardised training program have found large individual differences in VO2max.

Collectively, the Heritage studies, the Dose Response to Exercise in Women (DREW) study and SSTRIDE studies have found an average training-induced improvement in VO2max of 15.2±9.7%, but the interindividual differences are significant.

For example, approximately one in seven individuals (14%) improved VO2max by less than 200 ml/min (less than 8% improvement compared to baseline).

In contrast, 8% of the population improved by more than 700 ml/min (a 28% improvement).

Both genetic and environmental factors have been reported to determine the VO2max in the untrained state and in response to training.

Approximately 50% of these two VO2max traits are heritable.

Genomic scans have identified markers on chromosomes 4, 8, 11 and 14 that are linked to VO2max in the untrained state, while a different set of markers on chromosomes 1, 2, 4, 6 and 11 were linked to VO2max trainability.

Using GWAS (*genome-wide association study*) with a panel of±325 000 SNPs, 21 of the SNPs were found to account for 49% of the trainability in VO2max.

One of the SNPs located within the acyl-coenzyme synthase long chain number 1 gene accounted (albeit mathematically) for 6% of the training response.

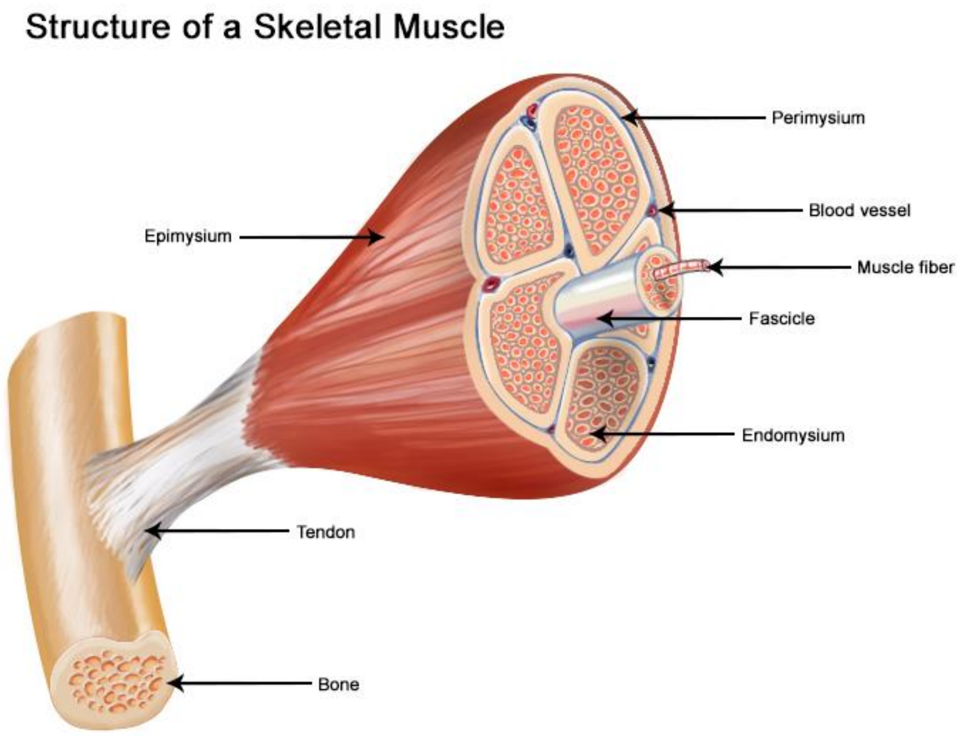
Significantly, individuals who carried nine or fewer of the previously mentioned 21 SNPs were found to have improved by less than 221 ml/min, whereas individuals who carried 19 or more of these alleles had improved by an average of 604 ml/min.

Clearly, the presence of certain SNPs has a strong influence on the response to training, which contradicts the conclusion made by Ericsson, and suggests a very powerful role for genes in performance.

Skeletal muscle

Skeletal muscle is a highly adaptable tissue responding positively to exercise but negatively to ageing, disuse and disease.
Skeletal muscle can be characterized by several traits. For the purposes of this lecture, these traits will be divided into:
(1) muscle mass and strength and
(2) muscle power and metabolism.

Although a large range, from 15 to over 90%, has been reported, all studies have shown that muscle mass and strength has a heritable component. Less data is available for the heritability of muscle anaerobic power, which ranges from 46% to 84%. Although heritability values of nearly 50% have been documented, it has also been reported that the environment plays the predominant role in the aerobic capacity of skeletal muscle.



Final Considerations

Given the enormous complexity of genotype–phenotype relationships and the complexity of the human genome, it is perhaps not surprising that a candidate gene approach has not been able to successfully identify all the genetic variants associated with performance.

Considering that approximately 295 000 SNPs explain only 45% of the variance in height, it is clear that performance, arguably a far more complex variable than height, may require enormous sample sizes and a staggeringly large number of SNPs and other types of genetic polymorphisms before it becomes possible to fully understand and appreciate the contribution inheritance plays in elite performance.

Although case-control genetic association studies have played an important role in starting to understand the specific details of the heritability of performance, the field needs to move beyond this approach if it wants to unravel the complex interaction between genes and the environment in determining athleticism.

Final Considerations

Although not a focus of this lecture, further complexity within genomics is found in the concept of **epigenetics**, which refers to heritable alterations in chromosome function or gene expression caused by mechanisms other than changes in DNA sequence.

It has recently been reported that exercise causes epigenetic changes that lead to improved memory and coping mechanisms in response to stress within rats.

The potential role that epigenetic mechanisms may play in contributing to superior performance remains to be determined.

In addition, although the focus of research on the genetics of performance and related phenotypes to date has been on the protein-coding genes, the likely role of non-protein genes such as miRNAs (micro RNA) in contributing to performance phenotypes also needs to be investigated.

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REVIEW ARTICLE

The Great British Medalists Project: A Review of Current Knowledge on the Development of the World's Best Sporting Talent

Tim Rees[1] · Lew Hardy[2] · Arne Güllich[3] · Bruce Abernethy[4] · Jean Côté[5] · Tim Woodman[2] · Hugh Montgomery[6] · Stewart Laing[7] · Chelsea Warr[7]

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With the competition for medals at Olympics and World Championships intensifying, there is greater investment than ever in sporting systems and structures to identify and develop exceptionally talented athletes.

The Australian Institute of Sport has been credited with boosting Australia's medal haul from five medals in the 1976 Montreal Olympics to 60 medals in the 2000 Sydney Olympics.

Team Great Britain (GB)'s fourth position in the 2008 Beijing Olympics medals table was supported by a markedly increased investment (£235M), and this funding continued to support Team GB's climb to third position in the 2012 London Olympics (£261M).

TEAM GB

When organizations such as UK Sport (the UK's high performance sports agency) commit a further £355M of public funds to the Rio 2016 Olympic cycle, it becomes increasingly necessary to be able to draw on an evidence-based understanding of the identification and development of the world's best sporting talent to maintain the success that is expected with this expenditure.

In order to provide recommendations for best practice in which practitioners could have confidence, we believed it was important to move beyond a purely narrative description of research evidence to rate the quality of evidence available. Thus, we provide additional information, by focusing on three key aspects:

1. Categorization of the performance level of the study samples as
   - **non-elite** (juniors or seniors competing below national level),
   - **junior elite** (junior national to junior international level),
   - **elite** (senior international level) or
   - **super-elite** (Gold medalists at Olympics or World Championships).

2. Employing a modification to the GRADE (Grading of Recommendations Assessment, Development and Evaluation) system to rate the quality of evidence (based on **study design, consistency of evidence and directness of evidence**)—indicating the extent to which we can be confident that an estimate of effect is correct;

3. Offering a recommendation (as noted in the GRADE guidelines) to **policy makers** and/or **practitioners** on whether to draw on the evidence and use it in practice.

Focus on: the Performer

Birthdate

Athletic success may be influenced by birthdate. The **relative age effect** (RAE) refers to a biased distribution of elite athletes' birthdates, with an over-representation of **those born at the beginning of any given competitive year** (e.g. September in most Western societies) and an underrepresentation of those born at the end (e.g. August).

A **meta-analysis** of studies from 1984 to 2007, examining non-elite, junior elite and elite-level athletes showed robust support for the RAE across ice hockey, soccer, baseball, basketball and volleyball.
More recent research with junior elite samples has provided additional evidence for this RAE with ice hockey, handball and soccer.

There is also evidence at junior elite level that RAEs **may be more prominent in boys than in girls**, as well as evidence that younger athletes figure more prominently in earlier rounds of drafting into US National Hockey teams, and some elite-level data demonstrating a greater proportion of relatively younger players at later stages of careers.

Research with non-elite- and elite-level samples has cautioned against the normal comparison of observed birthdates with an expected distribution of birthdates, because the distribution of birthdates within sports may be uneven due to younger athletes not choosing a particular sport— **a form of 'self-restriction'**—and younger athletes being more likely to drop out.

With **moderate study** design, **low consistency** and **moderate direct evidence** (up to elite level), the quality of the evidence that being relatively older is an advantage with regard to the development of super-elite performance in sport is **moderate to low**.

The evidence suggests that any advantage associated with being born in the first two quarters of the year may disappear by the time athletes reach elite level.

We therefore recommend that practitioners **do not make use of RAEs for talent selection or development purposes,** but rather policy makers and practitioners focus on **structuring the environment to limit the negative effect of relative age.**

Genetics

It would appear no longer a case of whether there is a genetic component to sporting performance, but rather which genetic profiles make the greatest contribution.

There is evidence at non-elite level that genetic factors explain 20–80 % of the variance in a host of measures: explosive strength, speed of limb movement, running speed, reaction time, flexibility, balance, bone mineral density, lean muscle mass, eccentric arm flexor strength, concentric arm flexor strength, arm cross-sectional area, change in maximum voluntary force, isometric strength and VO2max.

Specific gene variants appear to influence participation in physical activity —the GENEATHLETE project claims to have identified a phenotype for athletic status by comparing athletic samples with sedentary people. Indeed, 66 % of the variance in non-elite ‘athlete status’ may be explained by genetic factors.

A **significant heritable** component has been identified with non-elite samples in **agility, sprinting, jumping, throwing, kinematics and reaction time**, and also in **personality/character**.

Specific gene variants **may influence** the determination of **endurance/aerobic and muscle strength/anaerobic** performance.

In particular, substantial attention has been paid to the relationship of ACTN3 (actinin alpha 3) and VDR (vitamin D receptor) gene variants with strength/power.

Genetics are also related to susceptibility to injury.

The E4 variant of the apolipoprotein E epsilon4 (ApoE4) may be associated with increased severity of chronic neurological deficits in high-exposure non-elite boxers, while genetic variation within the collagen type 5 alpha 1 (COL5A1) gene has been associated with Achilles tendon [105] and anterior cruciate ligament injury in non elite athletes when compared with non-injured controls.

With **high study designs**, **moderate consistency** and **moderate direct evidence** (up to elite level), the quality of the evidence that genetics could make an important contribution to talent selection and development in sport **is at least moderate**.

Indeed, although rare combinations of gene variants are likely to act in concert to yield propensity to super-elite athlete status, and elite performance cannot necessarily be predicted well from genetic factors, genetic factors may influence the sport in which athletes are most likely to successfully compete.

Genetic selection methodologies may, however, come with negative reputational, personal, ethical and societal impacts.

We therefore recommend that **policy makers** and **practitioners** consider **the possibility of using genetic profiling to help athletes** make more informed and appropriate decisions about sport type and discipline during their development years.

We may only be able to evaluate the true benefits of genetic testing when geneticists and sports scientists collaborate in large prospective cohort studies that empirically determine the utility of genetic analyses in predicting future performance.

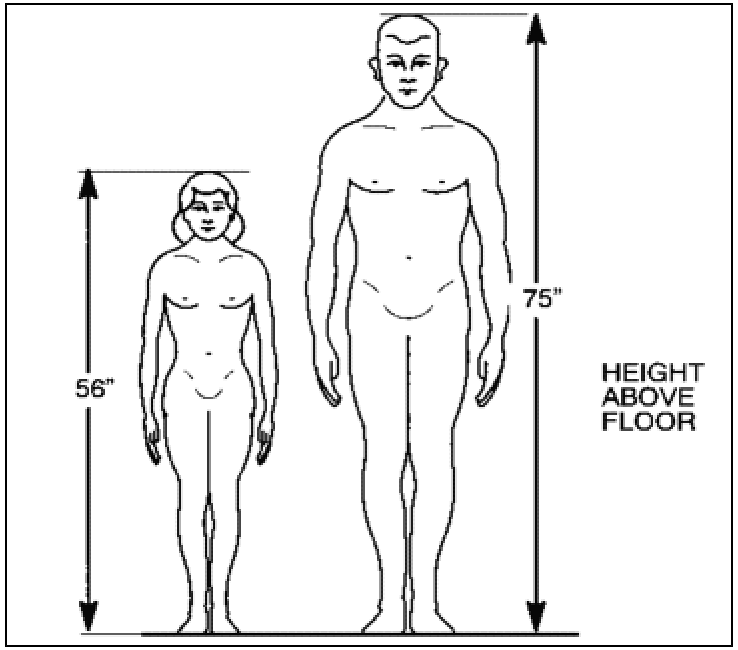
The potential impact of genetics could be great, and thus further research in this area is warranted, in particular in relation to specific performance genes, training/learning genes and genes underpinning injury proneness.

Anthropometric and Physiological Factors

There is a long history of anthropometric studies of Olympic athletes, dating back to documenting the physique of track and field athletes at the 1960 Rome Olympics. As a result, both anthropometric and physiological factors have now been identified across a number of sports at all levels of performance: non-elite, junior elite, elite and super-elite.

Among the many variables examined are: height, weight and (lean) body mass; bone mineral content and density; limb length and circumference; amount of adipose tissue; jumping and sprinting ability; strength; and VO2max.

This research has examined a wide range of sports, including: Australian Rules football, basketball, canoe polo, field hockey, football, handball, netball, rowing, rugby league and tennis.



Clearly, **aerobic capacity, anaerobic endurance and anaerobic power** are important for optimal sport performance, with a large proportion of training focused on these qualities, and with specific protocols for physiological assessments likely to be different across different sports.

Although morphology-related factors may be involved in directing some athletes to specific sports —e.g. gymnasts and divers are typically the smallest and lightest of all athletes; weightlifters and powerlifters have a high ratio of sitting height to stature caused by shorter than average upper and lower limb **lengths—some argue that anthropometric research has been over-interpreted**, **leading to the questionable practice of anthropometric profiling** to identify athletes for early selection and Specialization in a sport.

Factors such as **individual variability** in growth, the **unstable nature** of anthropometric—as well as physiological—measures throughout adolescence and the limited predictability of performance **potentially limit the utility of anthropometric and physiological measures for talent identification purposes**.

Biological maturation should thus be accounted for in talent identification. Hormonal changes during puberty result in physical and physiological changes, which are important for sporting performance. **A review across many sports with non elite and junior elite data concluded that significant changes during puberty make the prediction of adult performance from adolescent data challenging**.

With **high study design**, **high consistency** and **high direct relevance** (up to super-elite level), the quality of the evidence that anthropometric and physiological factors contribute to the development of super-elite performance in sport is **high**. **However, changes during puberty make the prediction of adult performance from adolescent data unreliable**. We therefore **recommend** that practitioners make use of physiological testing for purposes of informing the training process, and make use of anthropometric profiling and physiological tests for both talent selection and development purposes, but policy makers and practitioners should ensure that such action is accompanied by **appropriate procedures (considering biological maturation) to 're-capture' lost/missed late maturers.**

Psychological Skills and Motivational Orientations

As long ago as 1977, Mahoney and Avener attempted to identify some of the psychological characteristics of elite gymnasts. There is now evidence at non-elite, junior elite, elite and superelite level that more successful athletes display higher levels of motivation, higher levels of confidence and perceived control, higher levels of mental toughness and resilience, better ability to cope with adversity, greater resistance to 'choking' (i.e. performing worse than expected) in high-pressure situations, and command a wide range of mental skills (e.g. goal-setting, anxiety control, imagery, self-talk and decision-making).

Evidence at elite and super-elite level suggests that athletes display a strong orientation to base their perceptions of competence on personal improvements, but that at non-elite, junior elite, elite and super-elite, level athletes also display a strong ego orientation to formulate perceptions of competence by comparing their own ability with that of others.

There is also evidence that non-elite- and elite- level athletes can use anxiety to enhance their performance. In particular, athletes have been noted to produce both their best and their worst performances when anxious.

This may be because anxiety is associated with higher levels of effort which could lead to higher levels of performance, provided the performer does not lapse into attempting to consciously control each specific movement or action . Higher performing athletes also interpret their anxiety symptoms as being more facilitative to their performance than lower performing athletes .

There is evidence at non-elite and elite level
that successful athletes display self-determined forms of motivation, and that the greater the levels of this form of motivation, the lower the risk of burnout.

However, there is also evidence that elite athletes have higher levels of extrinsic motivation and lower levels of intrinsic motivation than less accomplished athletes .

More recent research has found that obsessive (more controlling) passion in non-elite athletes is a stronger predictor of deliberate practice, and thus sports performance, than harmonious (more self-determined) passion.

With **moderate study design**, **high consistency and high direct relevance** (up to super-elite level), the quality of the evidence that psychological factors are an important contributor to the development of super-elite performance in sport is **high to moderate**, although the evidence is more widespread across some psychological characteristics than others.
We therefore recommend that practitioners make use of psychological profiling for talent development purposes.

Key questions for future research include examining the causes of exceptional levels of motivation, resilience and mental toughness, including assessing whether and how psychological skills at junior level influence long-term adult elite/super-elite performance.

How do exceptionalperformers use their anxiety in a positive way? How do the world's best performers maintain focus and concentration, while avoiding lapses into conscious control? How can these skills be trained?

Personality Traits

There is evidence at non-elite, elite and super-elite level that more successful athletes display greater **conscientiousness, dispositional optimism and hope than less successful athletes**. There is also evidence at non-elite, elite and super-elite level that athletes display adaptive perfectionism—a tendency to maintain perspective on performances while striving to achieve exceptional standards. This contrasts with the many negative outcomes (e.g. burnout, preoccupation with mistakes and self-doubts) associated with (maladaptive) perfectionism. There is evidence at non-elite level for the influence of **narcissism** on performance. Narcissists have an inherent (albeit unrealistic) belief in their ability, but this selfbelief may well facilitate **very high levels of performance under pressure**.

With moderate study design, moderate to low consistency (generally consistent, though relatively infrequent) and high direct relevance (including super-elite level), the quality of the evidence that personality is an important contributor to the development of super-elite performance in sport is moderate.

Furthermore, the risks associated with practitioners acting on the available evidence for talent development purposes seem to be only modest, although the same cannot be said with regard to using it for talent selection purposes. We therefore recommend that practitioners might make use of personality profiling for talent development but not talent selection purposes.

Future research could focus on whether there are other important (combinations of) personality characteristics that are necessary for the development of a strong competitive personality and how these characteristics might be best developed.

The Environment

Birthplace

There is evidence across junior elite and elite levels that the size of the city where an athlete spends his/her developmental years can affect the likelihood of attaining elite-level performance. Small to medium-sized communities (circa 30,000–1,000,000) appear to offer the greatest opportunities for success, although there is wide variation (not least because a medium-sized city in one country may be considered small or large in another), and in UK-based data, areas with populations of 10,000 and 29,999 are more likely to produce Olympic athletes, with areas between 500,000 and 999,999 being disadvantaged.

With moderate study design, high consistency and high direct relevance (up to super-elite level), the quality of the evidence that **birthplace offers an advantage** with regard to the development of super-elite performance in sport is **high to moderate**.

We therefore recommend that policy makers and practitioners at least **take consideration of birthplace** when designing talent search initiatives as well as profiling athletes during talent selection and development.

Understanding more about the physical and social environment, organization of resources and the number of participants competing for available places in sports are key areas for research—i.e. understanding more about the environments and neighbourhoods that potential sporting talents are exposed to, and less about birthplace population size.

Support from Parents, Family, Siblings and Coaches

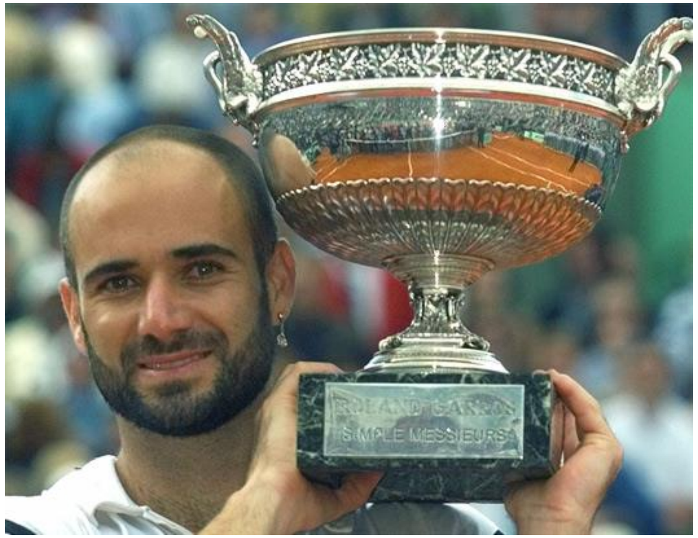
The importance of family and siblings during athletes' developmental years has been highlighted . Evidence from non-elite, junior elite, elite and super-elite athletes attests to the influence of social groups, social support and support networks (including family, coaches, other athletes/ peers and support staff).

In addition to their key role in the provision of expert coaching and training, coaches can help to enhance the development of psychological skills and mental toughness in athletes during their developmental years. Non-elite data suggest that the supportiveness and feedback effectiveness of coaches is dependent on a unique fit (and common identity) between the characteristics of the coach and the personality of the athlete.

With moderate study design, moderate consistency and high direct relevance (up to super-elite level), the quality of the evidence that support plays a role in the development of super-elite performance in **sport is at least moderate**.

We therefore recommend that policy makers and practitioners heed the important influence of the support process during talent development.

However, it is worthy of note that the nuances of providing appropriate support appear to be much more complex than most lay people realize. There is still a relative lack of knowledge with regard to the influence of early family experiences, and we need to know more about the role of the family (parents, siblings, interrelations) more generally with respect to who reaches super-elite level in sport



Athlete Support Programmes

Evidence from 19 European countries suggests that most talent identification systems in sport use current junior performance and/or early competitive success as the main criterion for selection to a development programme. Although most elite and super-elite athletes have been involved in athlete support programmes at some stage, there is evidence across all performance levels that junior success does not significantly predict long-term senior success.

A 7-year longitudinal study of 4686 German athletes (from athletics, cycling, field hockey, rowing, table tennis, weight lifting and wrestling) across all performance levels and a 12-year longitudinal study involving 1420 members of 13 soccer academies revealed:

(a) considerable annual turnover of athletes within each squad;

(b) the younger the first recruitment to a support programme, the younger the exit from the programme; and

(c) the higher the attained level within an athlete support programme and the higher the level of senior success, the later the age of first recruitment.

Various other studies have highlighted superelite performers being recruited to support programmes at significantly later ages than their elite counterparts.

With moderate study design, moderate to low consistency (i.e. consistent but infrequent), and high direct relevance (up to super-elite level), the quality of the evidence regarding early athlete support programmes' contribution to the development of super-elite performance in sport is moderate.

The trajectory to super-elite status appears distinctly **non-linear**, involving repeated selection and de-selection, rather than linear progression within athlete support programmes.

We therefore recommend that policy makers and practitioners appreciate that junior success does not contribute significantly to predicting longterm senior success, that early athlete support programmes are not the sole route to the development of talent, that support programmes be open for access at all age ranges, and thus that de-selected athletes be monitored for potential return.

Practice and Training

Volume of Sport-Specific Practice and Training

Despite wide variation across sports, most junior elite, elite and super-elite athletes have accumulated enormous volumes of organized practice and training. Extensive sport-specific deliberate practice (DP) is thus a pre-requisite to world-class performance in sports with a large participant base.

A widely held view, based on seminal work in chess and music, is that 10 years and 10,000 h of DP are necessary and sufficient to reach expert level.

Indeed, many elite and super-elite athletes have been practicing and training for ten years or longer. In discussing his DP framework, however, Ericsson has recently emphasized he did not intend for his original (i.e. 1993) conclusions to constitute a 10,000 h 'rule'. In fact, there is considerable variation within and across sports at elite and super-elite level, with some data suggesting an average time from novice to senior national representation of just 7.5 years, and even Olympic level in just 14 months.

Evidence at super-elite level suggests as few as 4400 h may lead to Olympic Gold in field hockey, and 4500 h to representing the German national soccer team, with just 4000 h sufficient to reach elite and super-elite levels in basketball, field hockey and netball. Interestingly, organized practice/training has been shown at junior elite and super-elite level to comprise considerable non-DP activity (e.g. play).

DP theory also asserts [Ericsson, 1993] that the more DP accumulated, the higher the performance attained. There is evidence that more successful athletes have averaged larger amounts of organized sport-specific practice/training.

Although the DP framework has gained popularity in sport science and in popular literature, its applicability to high-performance sport may be limited. The suggestion of 10 years/10,000 h was originally based on:
(a) musicians, not outstanding athletes; and
(b) a strict interpretation of DP, excluding intrinsically enjoyable activities, team practice, play, competition, non-organized sporting activities, and also ruling out implicit (improved task performance in the absence of conscious awareness) and incidental learning (learning in the absence of an intention to learn).

DP also implies full attention and concentration, while research indicates that full concentration does not always generate optimal learning/performance. Increasing conscious awareness may even result in poorer performance (e.g. paralysis by analysis; the regression hypothesis —(i.e., regressing to a performance level akin to earlier learning). Evidence at non-elite level also indicates that implicit learning leads to more robust performance under pressure.

With moderate/high study design, moderate consistency and high direct relevance (up to super-elite level), the quality of evidence that extensive DP is an important contributor to the development of super-elite performance in sport is high to moderate, while high/moderate quality of evidence suggests that the applicability of the 10 years/ 10,000 h rule is limited and **that DP alone does not guarantee sporting success**.

Additionally, the contribution of practice/training to the development of sporting expertise may only apply to domain-specific practice accrued during late adolescence or adulthood, with practice volume not discriminating elite from super-elite athletes.

Finally, there is some low quality evidence to suggest that automaticity and implicit learning may contribute to the development of sporting expertise.

We therefore recommend that policy makers and practitioners continue to promote deliberate practice, but consider the present evidence before routinely increasing practice volumes with junior athletes, and acknowledge the potential benefits of automaticity, implicit learning and also enjoyment in practice and play. The links between early sport-specific practice/training and shortand long-term outcomes are a research priority.

Early Specialization Versus Sampling and Play

Where peak performance in sport is achieved before biological maturity, early specialization may be necessary to reach elite level.
For example, super-elite athletes in artistic composition sports (artistic gymnastics, figure skating, platform diving and rhythmic gymnastics) performed three to seven times more sport-specific training until age 10 years compared to all other types of Olympic sports.

Their volumes of practice/training did not, however, differ from their elite counterparts within their respective sports.

A super-elite sample of rhythmic gymnasts also experienced reduced involvement in other sports compared to their elite counterparts.

However, evidence at non-elite, junior elite, elite and super-elite level suggests that many athletes have not progressed exclusively within one discipline, but have practiced multiple sports during childhood and adolescence

Further, evidence from non-elite and super-elite data points to the potential costs and risks associated with early specific practice, training and competitions (e.g. less enjoyment, time demands, restricted activities outside sport, exhaustion, overuse injuries and increased risk of dropout).

Comparisons between super-elite and elite athletes from field hockey, soccer, tennis and 47 Olympic sports have even demonstrated larger volumes of practice/training and/or play in other sports among the super-elite, mostly associated with a later start in their main sport and a later specialization.

There is also evidence at non-elite, junior elite, elite and super-elite level that many athletes have spent considerable time in non-organized play during childhood.

A positive relationship between non-organized play and junior elite and super elite success has been noted, but equally other studies have noted no differences between performance levels, with some demonstrating more play among non-elite compared with elite/super-elite athletes.

Elite and non-elite soccer players could be differentiated by a combination of above average volume of organized soccer training/practice with either above-average involvement in other sports or above average non-organized soccer play.

With moderate study design, moderate (early sampling of diverse sports, late specialization)/low (play) consistency, and high direct relevance (up to super-elite level), the quality of the evidence that early specialization or sampling **represent the best route to the development of super-elite performance in sport is moderate**.

Both early specialization and sampling (and play) may be routes to expertise under optimal conditions.

However, the probability of attaining elite or super-elite level may be enhanced by the coupling of a large volume of intensive, organized specific training/practice in the main sport with appreciable amounts of organized training/practice and competitions in other sports and/or non-organized play in the main or other sports.

We thus recommend policy makers and practitioners to draw on this evidence, bearing in mind the need to **minimize the potential hazards of early specialization** when such specialization is necessary, and with regard to promoting opportunities for young athletes **to experience non organized play and sampling in a variety of sports.**

Future research is needed to understand how participation in various sports benefits super-elite performance in one main sport. Further, how does the process of late specialization following prior diversification or 'talent transfer' proceed? Are there certain sports or clusters that lay the best foundation for super-elite success in a final sport?

Other Potential Factors

They include:

- the role of the family's socioeconomic status in different sports and countries;
- the different routes to super-elite level across cultures;
- making errors in the learning process without penalties or consequences;
- the significance of recovery, rest and sleep to optimize the benefits of practice;
- potentially linked to the reminiscence effect (i.e. 'improvement in the performance of a partially learned act that occurs while the subject is resting';
- the opportunity in sport for athletes to identify, express and (thereby) exercise control over their emotions, which in normal life they find difficult to express;
- and finally, a potential impact of childhood emotional trauma on qualities such as mental toughness, grit, resilience, growth mindset, achievement striving and ability to overcome difficulties —and relatedly, positive or negative 'critical' events with high personal significance (e.g. success milestones, squad selection, non-selection, losses, injury, school disruption, parental divorce and bereavement.

Table 1 Overview of research into the development of the world's best sporting talent: study design quality, consistency of evidence, directness of evidence and key points

Topic	Study design quality	Consistency of evidence	Directness of evidence
The performer			
Birthdate	Moderate	Low	Moderate
Relative age effects exist but may not be robust across all sports			
Genetics	High	Moderate	Moderate
Genetics may influence and thus limit the development of performance. Performance cannot, however, be well predicted from genetic factors. Caution should be urged for ethical and societal reasons when considering genetic selection methodologies			
Anthropometric and physiological factors	High	High	High
Anthropometric and physiological factors are important for performance. However, caution should be urged when using anthropometric and physiological tests for talent selection purposes with adolescents because of variation in biological maturation			
Psychological skills and motivational orientations	Moderate	High	High
Psychological factors (e.g. motivation, confidence, perceived control, mental toughness, resilience, coping with adversity, resistance to 'choking', mental skills) appear to be important contributors to the development of super-elite performance			
Personality traits	Moderate	Moderate/low	High
Super-elite athletes are conscientious, optimistic, hopeful and perfectionist			
The environment			
Birthplace	Moderate	High	High
Small-to-medium communities provide favourable environments for developing athletes. Talent hotspots may exist			
Support from parents, family, siblings and coaches	Moderate	Moderate	High
Super-elite athletes have benefitted from supportive families, coaches and networks during their development. The subtleties of the provision of support are not well understood			
Athlete support programmes	Moderate	Moderate/low	High
Early success is a poor predictor for later super-elite success, and thus for early talent identification purposes. Super-elite success is mostly preceded by relatively late entry into organized support programmes			
Practice, training and play			
Volume of sport-specific practice and training	High/moderate	Moderate	High
Super-elite performance develops from extensive deliberate practice, but the applicability of the 10 years/10,000 hours 'rule' to high-performance sport is limited. Play may also be relevant, as may implicit/automatic and incidental skill learning			
Early specialization vs. sampling and play	Moderate	Moderate/low	High
The key to reaching super-elite level may be involvement in diverse sports during childhood and appreciable amounts of sport-specific practice/training in late adolescence and adulthood			

THANK YOU ALL FOR YOUR ATTENTION AND KIND SUPPORT!

Prof. Bruno Ruscello
bruno.ruscello@uniroma2.it