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Research into talent development in youth sports

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Published in
Frontiers in Sports and Active Living

RPTU

ISSN 1664-8714
ISBN 978-2-8325-3583-7
DOI 10.3389/978-2-8325-3583-7

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Research into talent development in youth sports

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Citation
Gonçalves, C. E., Carvalho, H. M., Güllich, A., eds. (2023). *Research into talent development in youth sports*. Lausanne: Frontiers Media SA.
doi: 10.3389/978-2-8325-3583-7

This Research Topic and e-book was sponsored by RPTU Kaiserslautern, Germany.

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TYPE Editorial
PUBLISHED 10 August 2023
DOI 10.3389/fspor.2023.1257643

OPEN ACCESS

EDITED AND REVIEWED BY
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RECEIVED 12 July 2023
ACCEPTED 18 July 2023
PUBLISHED 10 August 2023

CITATION
Güllich A, Gonçalves CE and Carvalho HM (2023) Editorial: Research into talent development in youth sports.
Front. Sports Act. Living 5:1257643.
doi: 10.3389/fspor.2023.1257643

Editorial: Research into talent development in youth sports

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KEYWORDS
youth sports, talent identification, talent development, review, theory, research programme

Editorial on the Research Topic
Research into talent development in youth sports

What explains exceptional performance? This is the subject of one of the oldest lines of scientific research (1, 2). Traditionally, one community of thought (3) has emphasised the importance of inborn "natural abilities" and initial performance level [giftedness approach, e.g., (1, 4)], yet acknowledging the relevance of a long-term practice process. Another community of thought has emphasised the importance of the practice process [environmentalist approach, e.g., (2, 5)], yet acknowledging the relevance of physical attributes and early performance.

In sports, dedicated research into talent development has begun in the 1960s [e.g., (6, 7)] and has then continuously grown, in parallel with the expansion, popularity, and commercialisation of the sport industry. Today, many national sport systems around the world have established talent promotion programmes at local, regional, and national levels. Talent promotion is considered a critical building block of athletes' pathway towards athletic excellence and the "global sporting arms race" has incited nations to make expanding strategic investments in talent promotion programmes.

Although theoretical approaches to talent development partly vary, there is large consensus that every youth athlete has some initial level of performance. Their subsequent performance development is driven via a multi-year practice process (typically composed of drill-like exercise forms, playing forms, and competitions), which is moderated by personal and environmental factors. This practice process eventually leads to their senior peak performance (**Figure 1**).

This book assembles 13 reviews of available research on many of these subjects. Four chapters focus on characteristics of the practice process itself (**Figure 1**). Araújo et al. first explain how "talent" is socially defined. Then, based on an ecological-dynamics rationale, they discuss talent development as a socialisation process transforming ubiquitous skills into specialised skills via exploration, stabilisation, and calibration of the performer-environment coupling. Larkin et al. review existing research into the micro-structure of youth athletes' practice sessions, especially the allocation of training vs. playing forms. They also discuss coaches' behaviours employed to foster athletes' learning and performance. Güllich et al. synthesise the available empirical evidence on participation patterns of higher- and lower-performing athletes. Predictors of early junior performance and of long-term senior performance (i.e., in the highest, open-age category) are opposite in five regards: starting age, amounts of main-sport and other-sports practice, age to enter

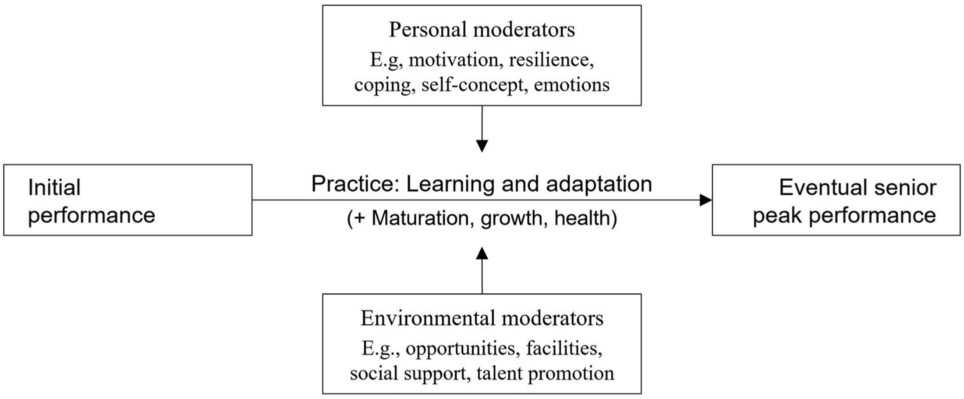

FIGURE 1
Basic model of talent development.

talent promotion programmes, and age to reach defined performance "milestones." Peters et al. analyse the literature specifically addressing girls' and women's participation variables. The participation patterns of many successful female athletes deviate from popular theoretical hypotheses such as Ericsson et al.'s (5) "deliberate practice" framework and Côté et al.'s (8) "Developmental Model of Sport Participation."

Three chapters discuss several potential risks associated with talent development, including those of selection biases. Carvalho and Gonçalves illustrate how youth athletes' varying timing of biological maturation (puberty, growth spurt) and relative age within a birth-year cause specific biases in talent selection. This leads to increased risks of false-positive and false-negative selection decisions, given that both the biological-age effect and relative-age effect diminish or may even be reversed by adulthood. Wik describes injuries in talent development, exemplified by youth soccer. He explains how players' age, biological maturity, and growth affect the prevalence, types, and locations of injuries, highlighting particular vulnerability of youth athletes' growth plates and apophyses. Soares and Carvalho discuss fundamental issues associated with previous research into dropout of young talents. Dropout studies have typically addressed sport-specific, not general sport dropout; considered unselected, not talent development populations; and definitions of dropout have varied. In consequence, substantiated knowledge about the actual prevalence and factors of dropout from talent development pathways is still meagre.

Five chapters address several moderators of the process of practice and performance development (**Figure 1**). Weissensteiner discusses international trends in the historical development of national talent promotion systems, illustrated by the GDR, Australia, and the UK. Employing historical analyses, she works out the commonalities and particularities of three extremely successful talent promotion systems, and key learnings each of them obtained from the previous one. Hancock et al. review the state of research into the geography of talent development. Athletes born in places with medium population size and density typically have increased success probabilities. The authors also acknowledge that birthplace effects vary across sports, countries, and sexes; definitions of "medium" population size and density differ between countries; and athletes' birthplace and development place(s) may not be identical. Taking a holistic ecological approach, Henriksen and Stambulova conceptualise the athletic career as a journey through varying athletic and non-athletic social environments. They summarise qualitative investigations of successful environments and highlight shared features regarding organisational structure and culture that have been perceived to foster athletes' performance, wellbeing, and personal development. Quinaud et al. address the combined athletic and academic development of youth athletes, labelled "dual career." Combining athletic and academic engagement implies competing time demands from sport and education. Considering position and policy papers, the authors call for clear definitions of guidelines, resources, roles, and responsibilities in the establishment of dual-career support programmes. Dehghansai et al. show that traditional talent development models are only partly applicable, at best, to Paralympic sports. Athletes' development differs between congenital vs. acquired impairment and across ages of acquiring an impairment. Furthermore, types and severity of impairments require varying resources in terms of equipment and coaching, and it is difficult to establish classifications that ensure fair competition systems. In conclusion, Paralympic talent development requires especial dedication, flexibility, creativity, and resources.

Finally, Baker et al. advocate for embedding talent development models and research in multidimensional lifespan development models and research. The authors highlight the complexity of athletes' development within and between competitive and recreational participation and discuss challenges associated with that research.

Generally, an overarching research question concerning all the potential factors of talent development is: To what extent do individual differences in childhood/adolescent factors predict individual differences in later senior performance? Given that youth athletes, parents, and coaches seek to expand athletes' benefits (e.g., enjoyment, performance, prestige) while controlling and limiting their risks (e.g., injuries, burnout, dropout) and costs (especially opportunity costs, i.e., the lost benefit of foregone other activities such as time with family, friends, academics; declining academic achievements; declining response to training with growing previous training amounts; reduced psychosocial wellbeing), that research question can be further specified: What childhood/adolescent factors facilitate long-term senior performance, and *at what risks and costs*?.

Researchers elaborate theories that are then evaluated based on two truth values: logical consistency and empirical correspondence, where their empirical content constitutes their potential falsifiers (9). I.e., researchers propose systems of hypotheses and nature disposes of their truth or falsity (10). For many potential factors in talent development, multi-year experimental manipulation is difficult, if not impossible, for example: training volume and methods, parental and peer support, athletes' psychological characteristics, health, or psychosocial wellbeing. The methods of choice are therefore typically multi-year longitudinal quasi-experiments using prospective and retrospective designs while seeking to control for potential confounds.

There is a group of factors for which ample childhood/adolescent data of (later) senior athletes are available. For example, data on competitive performance development (11), relative age (Carvalho & Gonçalves), and birthplace (Hancock et al.) can typically be gathered from public records. Biological maturation (Carvalho & Gonçalves) and childhood/adolescent motor test scores are sometimes available from past routine monitoring procedures (12). Furthermore, athletes can reliably recall childhood/adolescent participation variables and involvement in talent promotion programmes (Güllich et al.; Peters et al.; Quinaud et al.; Dehghansai et al.) in retrospective interviews or questionnaires. This has led to a broad body of evidence on effects of these childhood/adolescent predictors on long-term senior performance across wide ranges of sports, performance levels, and countries.

Research into another group of potential factors is more difficult. For example, investigating the extent to which higher- and lower-performing senior athletes differed in earlier childhood/adolescent factors such as: 1. their microstructure of practice (Larkin et al.); 2. correspondence of their practice to principles of ecological dynamics (Araújo et al.); 3. psychological characteristics [e.g., (13, 14)]; 4. characteristics of athletes' social environment (Henriksen & Stambulova); or 5. support measures applied in talent promotion and dual-career programmes (Güllich et al.; Quinaud et al.). These variables are usually not available from public records or past routine monitoring procedures and senior athletes cannot reliably reconstruct them from their early years. This difficulty is perhaps one of the reasons why for these potential predictors, there is a broad body of theoretical hypotheses, normative assumptions, descriptive studies of youth athletes, and investigations of short-term effects on early junior performance. In contrast, evidence on effects of individual childhood/adolescence differences in these factors on long-term individual differences in senior performance is lacking.

However, we cannot infer predictors of senior performance by extrapolating findings from junior athletes because 1. successful juniors and successful seniors are largely two disparate populations (11) and 2. predictors of early junior performance vs. long-term senior performance are different and partly opposite (Güllich et al.; Carvalho & Gonçalves). Likewise, although the goal is to expand athletes' benefits while limiting their risks and costs (see above), there is only scarce empirical evidence, if any, concerning childhood/adolescent predictors of adult high performance *combined* with other outcomes in adulthood such as psychosocial wellbeing (Henriksen & Stambulova), health (Wik), academic/vocational achievement (Quinaud et al.), or prolonged sport engagement (Soares & Carvalho; Baker et al.).

The chapters in this book suggest several clear implications for future research.

1. The process of talent development is complex and multi-factorial, calling for more multi-theoretical approaches and multivariate analyses of interactions between factors. In addition, associations between several childhood/adolescent predictors and senior-age outcomes are likely non-linear rather than linear, while organised in multi-level structures. For example, based on the available evidence, several relationships are presumably better reflected by parabolic (e.g., earlier cumulative practice amount and later performance), saturation (e.g., earlier motivation and later performance), or threshold patterns (e.g., earlier cumulative physical load and later overuse injury). These plausibility assumptions call for multivariate non-linear analyses and advanced modelling.
2. We should seek to expand the empirical evidence on long-term effects of several hypothesised childhood/adolescent factors that are under-researched to date: E.g., early talent indicators, talent selection criteria, microstructure of practice, its correspondence to principles of ecological dynamics, psychological characteristics, social environment, parental and peer support, and support measures applied to participants in talent promotion and dual-career programmes. This implies investigating the research question: To what extent had (a) higher- vs. lower-performing senior athletes with (b) better vs. poorer wellbeing, health, or academic/vocational achievement differed in these factors during childhood/adolescence.
3. Given that (1) the goal is to expand the athlete's benefits while limiting their risks and costs, while (2) effects of childhood/ adolescent factors may vary and even be opposite regarding short-term and long-term outcomes, the economic concepts of efficiency of practice—performance improvement per invested practice amount—and sustainability are paramount. They apply to research into youth athletes' participation patterns, microstructure of practice, ecological dynamics, coaching, talent promotion programmes, dual-career support, athlete services, and youth sport programmes in general, and lead to three critical research questions (Güllich et al.): (a) What short- and long-term, material and immaterial benefits, risks, and costs does a programme (or do different programmes) yield? (b) What objective and subjective value does each of the benefits, risks, and costs have? (c) What is the eventual ratio of the summed value of all benefits relative to the summed value of all risks and costs yielded by a programme (or by different programmes)?

This research will advance our understanding of long-term talent development, foster our refinement of sound theories, provide the corresponding empirical evidence, and thereby facilitate evidence-based practice of talent development.

Author contributions

AG: Conceptualization, Writing—original—draft, Writing—review & editing. CG: Conceptualization, Writing—original draft, Writing—review & editing. HC: Conceptualization, Writing—original draft, Writing—review & edition.

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References

1. Galton F. *Hereditary genius*. New York: Macmillan (1869).

2. Watson JB. *Behaviorism*. Chicago: University of Chicago Press (1930).

3. Fleck L. *Genesis and development of a scientific fact [original 1935 in German: Entstehung und Entwicklung einer wissenschaftlichen Tatsache]*. Chicago: University of Chicago Press (1979 [1935]).

4. Gagné F. *Differentiating giftedness from talent*. New York: Routledge (2021).

5. Ericsson KA, Krampe RT, Tesch-Römer C. The role of deliberate practice in the acquisition of expert performance. *Psychol Rev*. (1993) 100:363–406. doi: 10.1037/0033-295X.100.3.363

6. Thieß G. Capabilities for suitability diagnostics in youth training [in German: Möglichkeiten der Eignungsdiagnostik im Nachwuchstraining]. *Theory Pract High-Perform Sport*. (1967) 6(8):109–10.

7. Kupper K. Elaboration of scientifically substantiated selection criteria in competitive swimming [in German: Die Erarbeitung wissenschaftlich begründeter Auswahlkennziffern für Sportschwimmen]. *Theory Pract High-Perform Sport*. (1968) 6(8):128–33.

8. Côté J, Baker J, Abernethy B. Practice and play in the development of sport expertise. In: Eklund R, Tenenbaum G, editors. *Handbook of sport psychology*. Hoboken, NJ: Wiley (2007). p. 184–202.

9. Popper R. *The logic of scientific discovery [original 1935 in German: Logik der Forschung]*. New York: Routledge (1959 [1935]).

10. Lakatos I. Falsification and the methodology of scientific research programmes. In: Lakatos I, Musgrave A, editors. *Criticism and the growth of knowledge*. Cambridge: Cambridge University Press (1970). p. 170–96.

11. Güllich A, Barth M, Macnamara BN, Hambrick DZ. Quantifying the extent to which successful juniors and successful seniors are two disparate populations: A systematic review and synthesis of findings. *Sports Medicine*. (2023) 53:1201–17. doi: 10.1007/s40279-023-01840-1

12. Güllich A, Larkin P. Talent identification and talent promotion. In: Williams AM, Ford PR, Drust B, editors. *Science and soccer—developing elite performers*, 4th ed. New York: Routledge (2023). p. 363–81.

13. Murr D, Feichtinger P, Larkin P, O'Connor D, Höner P. Psychological talent predictors in youth soccer: a systematic review of the prognostic relevance of psychomotor, perceptual-cognitive and personality-related factors. *PLoS ONE*. (2018) 13(10):e0205337. doi: 10.1371/journal.pone.0205337

14. Ivarsson A, Kilhage-Persson A, Martindale R, Priestley D, Huijgen B, Ardern C, et al. Psychological factors and future performance of football players: a systematic review with meta-analysis. *J Sci Med Sport*. (2020) 23(4):415–20. doi: 10.1016/j.jsams.2019.10.021

frontiers | Frontiers in Sports and Active Living

TYPE Mini Review
PUBLISHED 03 May 2023
DOI 10.3389/fspor.2023.1181752

OPEN ACCESS

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RECEIVED 07 March 2023
ACCEPTED 20 April 2023
PUBLISHED 03 May 2023

CITATION
Araújo D, Roquette J and Davids K (2023) Ubiquitous skill opens opportunities for talent and expertise development.
Front. Sports Act. Living 5:1181752.
doi: 10.3389/fspor.2023.1181752

Ubiquitous skill opens opportunities for talent and expertise development

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In this article we aim to define and present the complementary nature of talent, skill and expertise. Human daily life is replete with expressions of skillful behaviours while interacting with the world, which in specific socio-culturally defined domains, such as sport and work, demand a specialization of such ubiquitous skill. Certain manifestations of ubiquitous skill are identified by experts from the specialized domain of sport with the label of "talent". In this paper we propose that "talent" is thus socially defined, considered identifiable at an early age and forms the basis for selection and entry at the starting point in domains like sport. Once an individual, defined as "talented" enters the "pathway" for participating in the sport domain, there begins an intense socialization process where training, evaluation, institutionalization and framing takes place for continued development of such talent. This is the formalised process of working on ubiquitous skills refining and changing them into specialized skills in sport. An ecological dynamics rationale is used to explain that this specialization approach is developed through a process of expert skill learning, which entails the stages of exploration and education of intention stabilization and perceptual attunement, and exploitation and calibration. Skill learning aims to develop potentiality and its expression in actuality, i.e., how learning is expressed in contextualized expert performance.

KEYWORDS

sport, social, ecological dynamics, learning, expert performance

1. Introduction

A pressing issue for scientific and sport communities is to understand how skill learning supports and shapes the continued development of talent and expertise in a specific domain (1, 2). Although, as Baker and colleagues (3) have argued, concepts like talent, skill, expertise and performance tend to be used in an overlapping way in the sport sciences domain. What these concepts mean is often far from clear and a key source of confusion is the lack of socio-cultural framing of these concepts.

Collins and Evans (4, 5) have proposed the idea of expertise as a socialization process, distinguishing between ubiquitous and specialised skill. Here, we explore the insight that contextualized ubiquitous skills form the foundation of social life, facilitating the socialization process in specific specialist and expert groups. Ubiquitous skill can be expressed by every individual, consequently opening possibilities and providing a necessary basis for participation in more specialized or expertise programmes. In this paper we discuss this position, seeking to explore how skill learning contributes to talent and expertise development. We start by clarifying how skill is *ubiquitous* to human activities, examining how ideas on talent and expertise need to be framed into specialised socio-cultural domains. The key idea that we discuss is that skill in not an "entity" that can be “acquired” and “possessed” by an individual but rather is contextually defined, providing an “adaptive, functional relationship between an organism and its environment” (6, pp.18).

2. Expertise is socialization into a specific domain

Socialization is foundational for expertise (4) since expert performance is realized in specific social settings. Performing skillfully is not something an individual or a team possesses to begin with, but is a relational tendency that emerges to become more stable with practice and experience and is expressed and adapted in a given social setting. This socialization process has, according to Carr (7), four main properties: (i) Training, undertaken socialization practices through which novices are initiated with that culture; (ii) Evaluation, captured as methods to distinguish among expertise levels in social settings where those practices are performed; (iii) Institutionalization, indicating how expert knowledge (specializations, and differentiations) is formalised, stabilized and certified in institutions and everyday practices; and (iv), Framing or naturalization, which identifies manifestations of expert performance as bodies of knowledge, highlighting cultural and historical assumptions embedded within dominant forms of expertise, framed as evidence of performing skillfully.

This extensive process of socialization in a specific cultural domain that characterizes expertise implies participation, i.e., experience and engagement in relevant social practices (5). Social embedding when developing skill needs to be specified in an expert community to be considered as specialization. Consequently, ubiquitous skills, such as bipedal walking, are not framed into an expert community, contrasted with race walking which depends on voluntary participatory immersion in a *form of life* (8) in an Athletics organization. A manifestation of skill in race walking is a specialization of a skill, which contrasts with the ubiquitous skill involved in daily walking to navigate through everyday environments. Importantly, specialized skills are socio-culturally defined by an expertise community (e.g., national and international Athletics federations).

Expertise is expressed in, and sustained by activities of a social group. Therefore, the distinction between ubiquitous skill and expert skill could be construed as a sociological distinction, not an epistemological nor biological distinction. Such a distinction led Collins and Evans (5) to call those specialized skills practiced by a small community *esoteric*, such as skills for performing abstract algebra procedures in mathematics or for performing a triple jump in athletics, contrasting with ubiquitous skills such as counting when shopping or jumps in the backyard.

Developing skills needed to become an expert means becoming a full and active member of a social group and learning to act in ways that go beyond what novices can achieve. Collins and Evans (5) rightly argued that expertise is both context-sensitive and dependent on tacit knowledge. Only context-specific socialization can enable an individual to share and use the collective knowledge of the group and so develop (tacit) skills needed for future circumstances.

3. Talent as the starting point for entering into an expert domain

To overcome the lack of clarity in conceptualising “talent”, Baker and colleagues (3) present it as the starting point for the processes of learning and development that may lead to expertise. Clearly, in many instances talent is presented as a relationship to be developed (9, 10) between an individual and a specific domain. Therefore, an entry point into a socially specialized domain, implies identification and selection processes sustained by what those in a community understand as a possibility to excel, or the prerequisites and precursors of the specialised expression of skilled behaviours that characterises members of an expert group (11). Applied scientists and sport practitioners have accurately highlighted research indicating that the variables that correlate with performance at young ages are not necessarily the same variables that explain expert performance later (3), an important contribution to clarify what the notion of *talent* entails. Intriguingly, Baker et al. maintain the pervasive idea that talent can be predicted before any learning or development occurs, i.e., the idea that talent is innate. We have questioned elsewhere (9) the idea that measuring an alleged innate or foetal property at birth, or just after, is relevant for predicting sport performance potential in later life. Such properties, measured at early points in time, could be categorized as innate, but will certainly change over time shaped by the nonlinear nature of interactions with varying constraints of genes, epigenetics, experiences, surroundings and chance. These questions signal that observed skill or performance should always be understood and defined at the level of the performer-environment system (12).

In sum, talent is the starting point to entry into the expert domain of sport. This starting point emerges when performers express particularities of ubiquitous skill in occasions where expert members of a sport community can identify those particularities in sport related tasks, and consequently these performers are facilitated to enter into “pathways” of an organised domain of sport specific practices for training, evaluation, institutionalization and framing. From this time on, ubiquitous skills may be prepared to be socialised (trained, practised, integrated) in a sport domain and thus to be developed into expert skills in sport.

Clarifying what particularities of ubiquitous skill look like, implies the understanding that skills are always expressed in actions, they are part of an activity (1). Realizing an activity involves the whole organism in a dynamic transaction in the environment to achieve a task goal. Actions, thus, have to be intentional and future-oriented. Actions (i.e., goal-directed changes of body movements and postures) are guided by prospective information available in the task context (13). The perception of prospective information informs how upcoming changes in movement kinetics and kinematics can be counteracted before they perturb the dynamic flow of action. By moving, the performer learns about properties that change and properties that remain invariant, about how to coordinate with events and objects of the environment, and about information that makes it possible to guide action prospectively. In short, entangled in a complex system, actions develop through acting (13). Skill learning is the process of *sophisticating* (refining) how one acts and engages with the interconnected world, in ubiquitous or in expert domains, to achieve a task goal.

4. Skill is ecological (embodied and embedded)

Skills may be best defined as embedded or ecological instead of disembodied or mentally represented (14). They are not internalised and possessed by the performer, but they reciprocally characterise an emerging relationship between the whole individual and possibilities for action available in a performance context (15). Skills are part and parcel of performing in socially-defined activities (16), usually entangled with other skills, such as talking, standing, grasping, pushing or concentrating. These skills frame the experience of performing an activity in a context - such as starting, accelerating, maintaining, curving and finishing when running a lap on a track - they are not isolatable, nor they can be split into components in performance. By purposefully engaging with community activities, performing skills reveals information for affordances (i.e., action possibilities offered by the environment (17), which reveal new skills to be performed, and so on. In this way, skills are framed by *knowledge of*, rather than *knowledge about* the environment (18). From this viewpoint, the role of practice is to enhance the degree of fit between an athlete and the performance environment, instead of the enrichment of an athlete's mental representations. In this regard, the term "knowledge of" explains how to (perceive and) act, which is in contrast with verbalizable knowledge or "knowledge about" (e.g., a verbal description of performance) which may or may not correlate with a performer's contextualised manifestation of skillful performance in sport (19).

Social-cultural behaving domains (including sports) have been developed in such a way that they facilitate non-conventional behaviors, from which new skills emerge. This skill adjustment process implies a form of learning that is not based on intellectually or passively detached memorization of instructions, but by evolving bodily engagement in a task context (20). What the skill develops through experience is not represented in the mind, but it is presented to participants as more and more finely salient affordances (21). If an invitational affordance does not demand a response, or the response does not generate an intended outcome, the participant is led to further refine their perceptual attunement, which in turn, solicits more refined actions, and so on. This continuous adaptive process is not a mental evaluation of what is going on, instead it is constitutive of being corporeally engaged in the activity. In other words, acting is experienced as an ongoing process of developing skillful behaviors solicited by a task context.

This understanding of skill as a refined coupling of perception and action performed in a specific domain, challenges traditional notions of skill acquisition. These models have an explanatory preference for automatic mental processing (22) or building complex mental representations that do not support premature automatization of performance (23) to be the end goal of the skill acquisition process. Contrastingly, from an ecological dynamics perspective, a skill cannot be acquired or possessed (6). Skill learning is a non-linear process which continually refines the fit between an individual and a performance environment. To adjust performance in a sport task to the affordances of a specific task context, implies "sophisticating" *knowledge of* the environment and not the acquisition of *knowledge about* the environment (e.g., memories, fast mental processing).

5. Ecological dynamics of skill learning

From an ecological dynamics approach, the primary challenge facing any individual is the successful performance of goal-directed behaviors. Therefore, skill learning is more about the fine-tuning of perceiving and acting abilities than it is about the building mental representations about the world (24). Moreover, this process of fine-tuning perception, cognition and actions emerges from the refinement of the ability to detect and exploit information about affordances rather than the modification or enrichment of mental representations.

Skill performance involves perceiving an affordance, which is predicated on an individual's ability to detect information in a given environment relative to their action capabilities. As skill is developed in an (expert) cultural context, a person becomes attuned to a wider range of affordances and gains a greater sensitivity to contextual consequences of their actions (25). A stage-like model of skill learning was elaborated from the work of pioneers influencing ecological dynamics (e.g., 26–29), resulting in a non-linear three-stage model of skill learning in sport (1, 19, 30). These stages are nested together, not sequentially where one necessarily comes before the other, but can emerge at all three stages. The stages are dependent on continuous behaviours and activity, and not stored as rule-like prescriptions in the individual's mind.

5.1. Search: exploring possibilities

Learning which behaviors to perform, what affordances to perceive, and how to explore and discover information about those affordances is called the *education of intention* (29). Intentions shape perception–action links during skill performance. A practice environment can be designed to constrain intentions of actors, influencing which particular affordances may be perceived and when. When a performer's intentions converge on a task goal, affordances inform them how to attain the intended goal. Intention directs the attention of an actor, and stimulates exploratory behaviors that channel perception, which further constrains action, and so on in a cyclical way (31). Intention directs perception for particular affordances (1). Performers increase their exploratory actions, when it is difficult to discriminate which properties of the environment constitute information to act upon a task and which do not. Exploring what is available in a performance context is a relevant behaviour that can disclose what environmental properties are informative relative to task goal achievement (25). By exploring a task context, the intentions of a performer become constrained by the task.

5.2. Discover: steadying the person-environment coupling

When the performer discovers tentative "solutions", they can maintain the person-environment link in behaviours that guide them towards goal achievement. Discovery potentiates the possibility that later the performer comes to know of task properties that change and properties that remain invariant, about how to coordinate actions with the environment, and about information that makes it possible to guide action prospectively to task goal achievement. This approach in "repetition without repetition" (26, p 234) stabilizes perception-action couplings. When the performer's intentions converge towards a task goal, the need arises to organize body movements specifically for achieving these intentions. Stabilizing body movements can be done by "freezing" corporeal degrees of freedom (32). However, with practice, corporeal degrees of freedom begin to "free up" when acting. More relevant perception-action couplings are next discovered, i.e., the conditions for *how* and *when* affordances are perceived and acted on. Perceiving and acting abilities can be fine-tuned to subtle adaptations in which specific components of a given ambient structured energy array (i.e., ecological information) are detected and exploited in perceiving an affordance. Ideally, during learning, performers will progress toward detecting information that provide more useful information about an affordance. Learning which patterns in a given structured energy array provide information about a given affordance has been called the *education of attention* or perceptual attunement (27, 31).

5.3. Exploit: linking with refined affordances

Changes in intention and attention often result in changes in how a performer *uses* a given ambient stimulation pattern (i.e., ecological information) to perceive a given affordance. Learning how to use the information about a given affordance to appropriately perceive a given property or perform a given behavior is called calibration (29). Exploiting perception and action supports adjustment to contextual demands. Body dimensions and characteristics are not fixed, but change across time. When body characteristics change (e.g., with practice and training), actions may become more or less challenging (33, 34). Consequently, attunement to a wider range of informational variables in a performance context, becomes important as well as greater sensitivity to contextual consequences of one's actions. Calibration involves refinement of mapping between prospective information and acting (and perceiving) (35). Continued experience leads to better calibration.

6. Skill learning: from possibility (talent) to actuality (expert performance)

Understanding behavior at the level of the performer-environment system means that skill is not a property located in the athlete nor in the environment, but it implies a linkage of the performers' corporeal characteristics with affordances offered by a task context. Additional constraints are related to the personal characteristics of a specific performer who is ready to act upon an affordance. One thing is to qualify for the Olympics (a real possibility) and another is to be ready to compete on the day of the event (e.g., in excellent condition without injuries). So, the personal potentiality for acting on the affordances available in competition implies satisfying an additional layer of constraints. This potentiality is further constraining as competition starts. Actual performance is a another narrowing down of possibilities. Performers form intentions in circumstances where they are directly informed of possibilities offered to them. Out of many successful paths connecting initial conditions to a performance goal, one path emerges (actuality), although this path has already been constrained by previous skill learning experiences (potentiality) (36, 37). Skill learning is the process of developing the potentiality that links the possibility of entering in the sport domain, e.g., when a youth is identified as "talented" with potential to compete in a given sport, to that of actuality, i.e., when expert performance is expressed in elite competition.

7. Concluding remarks

In this paper, we explored the social foundation of sport expertise, seeking to clarify the complementary relations between talent, skill, learning and expertise. With respect to talent development, a performer intent on belonging to an expert community and identified by that community as a talent (based on their ubiquitous skills), is at the initiation point, with an *opportunity* to enter a domain of expertise, such as sport. Then, individuals expressing talent become socialized and attuned to the historical and cultural constraints of a sport to develop their expertise. This skill adaptation process is when specialized sport skill learning takes place, and the *potentiality* for expert performance is developed. However, the *actuality* of expert performance only exists when skilled behaviours are expressed in a given task context. The development of talent to expert performance is grounded on continued *sophistication* of sport skills through learning.

Author contributions

DA: conceived the idea. JR and KD: reviewed literature and helped in the writing of the paper. All authors contributed to the article and approved the submitted version.

Funding

The first and second authors were partly funded by the "Fundação para a Ciência e Tecnologia" (grant no. UIDB/00447/

2020, awarded to CIPER– "Centro Interdisciplinar para o Estudo da Performance Humana" (unit 447).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Button C, Seifert L, Chow JY, Araújo D, Davids K. *Dynamics of Skill Acquisition: An Ecological Dynamics Approach*. 2nd ed. Champaign: Human Kinetics (2020).

2. Sarmento H, Anguera MT, Pereira A, Araújo D. Talent identification and development in male football: a systematic review. *Sports Med*. (2018) 48:907–31. doi: 10.1007/s40279-017-0851-7

3. Baker J, Wattie N, Schorer J. A proposed conceptualization of talent in sport: the first step in a long and winding road. *Psychol Sport Exerc*. (2019) 43:27–33. doi: 10.1016/j.psychsport.2018.12.016

4. Collins H, Evans R. *Rethinking Expertise*. Chicago: University of Chicago Press (2007).

5. Collins H, Evans R. A sociological/philosophical perspective on expertise: the acquisition of expertise through socialization. In: Ericsson A, Hoffman R, Kozbelt A, Williams M, editors. *The Cambridge handbook of expertise and expert performance*. Cambridge: Cambridge University Press (2018). p. 21–32.

6. Araújo D, Davids K. What exactly is acquired during skill acquisition? *J Conscious Stud*. (2011) 18(3-4):7–23.

7. Carr ES. Enactments of expertise. *Annu Rev Anthropol*. (2010) 39:17–32. doi: 10.1146/annurev.anthro.012809.104948

8. Wittgenstein L. Philosophical Investigations (Trans. G.E.M. Anscombe). Oxford: Blackwell (1953).

9. Davids K, Araújo D. *Innate talent* in sport: beware of an organismic asymmetry – comment on Baker & Wattie. *Curr Issues Sport Sci*. (2019) 4:102. doi: 10.15203/CISS_2019.102

10. Henriksen K, Knight C, Araújo D. Talent development environments. In: Hackfort D, Schinke RJ, editors. *The routledge international encyclopedia of sport and exercise psychology*. London: Routledge (2020). p. 658–70.

11. Issurin VB. Evidence-based prerequisites and precursors of athletic talent: a review. *Sports Med*. (2017) 47:1993–2010. doi: 10.1007/s40279-017-0740-0

12. Araújo D, Davids K. The (sport) performer-environment system as the base unit in explanations of expert performance. *J Expert*. (2018) 1(3):144–54.

13. von Hofsten C. An action perspective on motor development. *Trends Cogn Sci*. (2004) 8:266–72. doi: 10.1016/j.tics.2004.04.002

14. Araújo D. Skill learning in making and experiencing artworks: technologies that transform detached intellectuals into bodily engaged actors. *Adapt Behav*. (2022) 30:513–6. doi: 10.1177/1059712321994687

15. Araújo D, Davids K, Bennett S, Button C, Chapman G. Emergence of sport skills under constraints. In: Williams AM, Hodges NJ, editors. *Skill acquisition in sport: research, theory and practice*. London: Routledge (2004). p. 409–33.

16. Baggs E, Raja V, Anderson ML. Extended skill learning. *Front Psychol*. (2020) 11:1956. doi: 10.3389/fpsyg.2020.01956

17. Gibson JJ. *The Ecological Approach to Visual Perception*. Hillsdale, NJ: LEA (1979).

18. Gibson JJ. *The Senses Considered as Perceptual Systems*. Boston: Houghton Mifflin (1966).

19. Araújo D, Davids K, Chow J-Y, Passos P. The development of decision making skill in sport: an ecological dynamics perspective. In: Araújo D, Ripoll H, Raab M, editors. *Perspectives on cognition and action in sport*. New York: NOVA Science Publishers (2009). p. 157–70.

20. Dreyfus H. On expertise and embodiment: insights from maurice Maurice Merleau-Ponty and Samuel Todes. In: Sandberg J, Rouleau L, Langley A, Tsoukas H, editors. *Skillful performance: enacting capabilities, knowledge, competence, and expertise in organizations*. Oxford: Oxford (2017). p. 147–59.

21. Withagen R, de Poel H, Araújo D, Pepping G-J. Affordances can invite behavior: reconsidering the relationship between affordances and agency. *New Ideas Psychol*. (2012) 30:250–8. doi: 10.1016/j.newideapsych.2011.12.003

22. Fitts PM, Posner MI. *Human Performance*. Belmont, CA: Brooks/Cole Pub. Co (1967).

23. Ericsson KA. The scientific study of expert levels of performance: general implications for optimal learning and creativity. *High Ability Studies*. (1998) 9(1):75–100. doi: 10.1080/1359813980090106

24. Gibson EJ, Pick AD. *An Ecological Approach to Perceptual Learning and Development*. New York: Oxford University Press (2000).

25. Araújo D, Davids K, Serpa S. An ecological approach to expertise effects in decision-making in a simulated sailing regatta. *Psychol Sport Exerc*. (2005) 6(6):671–92. doi: 10.1016/j.psychsport.2004.12.003

26. Bernstein N. *The Co-Ordination and Regulation of Movements*. Oxford: Pergamon Press (1967).

27. Gibson EJ. *Principles of Perceptual Learning and Development*. New York: Appleton Century Crofts (1969).

28. Newell K. Coordination, control, and skill. In: Goodman D, Wilberg R, Franks I, editors. *Differing perspectives in motor learning, memory and control*. Amsterdam: North-Holland (1985). p. 295–317.

29. Jacobs DM, Michaels CF. Direct learning. *Ecol Psychol*. (2007) 19:321–49. doi: 10.1080/10407410701432337

30. Araújo D, Dicks M, Davids K. Selecting among affordances: a basis for channeling expertise in sport. In: Cappuccio ML, editors. *Handbook of embodied cognition and sport psychology*. Cambridge, MA: The MIT Press (2019). p. 557–80.

31. Arzamarski R, Isenhower R, Kay B, Turvey M, Michaels C. Effects of intention and learning on attention to information in dynamic touch. *Atten Percept Psychophys*. (2010) 72:721–35. doi: 10.3758/APP.72.3.721

32. Vereijken B, van Emmerik RE, Whiting HT, Newell K. Free(z)ing degrees of freedom in skill acquisition. *J Mot Behav*. (1992) 24:133–42. doi: 10.1080/00222895.1992.9941608

33. Fajen BR, Riley MA, Turvey MT. Information, affordances and the control of action in sport. *Int J Sport Psychol*. (2009) 40:79–107.

34. Burnie L, Barratt P, Davids K, Worsfold P, Wheat J. Effects of strength training on the biomechanics and coordination of short-term maximal cycling. *J Sports Sci*. (2022) 40:1315–24. doi: 10.1080/02640414.2022.2080159

35. Bruggeman H, Warren WH. The direction of walking—but not throwing or kicking—is adapted by optic flow. *Psychol Sci*. (2010) 21(7):1006–13. doi: 10.1177/0956797610372635

36. Araújo D, Davids K, Hristovski R. The ecological dynamics of decision making in sport. *Psychol Sport Exerc*. (2006) 7:653–76. doi: 10.1016/j.psychsport.2006.07.002

37. Shaw R, Kinsella-Shaw J, Mace W. Affordance types and affordance tokens: are Gibson's affordances trustworthy? *Ecol Psychol*. (2019) 31:49–75. doi: 10.1080/10407413.2018.1508353

frontiers | Frontiers in Sports and Active Living

MINI REVIEW
published: 22 July 2022
doi: 10.3389/fspor.2022.957086

The Practice Environment—How Coaches May Promote Athlete Learning

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The coaching environment is the primary teaching and learning medium for the development of athlete skills. Therefore, by understanding how practice environments are designed to facilitate learning, coaches can make decisions around the structure of specific activities and behavior to promote athlete learning and development. This short review examines the coaching environment literature, with a particular focus on the structure and content within a practice session. The review will highlight the specific activities coaches utilize to develop athletes technical and tactical skills. Further, the coaching behaviors used to promote athlete learning is discussed, and how coach athlete interactions may influence learning. Finally, we provide applied recommendations for coaches, and highlight areas for future coaching science research.

Keywords: talent development, youth, coaching, training, microstructure

Edited by:
Carlos Eduardo Gonçalves, University of Coimbra, Portugal

Reviewed by:
Carlota Torrents, University of Lleida, Spain

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Specialty section:
This article was submitted to Elite Sports and Performance Enhancement, a section of the journal Frontiers in Sports and Active Living

Received: *30 May 2022*
Accepted: *17 June 2022*
Published: *22 July 2022*

Citation:
Larkin P, Barkell J and O'Connor D (2022) The Practice Environment—How Coaches May Promote Athlete Learning. Front. Sports Act. Living 4:957086. doi: 10.3389/fspor.2022.957086

INTRODUCTION

The development of sporting expertise is associated with the engagement in a range of sport-specific activities that aid athlete development. To investigate this, researchers have used cross-sectional retrospective recall techniques, to identify the types of activities and the associated time invested in them by high performing athletes compared to their lower level counterparts (i.e., intermediate; novice). Findings have revealed a variety of sport-specific activities, which contribute to athlete performance, including primary sport coach-led practice; primary sport peer-led play and other sport practice and play (Güllich, 2019; Güllich et al., 2021). However, during this period of development, researchers have indicated one of the central factors in athlete growth is coach-led practice as time invested in this type of practice differentiates high-performing and lower skilled individuals (Güllich, 2019; Barth et al., 2020). While these findings highlight the importance of investing time in certain activities, such as coach-led practice, there is still limited knowledge regarding the micro-structure of these sessions and how they may contribute to athlete development. It should be noted, while the findings do not discount the importance of other activities, such as peer-led play, the current review paper aims to provide an overview of coach-led practice. Specifically, the elements within a session including the structure and behaviors used by coaches is examined, followed by practical implications and future research directions. It should be noted, the literature reviewed in the following section provides an overview of the key findings. Within the studies the participants, both athletes and coaches, may have been either male or female. As the papers reviewed do not provide gender based differences, we do not believe it is imperative to differentiate between male and female participants. Thus, the findings and recommendations can be applied for both genders.

MICRO-STRUCTURE OF PRACTICE

A key element of the motor learning literature is understanding the importance of practice structure on the acquisition of motor skills during practice (e.g., Barreiros et al., 2007; Spittle, 2013; Broadbent et al., 2015). This is especially true as the coaching environment is the primary teaching and learning medium for the development of players' technical and tactical skills (Cushion and Jones, 2001; Ford et al., 2010; Partington and Cushion, 2013). By determining how practice environments should be designed to facilitate learning, coaches and practitioners will be more aware of how activities should be designed to facilitate skill development (Roca and Ford, 2020). However, there is limited understanding of the specific practice structures and pedagogies coaches use across a range of sports and contexts (Kinnerk et al., 2019). Determining the underlying structure of practice sessions will inform the coaching process and provide insight into current coaching philosophy and pedagogical approaches (Hüttermann et al., 2014; Kinnerk et al., 2019). One method used to determine the structure of coaching sessions, is *via* systematic observational tools which monitor the time invested in specific activities (Cushion and Jones, 2001; Ford et al., 2010; Partington and Cushion, 2013). Generally, researchers have aimed to describe the time invested in training form (i.e., activities focused on developing skills *via* drills and isolated activities performed in non-pressurized environments (Ford et al., 2010; Partington and Cushion, 2013; Partington et al., 2014); and playing form activities (i.e., activities that replicate the demands of the game *via* small-sided or conditioning games (Partington and Cushion, 2013).

Researchers exploring the microstructure of practice examined the breakdown of time invested in training and playing form activities. As shown in **Table 1**, researchers found a greater proportion of time was invested in training form activities (53–65% of practice time) compared to playing form activities (Ford et al., 2010; Harvey et al., 2013; Low et al., 2013; Partington and Cushion, 2013; Partington et al., 2014; Hall et al., 2016). This type of practice places an emphasis on isolated skill drills in non-pressured environments. However, more recent investigations have shown a shift, with studies in rugby and soccer indicating coaches developed sessions with more playing form activities (Hall et al., 2016; O'Connor et al., 2018a). While this is encouraging, O'Connor et al. (2018a), extended the previous literature by also analyzing periods of inactivity within a session (i.e., periods during a session where the team are not actively participating in either training or playing form activities) and found ∼30% of session players were inactive as they listened to the coach.

In relation to the specific sequencing of the session, researchers have found sessions are structured to provide training form activities (i.e., individual and paired activities; drills) at the start of the session and then progressed to more playing form activities (i.e., small-sided games then larger games) later in the session (O'Connor et al., 2018a; Kinnerk et al., 2019). For example, early in a session, coaches prescribe more individual or drill based activities (i.e., training form), where there is an emphasis on either skill execution or conditioning. As the session progresses, there is a decrease in the use of drills and individual activities, counteracted by increased use of modified, small and larger sided games (i.e., playing form) (O'Connor et al., 2018a). Interestingly, the micro-structure of practice may differ depending on competition level or athlete ability. O'Connor and Larkin (2017) investigated the activities conducted in practice sessions across a range of sports (i.e., soccer, rugby union, rugby league and Australian Rules football) and age groups (senior—elite adult; youth - Under 16/18; junior - Under 10/12). Results found significantly more periods of training form and less time allocated to playing form activities for junior athletes compared to youth and senior athletes. The findings demonstrate there is still an emphasis on drill-based activities at a junior level, with coaches less prone to incorporating game-based practice (26% of the session time). This difference in practice micro-structure was also demonstrated in professional and non-professional Norwegian U16 soccer teams (Fuhre and Sæther, 2020). The findings highlighted the non-professional teams used more playing form activities (63.3%) compared to the professional team (55.7%).

Studies have also examined the breakdown of activities conducted within a practice session, to provide a more detailed understanding of the use of playing and training form within practice sessions. O'Connor et al. (2017) found the greatest proportion of time within youth soccer practice sessions was allocated to large- (24.8%) and small-sided games (15.3%), with drill-based (15.1%), individual (5.4%), and paired activities (2.4%). Fuhre and Sæther (2020) examined the breakdown of the specific activities undertaken and found that training form was divided into fitness (i.e., improving individual fitness), technical (i.e., isolated technical drills) and skill (i.e., re-enactments of isolated game incidents, corner, free-kick) activities. While there were some similarities between the professional and non-professional club in the time allocated to fitness (18.3 and 13.4%) and technical (13 and 23.3%) activities, the non-professional club did not spend any time in skill activities, while the professional club spent 13% of time doing these activities. In relation to playing form, the sessions examined the time invested in small-sided games (i.e., match-play with reduced numbers), conditioned games (i.e., characteristics of small-sided games, but with variations in rules) and phase of play (i.e., unidirectional match play toward a single goal) activities. Findings revealed professional and non-professional clubs allocated similar proportions of time to small-sided games (14.3 and 26.9%) and conditioned games (28.7 and 36.4%), however, the non-professional club did not allocate any time to phase of play, while the professional club spent 12.7% of time completing this type of activity. Furthermore, when exploring the breakdown of activities within sessions, there were differences depending on the age group of the athletes (O'Connor and Larkin, 2017). Coaches of junior athletes prescribe sessions with more isolated skill activities (48.9%), followed by small-sided games (27.8%), drills (13.7%) and fitness (10.3%) activities. In comparison, youth coaches organize sessions with more tactical play (42.3%) and drills (30.3%), with less of a focus on isolated skill activities (13.7%), small-sided games (11.6%) and fitness (11.6%) activities. Whereas senior coaches structure

TABLE 1 | Comparison of the mean percentage of time invested in training form, playing form and inactivity across multiple examinations of youth coaching sessions.

			Training form		Playing form		Inactivity	
References	**Sport**	**Level of Competition**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Ford et al. (2010)	Soccer	Youth - Elite	60.00	20.00	40.00	20.00		
		Youth - Sub-elite	65.00	22.00	35.00	22.00		
		Youth - Non-elite	72.00	15.00	28.00	15.00		
Low et al. (2013)	Cricket	Elite adolescents	85.00	11.00	0.00	0.00		
		Elite children	65.00	34.00	21.00	39.00		
		Recreational ADOLESCENTS	83.00	31.00	11.00	33.00		
		Recreational Children	41.00	37.00	45.00	43.00		
Partington and Cushion (2013)	Soccer	Youth - Elite	53.00		47.00			
Harvey et al. (2013)	Hockey	Collegiate	41.45	18.11	35.09	16.12		
	Volleyball	Collegiate	45.29	12.69	39.14	12.02		
	Basketball	Collegiate	40.5	13.66	35.74	15.35		
Partington et al. (2014)	Soccer	Under 10s & 11s	54		46			
		Under 12s & 13s	73		27			
		Under 14s & 15s	38		62			
O'Connor and Larkin (2017)	Mixed	Junior	45.69	23.16	26.39	19.30	26.55	12.35
		Youth	18.85	14.01	50.26	17.06	28.61	6.54
		Senior	28.89	12.22	52.04	12.49	19.07	3.00
Ford and Whelan (2016)	Soccer	Child	20.00	13.00	63.00	12.00	17.00	5.00
		Adolescent	21.00	14.00	56.00	14.00	23.00	7.00
Hall et al. (2016)	Rugby Union	Senior - Elite	41.50		58.50			
O'Connor et al. (2018a)	Soccer	Youth	22.30	13.40	40.90	14.80	36.80	9.80
Roca and Ford (2020)	Soccer	Youth	20.00	8.00	62.00	9.00	17.00	3.00
Fuhre and Sæther (2020)	Soccer	Youth Professional	44.3		55.7			
		Youth Non-Professional	36.7		63.3			
Ahmad et al. (2021)	Soccer	Elite - Youth	46.8		34.7		18.5	
		Non-Elite Youth	45		36.6		18.4	

sessions with more tactical play (41.6%), with the rest of the time divided between isolated skill activities (19.1%), fitness (16.5%), drills (13.8%), and small-sided games (8.8%). The data highlights the differences associated with how coaches at different levels of competition structure practice for athlete development (O'Connor and Larkin, 2017; O'Connor et al., 2018a; Fuhre and Sæther, 2020; Ahmad et al., 2021).

When considering the reason for the structure of a training session, Kinnerk et al. (2019) found Gaelic football coaches' use of playing and training form was dependent on the stage of the macro-structure of the athletes' program. Therefore, during pre-season more time was dedicated to training form activities, however, there was a shift in-season with more time within sessions dedicated to playing form activities. It was postulated this was due to coaches believing it was important to increase the players fitness levels during pre-season, and thus increased levels of conditioning activities during this period. However, in-season, where there are more fatigue related issues for game performance, less time was associated with individual conditioning activities. Instead, these would be incorporated within playing form activities (Kinnerk et al., 2019). The authors conclude that coaches value both training and playing form activities, and suggest the reason for high amounts of training form activities was to increase the number of skill repetitions completed, thus providing immediate performance improvements (Gabbett et al., 2009; Kinnerk et al., 2019).

COACH BEHAVIOR DURING PRACTICE SESSIONS

Another important component of the practice session to consider is the coach's behavior and its influence on athlete learning. Coaching behaviors, the communication and interactions between the athlete and coach, play an influential role in overall athlete performance, skill development and learning (Cushion, 2013; Partington and Walton, 2019). This is inclusive of instruction styles, modeling, feedback, questioning, and observation either during or outside of activity (Cushion and Jones, 2001; Cushion, 2010; Ford et al., 2010; Partington et al., 2014; Cope et al., 2017; O'Connor et al., 2018a). Coaching behaviors have been evaluated using the Coach Analysis Intervention System (CAIS) (Cushion et al., 2012b) or a modified version (Partington and Cushion, 2013; O'Connor et al., 2018b), and is designed to provide operational definitions of a variety of coaching behaviors and measure their incidence within a practice session. In this review we are focusing on instruction, feedback and questioning as these behaviors tend to be most observed and therefore reviewed thoroughly within the research (see **Table 2**) (Partington and Cushion, 2013; Partington et al., 2014; O'Connor et al., 2018a). While these coaching behaviors are classified as singular events, Cushion (2010) describes these behaviors as often overlapping and intertwined depending on the circumstances in which they are utilized.

Research indicates the use of instruction dominates coaching behaviors within youth practice sessions (Cushion, 2010; Ford et al., 2010; Cushion et al., 2012a; Partington and Cushion, 2013; O'Connor et al., 2018a). However, the amount of instruction provided during sessions vary depending on a range of factors, including age and athlete ability (Ford et al., 2010; Partington et al., 2014). There is a moderate reduction in total instruction as athletes develop with age, with coaches explaining this shift being due to younger age athletes requiring more information to correct mistakes and ensure improvement compared to older athletes (Partington et al., 2014).

While instruction can be considered holistically, the instructions provided within a session can also be divided into three primary behaviors, pre-instruction; concurrent instruction; and post-instruction (Cushion et al., 2012b; Partington et al., 2014) providing a more transparent depiction of when instruction is being utilized in the practice session. Concurrent instruction tends to be the most used form of instruction accounting for significantly greater use than pre or post instruction (e.g., 20% concurrent v 11% pre v 3% post instruction for U14/15s; Partington and Cushion, 2013). Reasons for this might be that coaches tend to mimic other coaches and it becomes a learnt behavior (Partington and Walton, 2019). Coaches might also prefer to instruct in the present in the fear of forgetting to mention the point later (Partington and Cushion, 2013). A concern with becoming over reliant on concurrent instruction is that this behavior tends to be a more explicit method of instruction and may promote athlete dependency on the coach rather than athletes working it out for themselves. Athletes may benefit more from implicit and deeper levels of learning which could be promoted through thought-provoking behaviors such as questioning (Masters and Maxwell, 2004; Gebauer and Mackintosh, 2007). Coaches tend to use those behaviors that are associated with the perception of quality coaching (Jones et al., 2004; Partington et al., 2014; Cope et al., 2017). Anecdotally, there is the perception instruction also provides the coach with credibility in the sport, with more instruction being correlated with quality coaching. The desired result is more respect from the athletes (Potrac et al., 2002; Cushion, 2010).

Providing feedback is another common behavior coaches use (Cushion, 2010; O'Connor et al., 2018a; Partington and Walton, 2019). Positive feedback has been demonstrated to be related to task accomplishment within athlete groups and is considered a preferred coaching behavior (Cushion, 2010). Youth coaches have indicated a preference to using positive forms of feedback with negative feedback being the least used (Partington et al., 2014; O'Connor et al., 2018a). Although the dominant form of feedback tends to be general positive (Partington et al., 2014; O'Connor et al., 2018b), which promotes self-confidence, it provides little if any meaningful information pertaining to the athlete performance (Horn, 1987). Alternatively, corrective feedback which is deemed more task specific and relevant to athlete learning is used consistently less throughout training periods than general positive and even positive specific feedback (O'Connor et al., 2018a). Whilst keeping feedback positive is good for athlete motivation, corrective feedback improves learning and performance when provided alongside positive feedback (Tzetzis et al., 2008) and hence should be utilized more often in the athlete development environment.

Observations have identified a tendency for feedback delivery to be evenly distributed between concurrent (during activity) and post activity (Barkell and O'Connor, 2011). Furthermore, feedback is generally provided during periods of player inactivity such as the huddle or a "freeze" scenario (O'Connor et al., 2018a). Results identified that 16.5% of the total session was based on the "freeze" principle to provide feedback to the group in relation to where they had been positioned at a given moment (O'Connor et al., 2018a). The use of a huddle to listen to the coach accounted for 9.9% of the practice time. Whilst the huddle can provide clearer messaging due to a greater focus on the coach by the athletes, it is a questionable behavior to cease all activity if the feedback is only relevant for a fraction of the group. An alternative is to take the relevant athlete aside and provide specific feedback while the activity continues (O'Connor et al., 2022).

While the use of questioning as a key pedagogical practice is known (Partington and Cushion, 2013; O'Connor et al., 2022), studies have found coaches often do not apply this behavior effectively (Low et al., 2013). Several studies have examined the use of questioning, with reports of only 7–8% of total coach interactions coming in the form of questioning (Ford et al., 2010; Partington and Cushion, 2013; Partington et al., 2014). Furthermore, early studies identified greater use of convergent questioning (87%) compared with divergent questioning (13%) (Partington et al., 2014). However, recent studies (O'Connor et al., 2018a, 2022) reported a shift in coaching behavior with more questioning being utilized (i.e., an average 71 questions/session which equated to almost one per minute), with a balance of convergent (52.2%) and divergent (47.8%) questions being used (O'Connor et al., 2022). Of the divergent questions posed, only 7% asked athletes to problem solve. Questioning, especially divergent questioning, is believed to generate a more thoughtful and abstract understanding due to the deeper thought processes required to respond (Ford and Whelan, 2016; O'Connor et al., 2020) in comparison to instruction and general feedback. In fact using questioning as a form of feedback has been identified as being advantageous to learning (O'Connor et al., 2017, 2020).

DISCUSSION AND RECOMMENDATIONS

As learning is non-linear (i.e., learning is not generally a continuous linear progression of behavior but rather involves sudden changes over time; (Kelso, 1995), creating practice environments for optimal athlete learning is challenging for coaches. This review highlights there is a shift to more playing

TABLE 2 | Descriptions and examples of the coaching behaviors of Instruction, feedback and questioning (adapted from CAIS, Cushion et al., 2012b; Partington et al., 2014).

Behavioral category	Primary behavior	Definition	Example
Instruction	Pre-instruction	Initial instructions and information provided prior to the activity starting.	"The aim of the next activity is…"
	Concurrent instruction	Training cues or directions to explicitly inform an athlete toward a certain action or behavior.	"move right", "pass to (name)", "take the shot", "mark your player"
	Post-instruction	Information given after the execution of the desired action	"You should always take the shot when its available"
Feedback	Specific feedback—positive	Specific verbal statements that are positive or supportive that specifically provide information about the quality of performance.	"I liked the way you focused on the ball"
	Specific feedback—negative	Specific verbal statements that are negative or unsupportive that specifically provide information about the quality of performance.	"Come on, you need to stay focused on the ball"
	General feedback—positive	General verbal statements OR non-verbal gestures (either positive or supportive).	"good work" or "well done"
	General feedback—negative	General verbal statements OR non-verbal gestures (either negative or unsupportive).	"that was hopeless" or "that was horrendous"
	Corrective feedback	Corrective statements that contain information that specifically aim to improve the performance at the next attempt.	"try passing earlier next time"
Questioning	Divergent questions	Multiple responses/options—more open	"What did you notice about the space in the defensive zone?"
	Convergent questions	Limited number of correct answers/options—more closed	"Who was the player that was free in the attacking zone?" or "Was that pass the best option there?"

form activities within a session, although the use of certain activities may also be influenced by when in the season the session occurs. The most frequently used coaching behavior was instruction suggesting a prescriptive and direct approach is taken by coaches, although there is evidence of a greater use of questioning in recent times. Therefore, based on the literature reviewed in this short review, several practical recommendations can be provided for coaches to apply in their daily practice. To create learning environments for their athletes, the coach must deliberately plan each practice session. This involves knowing your athletes' capabilities and their needs and deciding what to prioritize in the upcoming practice session (Muir et al., 2011). When coaches know their athletes, they can differentiate or individualize practice rather than following a "one size fits all" approach (Amorose, 2007). As coaches don't want athletes to become bored or complacent if the task is too easy, or panic if the task is beyond their capability, they should plan to push athletes beyond their comfort zone where they are "stretched", for learning to take place. An example of differentiation in a mixed ability squad, is for coaches to vary the task constraints (e.g., different rules, participant numbers, and/or field dimensions will influence their movement patterns, and the time and space athletes have to make decisions and execute skills) that groups of athletes are participating in rather than all playing the same game (i.e., 4v4).

Coaches also need to be clear on what the aim is for their practice session. The aim of the practice session and intended learning outcomes will influence the structure of practice the coach devises [e.g., type of activities—training (drills, conditioning) or playing form (small or large-sided games, phases of play); technical, tactical, physical, biopsychosocial focus; variability of practice etc.] and the coaching behavioral strategies they decide to implement (e.g., amount of instructions; use of questions; when and how they provide feedback etc.) (Abraham et al., 2014; Kinnerk et al., 2021). For example, just prior to competition the coach may use more direct and explicit approaches during drills as the focus is on performance and confidence rather than learning (Otte et al., 2020). While a specific session aim is important, coaches also need to be flexible and adapt during the session to manage the complexity of athlete learning (Nash and Taylor, 2021).

In relation to the specific practice design, coaches will utilize a range of approaches to suit the session goal (Pill, 2021). One example is a constraints-led approach, where the coach is the "designer" and manipulates various constraints (i.e., player, task, and environment) to replicate key conditions of the performance environment (i.e., transitioning from defense to attack). This provides an opportunity for athletes to learn by adapting to the situation through guided discovery and solution finding (Davids et al., 2017; Woods et al., 2020a). The decision on what and how constraints will be manipulated will be influenced by the session goal, the specific affordances within the environment coaches want athletes to explore, and the skill capabilities of the athletes (Correia et al., 2019; Renshaw et al., 2020; Woods et al., 2020b). By creatively manipulating the constraints and setting representative problems, athletes are given the opportunity to interpret game-related cues, adapt to team-mates and the opposition, explore options, make decisions, and execute technical skills, all within one activity (Pinder et al., 2011; McKay and O'Connor, 2018). This less prescriptive approach by coaches allows athletes to explore the "how, why, where, and when", experiment and make mistakes as they evaluate and identify appropriate decisions and actions to game situations (Correia et al., 2019; Renshaw and Chow, 2019). For example, by manipulating rules, number of participants, and pitch size, coaches can challenge athletes and scaffold learning while increasing the frequency of repetition, reducing the conscious control of movement, and promoting high levels of athlete engagement, ownership, autonomy and motivation (Hornig et al., 2016; Woods et al., 2020a).

This review suggests coaches are still prone to over coaching with players inactive and listening to the coach for substantial amounts of time. As coaches are constrained by the amount of time they have with their athletes, they need to consider strategies to reduce inactivity, so athletes have greater opportunities to engage in active practice. This could include reducing the amount of direct instruction (e.g., using analogies to direct athletes to an external focus of attention, Otte et al., 2020), using brief cues or prompts; allowing the activity to progress longer to see if athletes can correct their own errors or find solutions before stopping to ask questions and provide feedback (O'Connor et al., 2018b); and where appropriate, providing feedback on the run to individual athletes rather than stopping the activity. Coaches need to consider where they want to provide the feedback—either in a huddle which takes time but has the athletes' attention compared to athletes "freeze where you are" and whether all athletes can see and hear (O'Connor et al., 2018b). They are also encouraged to be mindful of the amount of feedback they give, with a "less is more" approach recommended (Otte et al., 2020; Mason et al., 2021). Coaches are encouraged to plan and scaffold questions to assist athlete learning, basing the type of question posed on their athletes' needs and the nature of the situation (i.e., what do they want to draw the athletes' attention to?), while providing enough time for athletes to respond or encouraging athletes to collaborate to devise solutions (Woods et al., 2020a; O'Connor et al., 2022). Coaches are also encouraged to reflect on-action (i.e., athlete learning, what worked well or didn't and why) to inform planning of the next practice session (Gilbert and Trudel, 2001).

CONCLUSION AND FUTURE DIRECTIONS

In summary, this review highlights the practice environment and the specific elements that can influence athlete learning. Overall, the micro-structure of practice and the activities used to promote learning need to be well-planned. There should be a clear goal for each activity. Coaches also need to consider how they communicate with their athletes to ensure they are interacting in a manner that enables athlete growth. To develop further understanding, researchers should focus attempts on evaluating the micro-structure of practice and coach behaviors regarding effectiveness in promoting the intended athlete learning outcomes. Few studies have examined the women's practice environment. Longitudinal intervention studies involving individual elements (e.g., use of questioning) may provide further understanding of athlete learning to inform coaching practice as holistic evaluations require challenging research designs (large sample size, matched participants, control group, etc.).

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

REFERENCES

Abraham, A., Lorenzo, S., Saiz, J., Mckeown, S., Morgan, G., Muir, B., et al. (2014). "Planning your coaching: a focus on youth participant development," in *Practical Sports Coaching,* ed C. Nash (London: Routledge), 16–53.

Ahmad, M., Low, J., and Nadzalan, A. (2021). The microstructure of practice activities engaged by elite youth soccer players. *Int. J. Hum. Mov. Sports Sci.* 9, 1306–1313. doi: 10.13189/saj.2021.090626

Amorose, A. J. (2007). "Coaching effectiveness: exploring the relationship between coaching behaviour and self-determined motivation," in *Intrinsic Motivation and Self-determination in Exercise and Sport*, eds M. S. Hagger, and N. Chatzisarantis (Champaign, IL: Human Kinetics), 209–227.

Barkell, J. F., and O'Connor, D. (2011). "A case study of coach practices in skill acquisition training," in *Science and Football VII*, eds B. Dawson, H. Nunome, and B. Drust (Oxon: Routledge), 371–376.

Barreiros, J., Figueiredo, T., and Godinho, M. (2007). The contextual interference effect in applied settings. *Eur. Phys. Ed. Rev.* 13, 195–208. doi: 10.1177/1356336X07076876

Barth, M., Güllich, A., Raschner, C., and Emrich, E. (2020). The path to international medals: a supervised machine learning approach to explore the impact of coach-led sport-specific and non-specific practice. *PLoS ONE* 15, e0239378. doi: 10.1371/journal.pone.0239378

Broadbent, D. P., Causer, J., Ford, P. R., and Williams, A. M. (2015). Contextual interference effect on perceptual–cognitive skills training. *Med. Sci. Sports Exer.* 47, 1243–1250. doi: 10.1249/MSS.0000000000000530

Cope, E., Partington, M., and Harvey, S. (2017). A review of the use of a systematic observation method in coaching research between 1997 and 2016. *J. Sports Sci.* 35, 2042–2050. doi: 10.1080/02640414.2016.1252463

Correia, V., Carvalho, J., Araújo, D., Pereira, E., and Davids, K. (2019). Principles of nonlinear pedagogy in sport practice. *Phys. Ed. Sport Ped.* 24, 117–132. doi: 10.1080/17408989.2018.1552673

Cushion, C. (2010). "Coach behaviour," in *Sports Coaching Professionalization and Practice*, eds J. Lyle and C. J. Cushion (London: Elsevier), 243–253.

Cushion, C. (2013). Applying Game Centred Approaches in coaching: a critical analysis of the 'dilemmas of practice' impacting change. *Sports Coach. Rev.* 2, 61–76. doi: 10.1080/21640629.2013.861312

Cushion, C. J., Ford, P. R., and Williams, A. M. (2012a). Coach behaviours and practice structures in youth soccer: implications for talent development. *J. Sports Sci.* 30, 1631–1641. doi: 10.1080/02640414.2012.721930

Cushion, C. J., Harvey, S., Muir, B., and Nelson, L. (2012b). Developing the coach analysis and intervention system (CAIS): establishing validity and reliability of a computerised systematic observation instrument. *J. Sports Sci.* 30, 203–218. doi: 10.1080/02640414.2011.635310

Cushion, C. J., and Jones, R. L. (2001). A systematic observation of professional top-level youth soccer coaches. *J. Sport Behav.* 24, 354–376.

Retrieved from: http://search.ebscohost.com/login.aspx?direct=true&db=rss&AN=5483713&site=ehost-live

Davids, K., Güllich, A., Shuttleworth, R., and Araújo, D. (2017). "Understanding environmental and task constraints on talent development: Analysis of micro-structure of practice and macro-structure of developmental histories," in *The Routledge Handbook of Talent Identification and Development*, eds J. Baker, S. Cobley, J. Schorer, and N. Wattie (New York, NY: Routledge), 80–98.

Ford, P. R., and Whelan, J. (2016). "Practice activities during coaching sessions in elite youth football and their effect on skill acquisition," in *Advances in Coach Education and Development: From Research to Practice*, eds W. Allison, A. Abraham, and A. Cale (London: Routledge), 112–123.

Ford, P. R., Yates, I., and Williams, A. M. (2010). An analysis of practice activities and instructional behaviours used by youth soccer coaches during practice: exploring the link between science and application. *J. Sports Sci.* 28, 483–495. doi: 10.1080/02640410903582750

Fuhre, J., and Sæther, S. A. (2020). Skill acquisition in a professional and non-professional U16 football team: the use of playing form versus training form. *J. Phys. Ed. Sport* 20, 2030–2035. doi: 10.7752/jpes.2020.s3274

Gabbett, T., Jenkins, D., and Abernethy, B. (2009). Game-based training for improving skill and physical fitness in team sport athletes. *Int. J. Sports Sci. Coach.* 4, 273–283. doi: 10.1260/174795409788549553

Gebauer, G. F., and Mackintosh, N. J. (2007). Psychometric intelligence dissociates implicit and explicit learning. *J. Exp. Psychol. Learn. Mem. Cogn.* 33, 34–54. doi: 10.1037/0278-7393.33.1.34

Gilbert, W., and Trudel, P. (2001). Learning to coach through experience: Reflection in model youth sport coaches. *J Teach Phys Ed.* 21, 16–34. doi: 10.1123/jtpe.21.1.16

Güllich, A. (2019). "Macro-structure" of developmental participation histories and "micro-structure" of practice of German female world-class and national-class football players. *J. Sports Sci.* 37, 1347–1355. doi: 10.1080/02640414.2018.1558744

Güllich, A., MacNamara, B. N., and Hambrick, D. Z. (2021). What makes a champion? Early multidisciplinary practice, not early specialization, predicts world-class performance. *Perspect. Psychol. Sci*. 17, 6–29. doi: 10.1177/1745691620974772

Hall, E. T., Gray, S., and Sproule, J. (2016). The microstructure of coaching practice: behaviours and activities of an elite rugby union head coach during preparation and competition. *J. Sports Sci.* 34, 896–905. doi: 10.1080/02640414.2015.1076571

Harvey, S., Cushion, C. J., Cope, E., and Muir, B. (2013). A season long investigation into coaching behaviours as a function of practice state: The case of three collegiate coaches. *Sports Coach. Rev.* 2, 13–32. doi: 10.1080/21640629.2013.837238

Horn, T. (1987). "The influence of teacher-coach behaviour on the psychological development of children," in *Advances in Paediatric Sport Sciences, Volume 2: Behavioural Issues*, eds D. Gould, and M. Weiss (Champaign, IL: Human Kinetics), 121–142.

Hornig, M., Aust, F., and Gullich, A. (2016). Practice and play in the development of German top-level professional football players. *Eur. J. Sport Sci.* 16, 96–105. doi: 10.1080/17461391.2014.982204

Hüttermann, S., Memmert, D., and Baker, J. (2014). Understanding the microstructure of practice: training differences between various age classes, expertise levels and sports. *Talent Dev. Excell.* 6, 17–29.

Jones, R. L., Armour, K. M., and Potrac, P. (2004). *Sports Coaching Cultures: From Practice to Theory*. London: Routledge.

Kelso, J. S. (1995). *Dynamic Patterns: The Self-organization of Brain and Behavior*. Cambridge: MIT Press

Kinnerk, P., Harvey, S., Kearney, P., MacDonncha, C., and Lyons, M. (2019). An investigation of the self-reported practice activities and session sequencing of inter-county Gaelic football coaches. *Int. Sport Coach. J.* 6, 211–219. doi: 10.1123/iscj.2018-0090

Kinnerk, P., Kearney, P. E., Harvey, S., and Lyons, M. (2021). An investigation of high-performance team sport coaches' planning practices. *Sports Coach. Rev.* 1–28. doi: 10.1080/21640629.2021.1990653. [Epub ahead of print].

Low, J., Williams, A. M., McRobert, A. P., and Ford, P. R. (2013). The microstructure of practice activities engaged in by elite and recreational youth cricket players. *J. Sports Sci.* 31, 1242–1250. doi: 10.1080/02640414.2013.778419

Mason, R. J., Farrow, D., and Harris, J. (2021). An exploratory investigation into the reception of verbal and video feedback provided to players in an Australian Football League club. *Int. J. Sport Sci. Coach.* 16, 181–191. doi: 10.1177/1747954120951080

Masters, R. S. W., and Maxwell, J. P. (2004). "Implicit motor learning, reinvestment and movement: What you don't know won't hurt you," in *Skill Acquisition in Sport: Research, Theory and Practice*, eds A. M. Williams, and N. J. Hodges (London: Routledge), 207–228.

McKay, J., and O'Connor, D. (2018). Practicing unstructured play in team ball sports: a rugby union example. *Int. J. Sports Sci. Coach.* 5, 273–280. doi: 10.1123/iscj.2017-0095

Muir, B., Morgan, G., Abraham, A., and Morley, D. (2011). "Developmentally appropriate approaches to coaching children," in *Coaching Children in Sport*, ed I. Stafford (London and New York, NY: Routledge), 39–59.

Nash, C., and Taylor, J. (2021). "Just let them play": Complex dynamics in youth sport, why it isn't so simple. *Front. Psychol*. 12, 700750. doi: 10.3389/fpsyg.2021.700750

O'Connor, D., and Larkin, P. (2017). "Coaching practice and player development," in *Science and Football VIII*, eds Bangsbo, J., Krustrup, P., Riis Hansen, P., Ottesen, L., Pfister, G., and Elbe A. M. (London: Routledge), 210–219.

O'Connor, D., Larkin, P., and Höner, O. (2020). "Coaches' use of game-based approaches in team sports," in *Perspectives on Game-Based Coaching, 1st Edn,* ed S. Pill (London: Routledge), 117–126.

O'Connor, D., Larkin, P., Robertson, S., and Goodyear, J. (2022). The art of the question: the structure of questions posed by youth soccer coaches during training. *Phys. Ed. Sport Ped.* 27, 304–319. doi: 10.1080/17408989.2021.1877270

O'Connor, D., Larkin, P., and Williams, A. M. (2017). What learning environments help improve decision-making? *Phys. Ed. Sport Ped.* 22, 647–660. doi: 10.1080/17408989.2017.1294678

O'Connor, D., Larkin, P., and Williams, A. M. (2018a). Observations of youth football training: how do coaches structure training sessions for player development? *J. Sports Sci.* 36, 39–47. doi: 10.1080/02640414.2016.1277034

O'Connor, D., Wardak, D., Goodyear, P., Larkin, P., and Williams, M. (2018b). Conceptualising decision-making and its development: a phenomenographic analysis. *Sci. Med. Football* 2, 261–271. doi: 10.1080/24733938.2018.1472388

Otte, F., Davids, K., Millar, S.-K., and Klatt, S. (2020). When and how to provide feedback and instructions to athletes? – How sport psychology and pedagogy insights can improve coaching interventions to enhance self-regulation in training. *Front. Psychol*. 11, 1444. doi: 10.3389/fpsyg.2020.01444

Partington, M., Cushion, C., and Harvey, S. (2014). An investigation of the effect of athletes' age on the coaching behaviours of professional top-level youth soccer coaches. *J. Sports Sci.* 32, 403–414. doi: 10.1080/02640414.2013.835063

Partington, M., and Cushion, C. J. (2013). An investigation of the practice activities and coaching behaviours of professional top-level youth soccer coaches. *Scand. J. Med. Sci. Sports* 23, 374–382. doi: 10.1111/j.1600-0838.2011.01383.x

Partington, M., and Walton, J. (2019). "A guide to analysing coaching behaviours," in *Sports Coaching: A Theoretical and Practical Guide*, eds E. Cope, M. Partington (London: Routledge), 18–29.

Pill, S. (2021). *Perspectives on Game-Based Coaching*. London: Routledge.

Pinder, R. A., Davids, K., Renshaw, I., and Araújo, D. (2011). Representative learning design and functionality of research and practice in sport. *J. Sport Exerc. Psychol*. 33, 146–155. doi: 10.1123/jsep.33.1.146

Potrac, P., Jones, R., and Armour, K. (2002). 'It's all about getting respect': the coaching behaviours of an expert English soccer coach. *Sport Ed. Soc.* 7, 183–202. doi: 10.1080/1357332022000018869

Renshaw, I., and Chow, J. Y. (2019). A constraint-led approach to sport and physical education pedagogy. *Phys. Educ. Sport Ped.* 24, 103–116. doi: 10.1080/17408989.2018.1552676

Renshaw, I., Headrick, J., Maloney, M., Moy, B., and Pinder, R. (2020). "Constraints-led learning in practice: designing effective learning environments," in *Skill Acquisition in Sport*, eds N. Hodges, and A. M. Williams (London: Routledge), 163–182.

Roca, A., and Ford, P. R. (2020). Decision-making practice during coaching sessions in elite youth football across European countries. *Sci. Med. Football* 4, 263–268. doi: 10.1080/24733938.2020.1755051

Spittle, M. (2013). *Motor Learning and Skill Acquisition: Applications for Physical Education and Sport*. Melbourne, VIC: Palgrave MacMillian.

Tzetzis, G., Votsis, E., and Kourtessis, T. (2008). The effect of different corrective feedback methods on the outcome and self confidence of young athletes. *J. Sports Sci. Med.* 7, 371–378.

Woods, C. T., McKeown, I., O'Sullivan, M., Robertson, S., and Davids, K. (2020a). Theory to practice: performance preparation models in contemporary high-level sport guided by an ecological dynamics framework. *Sports Med*. 6, 36. doi: 10.1186/s40798-020-00268-5

Woods, C. T., McKeown, I., Rothwell, M., Araújo, D., Robertson, S., and Davids, K. (2020b). Sports practitioners as sport ecology designers: How ecological dynamics has progressively changed perceptions of skill "acquisition" in the sporting habitat. *Front. Psychol.* 11, 654, doi: 10.3389/fpsyg.2020.00654

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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frontiers | Frontiers in Sports and Active Living

TYPE Mini Review
PUBLISHED 18 May 2023
DOI 10.3389/fspor.2023.1175718

OPEN ACCESS

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RECEIVED 28 February 2023
ACCEPTED 03 May 2023
PUBLISHED 18 May 2023

CITATION
Güllich A, Barth M, Hambrick DZ and Macnamara BN (2023) Participation patterns in talent development in youth sports.
Front. Sports Act. Living 5:1175718.
doi: 10.3389/fspor.2023.1175718

Participation patterns in talent development in youth sports

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There has been a longstanding debate about the question: What amounts of what types of youth sport activities optimally facilitate later athletic excellence? This article provides a review of relevant research. We first evaluate popular conceptualizations of participation patterns—early specialization, deliberate practice, and deliberate play. Then, we review the available evidence on associations between performance and individual participation variables. The review reveals conceptual, definitional, and empirical flaws of the conceptions of early specialization, deliberate practice, and deliberate play. These approaches thus possess limited usefulness for empirical research. A review of studies considering individual, clearly defined participation variables provides a differentiated pattern of findings: Predictors of rapid junior performance and of long-term senior performance are opposite. Higher-performing juniors, compared to lower-performing peers, started playing their main sport, began involvement in talent promotion programs, and reached developmental performance milestones at younger ages, while accumulating larger amounts of coach-led main-sport practice, but less other-sports practice. In contrast, senior world-class athletes, compared to less-accomplished national-class peers, started playing their main sport, began involvement in talent promotion programs, and achieved performance milestones at older ages, while accumulating less coach-led main-sport practice, but more other-sports practice. We discuss implications for theory, practice, and future research.

KEYWORDS

youth sports, talent, performance, early specialization, deliberate practice, deliberate play

1. Introduction

What types and amounts of sport activities optimally facilitate the achievement of athletic excellence? There is consensus that extensive sport-specific practice over multiple years is necessary. However, the question of optimal amounts of different types of sport activities in childhood and adolescence is the subject of a longstanding debate (1–4).

Participation patterns in youth sports have often been discussed in the context of the constructs of "*early specialization*" versus "*early diversification*" [e.g., (3, 4)]. Early specialization has commonly been associated with Ericsson et al.'s (5) proposed framework of "*deliberate practice*," while early diversification has been associated with Côté et al.'s (3) proposal of childhood/adolescent multi-sport "*deliberate play*".

In this article, we first evaluate the approaches of early specialization, deliberate practice, and deliberate play. Then, we review current empirical research addressing effects of participation variables on performance. Finally, we discuss implications for theory, practice, and future research.

2. Review of current research

2.1. Evaluation of the constructs of early specialization, deliberate practice, and deliberate play

Scientific research generally seeks to describe and explain laws of relationships between variables. Here, the focus is on relationships between childhood/adolescent participation variables and later performance. A youth athlete's participation pattern is composed of several participation variables, including age to begin playing their respective main sport, age to reach defined developmental performance milestones (e.g., first state, national, or international championships), types and number of sports they play, and amounts of organized coach-led practice and of informal peer-led play, both in their main sport and in other sports. These participation variables can all be measured individually as continuous, parametric variables, and their linear or non-linear associations with performance, and interactions with one another, can be quantified.

The construct of *early specialization* is problematic for research, primarily because it is not a sound scientific construct in several regards [for general issues of unfalsifiability of claims about early specialization, see e.g., (6, 7)].

1. There is no theoretically and/or empirically based definition of the construct [reviews in (8, 9)]. Instead, there are countless *ad hoc* definitions in the literature.
2. *Early* specialization has referred to varying age periods (6 years to late adolescence).
3. Early specialization has commonly been described as one composite construct composed of several constituents (9). These vary study to study to include, for example,
   (a) participation in intensive/extensive/increased hours of competitions/training and/or deliberate practice
   (b) that is/are specific/structured/systematic/targeted/focused/regular/intentional/purposeful/committed and/or effortful,
   (c) done year-round/over 8 or 6 months annually,
   (d) and done mainly/almost exclusively or exclusively, at the exclusion/reduction or limitation of deliberate play/other sports and/or other activities in general,
   (e) to achieve skill improvement/performance/athletic expertise/elite success or scholarships (9).

Most constituents lack operational definitions, and both the activity attributes and athletes' motives (b, e) have typically been *ascribed* to the "specialized" activity, not empirically determined. Additionally, the early specialization composite construct and its constituents, although all continuous variables, have commonly been artificially dichotomized, dividing "specialized" versus "non-specialized" participants (9). These characteristics preclude the investigation of which individual participation variables are associated with performance and in which way [(7, 8), just as for other outcomes such as injuries or psychosocial wellbeing, e.g., (10, 11)]. Given that relevant participation variables can be recorded separately and as continuous variables, approaches at both forming one composite early specialization construct and its artificial dichotomization [or tripartition (10)] are neither necessary nor conducive to research (7).

Ericsson et al. (5) proposed that youth athletes should start *deliberate practice* at a young age and should subsequently maximize their amount of deliberate practice: individual sport-specific practice that is instructed and monitored by a coach, includes frequent repetition of a task, is done to improve one's performance, and is highly effortful and not inherently enjoyable. The authors partly *ascribed* activity attributes they deemed effective to performance (solitariness, effort, low enjoyment, performance motive) by way of synthetic *a priori* attribution (12) rather than empirical evidence [review in (13)]. Furthermore, athletes typically report high inherent enjoyment of practice activities that meet deliberate practice criteria, while their developmental sport engagement also includes extensive activities outside the original definition of deliberate practice: Team practice, playing forms, and competitions (13–19). Consequently, Ericsson (20) acknowledged that his conceptualization of deliberate practice has limited applicability to the sports domain.

In their proposal of *early diversification*, Côté et al. (3) suggested that youth athletes should delay increasing single-sport deliberate practice to the "investment stage" (16–18 years). This *late specialization* should be preceded by a "sampling stage" (6–12 years) and a "specialization stage" (13–15 years) with extensive *deliberate play* in multiple sports: Informal non-organized play that is regulated by the participants, rather than by a coach (i.e., peer-led), and is done for the inherent enjoyment of play, not for performance improvement (e.g., backyard soccer, street hockey, ice-hockey on a frozen lake). The authors distinguished deliberate play from other activities by several attributes (e.g., variability, time-on-task, motives, inherent enjoyment) and outcomes (skill transfer, future intrinsic motivation, prolonged engagement) *ascribed* by way of synthetic *a priori* attribution and extrapolation from general childhood non-sport play [for dissenting evidence from sports (13, 21–24)]. Furthermore, the age demarcations of Côté et al.'s (3) "stages" were normatively set rather than empirically determined and cannot take account of the great individual variation and gradual changes of different developmental sport activities through the course of an athletic career. In addition, given that age periods and amounts of each type of sport activity can be empirically recorded, an *a priori* normative categorization of career stages is unnecessary, but may constrict empirical research.

2.2. Effects of participation variables on performance

A commonality of the aforementioned approaches is that they *ascribed* participant motives, perceptions, and activity attributes to their composite constructs by way of *a priori* attribution or illegitimate extrapolation rather than empirical evidence. An alternative, appropriate research approach is to measure relevant, clearly defined participation variables separately—for example, athletes' age to start playing their main-sport, age to reach developmental performance milestones, and age periods and amounts of organized coach-led practice and informal peer-led play, both in one's respective main sport and in other sports. This approach also has limitations; for example, it does not consider participants' motives and perceptions [while these can also be integrated (13, 24)]. But its strengths include (a) the distinction of activity types considered critical in the aforementioned approaches by only the unambiguous criteria (the sport: main sport vs. other sports, and the setting: organized coach-led practice vs. informal peer-led play), and (b) enabling investigation of bivariate and potential multivariate interactive, linear and non-linear associations of performance with the individual participation variables. The approach would still allow for categorizations of participants, activity amounts, or career phases—but *a posteriori* based on the empirical data.

In a recent report (25), we systematically reviewed the findings from studies that have considered associations between achieved performance and these participation variables. Results of original studies have been inconsistent: Each of the participation variables was positively correlated with performance in some studies, but was uncorrelated or negatively correlated with performance in other studies. However, samples were heterogeneous in terms of athletes' age category (juniors, seniors), performance levels (local to Olympic level), and types of sports.

To establish robust and generalizable findings, the available studies were synthesized in two recent meta-analyses (26, 27), structuring the findings from original studies by athletes' age category (junior, senior), performance level (international, national, below), and types of sports. Analyses included 685 effect sizes from 131 studies with 9,241 athletes, 67% male, 33% female, 62% junior, and 38% senior athletes (i.e., competing in the highest, open-age category, typically in their 20–30 s); 1,003 athletes achieved international medals or top-ten placings and 4,818 competed at a national level.

Two questions were investigated:

1. Did higher- and lower-performing athletes differ in age to start playing their respective main sport, age to reach developmental performance milestones, and/or amounts of coach-led practice or peer-led play in either their main sport or in other sports?
2. Do effects of participation variables differ across athletes' age category (juniors, seniors) or types of sports?

Central findings are summarized in **Table 1**. Participation variables predicted junior and senior performance. Moreover, childhood/adolescent participation variables differentiated later senior world-class and national-class athletes. However, predictors of early junior performance and of long-term senior performance were opposite.

Overall, higher-performing juniors started playing their main sport at younger ages, achieved developmental performance milestones at younger ages, accumulated greater amounts of coach-led main-sport practice, and smaller amounts of other-sports practice, than lower-performing juniors (**Table 1**). In contrast, higher-performing senior athletes started playing their main sport at older ages, achieved developmental performance milestones at older ages, and accumulated greater amounts of coach-led other-sports practice, than lower-performing seniors. In addition, amount of coach-led main-sport practice was less predictive of senior performance than of junior performance, and senior performance was *unrelated* to *early* amount of main-sport practice (**Table 1**).

Senior world-class athletes started playing their main sport at older ages and achieved developmental performance milestones at older ages than their less-accomplished national-class counterparts. Relatedly, world-class athletes engaged in *less* coach-led main-sport practice, but more coach-led other-sports practice (**Table 1**). The senior world-class athletes practiced and competed in 1.9 other sports for 9.4 years, ending at age 18.1 years (sample-weighted means).

Although many athletes participated in considerable childhood/adolescent peer-led play—for example, senior world-class athletes' total childhood/adolescent sport activity was 32%

TABLE 1 Meta-analytic mean effects (Cohen's $\bar{d}$) of participation variables on performance, separately for mean effects on junior performance overall (left column), senior performance overall (central column) and senior world-class vs. national-class athletes (right column).

Predictors	Effects on higher versus lower performance		
	Junior athletes	Senior athletes	Senior athletes
	Overall[a]	Overall[a]	WCl vs. NCl[b]
	$\bar{d}$	$\bar{d}$	$\bar{d}$
Age-related predictors			
Main sport starting age	−0.33**	0.28**	0.41**
Age to reach milestones[c]	−0.49**	0.36**	0.42**
Amount of activity throughout one's career			
Amount of coach-led practice			
In one's main sport	0.61**	0.20*	−0.23**
In other sports	−0.23**	0.47**	0.50**
Amount of peer-led play			
In one's main sport	0.24	0.17	−0.03
In other sports	−0.12*	0.13*	0.11
Amount of only early activity until age 15 years			
Amount of coach-led practice			
In one's main sport	0.53**	−0.10	−0.29**
In other sports	−0.14	0.51**	0.54**
Amount of peer-led play			
In one's main sport	0.18	0.14	0.03
In other sports[d]	—	0.15	0.14

Upper part: mean effects of activities accumulated throughout one's entire athletic career. Lower part: mean effects of only early activities accumulated until age 15 years. Based on data from Barth et al. (27). $\bar{d}$ = meta-analytic mean Cohen's $\bar{d}$. Note the sign of effects for age- and activity-related predictors: a positive effect indicates that higher performance was associated with older (higher) ages and with greater activity amounts.

[a]Comparisons of higher- and lower-performing athletes across all performance levels (international, national, regional level).

[b]WCl, world class (international medalists or top ten), NCl, national class (national squad, top ten at national championships, national premier league).

[c]E.g., first national championships, first international championships.

[d]—, not enough effect sizes ($k < 5$) for juniors' early other-sports peer-led play.

*Significance: $p < .05$.

**Significance: $p < .01$.

peer-led play (sample-weighted mean)—effects of peer-led play amounts, both main-sport and other-sports, on the differentiation between higher- and lower-performing athletes were negligible, both for junior and senior performance (**Table 1**).

The findings were robust across different types of sports [cgs sports (performance is measured in centimeters, grams, or seconds), game, combat, and artistic composition sports] (26, 27). Furthermore, central findings have been confirmed in multi-year prospective quasi-experiments, matched-pairs designs, and multivariate linear and non-linear analyses (28–32).

Finally, to fully understand the pattern of findings, three specific results from several original studies are relevant (28–41).

1. Senior world-class and national-class athletes had similar performance development until late adolescence and only diverged in early adulthood. The senior world-class athletes, compared to national-class counterparts, performed equivalent or less main-sport practice through the age interval. Therefore, childhood/adolescent multi-sport practice apparently had a delayed moderator effect via improved subsequent sport-specific *efficiency of practice*—i.e., performance improvement per practice amount.
2. The greater later performance improvement was rather based on better sport-specific perceptual-motor skill development than physical development (speed, power, endurance). This suggests that the improved sport-specific efficiency of practice primarily rested on better perceptual-motor *learning*.
3. The effect was not moderated by relatedness of an athlete's main sport with the other sports they played.

2.3. Effects of early involvement in talent promotion programs on performance

Talent promotion programs (TPPs) in youth sports seek to increase the long-term senior performance of talent-identified youth athletes (42, 43). They preferably select high-performing youth athletes and, once selected, attempt to further accelerate childhood/adolescent performance via expanded specialized practice, competitions, and corresponding environments and resources (high-profile coaching, facilities, athlete services) (42, 43). TPPs seek to involve identified talents at a young age, typically around puberty or younger, to enable a long period of TPP nurture until the anticipated age of peak performance.

Many of the selected early high performers have an early biological maturation [e.g., puberty, growth spurt (44)], have been born early within their birth-year [relative age effect (45)], and have already had large amounts of sport-specific training (27). The question arises whether younger TPP involvement is associated with higher performance in subsequent years.

Nineteen studies, involving 38 study samples from multiple sports and countries (29, 31, 36–39, 46–58), have investigated associations of athletes' junior or senior performance with their age of beginning TPP involvement in terms of federations' youth squads, selection teams, or sport academies. **Table 2** reviews the findings. Consistent across performance levels and TPPs, higher-performing *juniors* were selected for TPPs at *younger* ages than lower-performing juniors. In contrast, higher-performing *seniors* were selected for TPPs at *older* ages than lower-performing seniors (**Table 2**).

TABLE 2 Mean effects (Cohen's $\bar{d}$) of the age of beginning involvement in talent promotion programs on early junior performance and on later senior performance.

Subsamples[a]	Effects on higher vs. lower performance	
	Junior athletes	Senior athletes
	$\bar{d}$	$\bar{d}$
Overall[b]	−0.60	0.61
World-class vs. national class[c]	−0.63	0.54
National class vs. regional class[c]	−0.50	0.67
Federation's squad/selection team[d]	−0.63	0.60
Youth sport academy[d]	−0.50	0.68

Junior athletes: $k = 13$, $N = 1,674$, senior athletes: $k = 25$, $N = 5,400$. $\bar{d}$ = sample-weighted mean Cohen's $\bar{d}$. Note the sign of effects: a negative effect indicates that higher performance was associated with a younger selection age, a positive effect indicates that higher performance was associated with an older selection age.
[a]References (29, 31, 36–39, 46–58).
[b]Pooled for federation's youth squad/selection team and youth sport academy and across performance levels.
[c]Pooled for federation's youth squad/selection team and youth sport academy. World class = international medalists or top ten, national class = top ten at national championships or playing national premier league, regional = below.
[d]Pooled across world-class, national, and regional performance levels.

3. Discussion

Investigating the association of performance with individual, unambiguous participation variables while distinguishing predictors of early junior performance and long-term senior performance provides a more differentiated pattern of findings than only considering task-specific deliberate practice or a composite, dichotomized early specialization construct. An early start, extensive coach-led main-sport practice with little or no other-sports practice, early TPP involvement, and rapid achievement of performance milestones appear to facilitate early junior performance. In contrast, a later start, reduced childhood/adolescent coach-led main-sport practice, more other-sports practice over more years, delayed TPP involvement, and delayed achievement of performance milestones appear to facilitate long-term senior world-class performance.

The findings do not call into question the importance of multi-year coach-led sport-specific practice and of juvenile performance progress. All the senior world-class and national-class athletes and high-performing junior athletes engaged in considerable main-sport practice and many had remarkable performance progress in their early years. However, athletes who had a particularly accelerated performance development in their early years—typically associated with increased main-sport practice, little or no other-sports practice, and early TPP involvement—are common among the highest junior performers and senior national-class athletes, but are rare among senior world-class athletes.

3.1. Theoretical implications

Traditional conceptions of deliberate practice, diversified deliberate play, as well as of giftedness (3, 5, 59), cannot adequately explain the full range of empirical observations concerning athletic performance, primarily because their central tenets are at odds with the empirical evidence. More specifically, they cannot explain the factors predicting the highest performance level, i.e., senior world class. Nor can they explain why predictors of short-term junior performance and long-term senior performance are opposite and why early non-specific practice facilitates later efficiency of sport-specific practice.

Alternatively, viewing youth sports participation through a neoclassical economic framework, especially the concepts of *efficiency* and *sustainability*, provides a fruitful heuristic to better understand the development into the highest athletic performance levels (26, 27, 30). In essence, as amounts of practice and competitions increase, *efficiency of practice* is paramount, because (1) resources are limited and must be economized (e.g., the athlete's time, body, load-tolerance, health), and (2) coaches and athletes seek to expand benefits (e.g., performance, enjoyment, prestige) while limiting costs (especially *opportunity costs*—the lost benefit of forgone other activities, such as time with family, friends, academics, hobbies, other sports) and risks (e.g., overtraining, injury, burnout). *Sustainability* is also paramount because (3) costs, risks, and benefits of participation patterns vary and may even be opposite regarding short- versus long-term outcomes.

Among high-level athletes who have all engaged in multi-year extensive sport-specific practice, the senior world-class athletes' reduced main-sport practice combined with multi-year other-sports practice suggests a rather resource-preserving, cost-reducing, and risk-buffering childhood/adolescent investment pattern that yielded greater benefit in terms of performance in the long run. Practice and competition experiences in various sports diversify athletes' "risk capital" and increase the odds that they find a sport that matches their talent and individual preferences [search and match theory (60, 61)]. Furthermore, childhood/adolescent multi-sport engagement has been reported to be associated with reduced risks of later overuse injuries and burnout (10, 11). Finally, the diverse learning experiences associated with practice and competitions in different sports may expand athletes' *learning capital* for future long-term sport-specific perceptual-motor learning [theory of learning transfer as preparation for future learning, PFL (62)]. The varied learning experiences facilitate the athlete's ability to adapt to and exploit different learning opportunities and situations (63). The experiences with varying learning designs and methodologies also help the athlete understand individually more and less athlete-functional learning solutions (30, 62).

In contrast, intensified early main-sport practice with little or no other-sports practice implies reduced long-term benefit and expanded costs and risks for youth athletes. Relatedly, early TPP involvement may impose additional costs (expanded time demands from additional training, competitions, athlete services, transit times) and risks (overtraining, later overuse injuries) on the youth athlete. In addition, there may be two specific selection effects, in that athletes who have an accelerated biological maturation [puberty, growth spurt (44)] and are relatively old within their birth year [relative age effect (45)] have a performance advantage during adolescence which, however, diminishes or is even reversed by adulthood (64–66).

3.2. Practical implications

Youth sport programs should seek to limit youth athletes' costs and risks while maximizing their benefits. The empirical evidence suggests three clear practical implications.

1. Youth sport coaches and managers make a choice that may be poorly- or well-informed: To reinforce rapid junior success at the expense of long-term senior success or to facilitate long-term senior success at the expense of early junior success. To facilitate long-term senior success (and youth athletes' physical and psychological wellbeing), youth coaches should avoid excessive specialized single-sport practice and encourage youth athletes and provide opportunities to practice and compete in 1–2 other sports.
2. Given that particularly early TPP involvement is negatively correlated with long-term senior performance, TPPs should postpone selection to later ages. In addition, aiming to select the youth athletes with the greatest future potential, talent selection should consider their participation history in terms of moderate sport-specific training with multi-sport practice prior to selection.
3. Evaluating the work of youth coaches and TPPs by their youth athletes' early junior performance may elicit dysfunctional incentives. Rather, it is functional to evaluate their work by the performance progress the youth athletes make in subsequent years into adulthood.

3.3. Future research directions

Factors that make the difference among the highest athletic performance levels—senior world-class and national-class performance—cannot be inferred by extrapolating findings from junior athletes, lower performance levels, or extreme contrast comparison [such as international versus local level, e.g., (19, 33, 67–70)]. To predict the highest performance levels, the goal for future research is to further investigate childhood/adolescent participation factors of the highest-performing senior athletes. The economic concepts of *efficiency* and *sustainability* provide a fruitful heuristic, and lead to three questions:

1. What short- and long-term, material and immaterial costs, risks, and benefits do different childhood/adolescent participation patterns yield?

2. What objective and subjective value does each of the costs, risks, and benefits have?
3. What is the eventual ratio of the summed value of all benefits relative to the summed value of all costs and risks emerging from different childhood/adolescent participation patterns?

This research will advance an economic theory of the development of athletic excellence, and contribute to a well-substantiated scientific foundation for designing youth sport programs.

Author contributions

AG, MB, DH, and BM equally contributed to this research. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

1. Hill GM, Hansen GF. Sport specialization in high school: a complex issue. *Phys Educ*. (1987) 44:422–6.

2. Wiersma LD. Risks and benefits of youth sport specialization: perspectives and recommendations. *Pediatr Exerc Sci*. (2000) 12:13–22. doi: 10.1123/pes.12.1.13

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

4. Kliethermes SA, Marshall SW, LaBella CR, Watson AM, Brenner JS, Nagle KB, et al. Defining a research agenda for youth sport specialization in the USA: the AMSSM youth early sport specialization summit. *Br J Sports Med*. (2021) 55:135–43. doi: 10.1136/bjsports-2020-102699

5. Ericsson KA, Krampe RT, Tesch-Römer C. The role of deliberate practice in the acquisition of expert performance. *Psychol Rev*. (1993) 100:363–406. doi: 10.1037/0033-295X.100.3.363

6. Bell DR, Snedden TR, Biese KM, Nelson E, Watson AM, Brooks A, et al. Consensus definition of sport specialization in youth athletes using a delphi approach. *J Athl Train*. (2021) 56:1239–51. doi: 10.4085/1062-6050-0725.20

7. Güllich A, Macnamara BN, Barth M, Hambrick DZ. Further muddying the waters? A comment on Bell et al.'s 2021 definition of youth sport specialization. *J Athl Train*. (2021) 56:1252–4. doi: 10.4085/1062-6050-1010-21

8. Baker J, Cobley S, Fraser-Thomas J. What do we know about early specialization? Not much!. *High Abil Stud*. (2009) 20:77–89. doi: 10.1080/13598130902860507

9. Mosher A, Fraser-Thomas J, Baker J. What defines early specialization: a systematic review of literature. *Front Sports Act Living*. (2020) 2:596229. doi: 10.3389/fspor.2020.596229

10. Bell DR, Post EG, Biese K, Bay C, Valovich McLeod T. Sport specialization and risk of overuse injuries: a systematic review with meta-analysis. *Pediatrics*. (2018) 142:e20180657. doi: 10.1542/peds.2018-0657

11. Waldron S, DeFreese JD, Register-Mihalik J, Pietrosimone B, Barczak N. The costs and benefits of early sport specialization: a critical review of literature. *Quest*. (2020) 72:1–18. doi: 10.1080/00336297.2019.1580205

12. Kant I. *Critique of pure reason [in German: kritik der reinen vernunft*. Riga: Hartknoch (1787).

13. Güllich A, Faß L, Gies C, Wald V. On the empirical substantiation of the definition of "deliberate practice" (Ericsson et al., 1993) and "deliberate play" (Côté et al., 2007) in youth athletes. *J Expert*. (2020) 3:1–19.

14. Starkes JL, Deakin HM, Allard F, Hodges NJ, Hayes A. Deliberate practice in sports: what is it anyway? In: Ericsson KA, editors. *The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games*. Hillsdale, NJ: Erlbaum (1996). p. 81–106.

15. Hodges NJ, Starkes JL. Wrestling with the nature of expertise: a sport-specific test of Ericson, Krampe, and Tesch-römer's (1993) theory of deliberate practice. *Int J Sport Psych*. (1993) 27:400–24.

16. Young BW, Salmela JH. Examination of practice activities related to the acquisition of elite performance in Canadian middle distance running. *Int J Sport Psychol*. (2010) 41:73–90.

17. Helsen WF, Starkes JL, Hodges NJ. Team sports and the theory of deliberate practice. *J Sport Exerc Psychol*. (1998) 20:12–34. doi: 10.1123/jsep.20.1.12

18. Abernethy B, Farrow D, Berry J. Constraints and issues in the development of a general theory of expert perceptual-motor performance: a critique of the deliberate practice framework. In: Starkes JL, Ericsson KA, editors. *Expert performance in sports: Advances in research on sport expertise*. Champaign, IL: Human Kinetics (2003). p. 349–69.

19. Ward P, Hodges NJ, Starkes JL, Williams MA. The road to excellence: deliberate practice and the development of expertise. *High Abil Stud*. (2007) 18:119–53. doi: 10.1080/13598130701709715

20. Ericsson KA. Towards a science of the acquisition of expert performance in sports: clarifying the differences between deliberate practice and other types of practice. *J Sports Sci*. (2020) 38:159–76. doi: 10.1080/02640414.2019.1688618

21. Wall M, Côté J. Developmental activities that lead to dropout and investment in sport. *Phys Educ Sport Pedagogy*. (2007) 12:77–87. doi: 10.1080/17408980601060358

22. Hendry DT, Crocker PR, Hodges NJ. Practice and play as determinants of self-determined motivation in youth soccer players. *J Sports Sci*. (2014) 32:1091–9. doi: 10.1080/02640414.2014.880792

23. Hendry DT, Hodges NJ. Pathways to expert performance in soccer. *J Expert*. (2019) 2:1–13.

24. Thomas A, Güllich A. Childhood practice and play as determinants of adolescent intrinsic and extrinsic motivation among elite youth athletes. *Eur J Sport Sci*. (2019) 19:1120–9. doi: 10.1080/17461391.2019.1597170

25. Güllich A, Barth M, Macnamara BN, Hambrick DZ. What makes champions? Childhood multi-sport practice facilitates long-term performance development. In: Toms M, Jeanes R, editors. *Routledge handbook of coaching children in sport*. New York: Routledge (2022). p. 225–37.

26. Güllich A, Macnamara BN, Hambrick DZ. What makes a champion? Early multi-disciplinary practice, not early specialization, predicts world-class performance. *Perspect Psychol Sci*. (2021) 17:6–29. doi: 10.1177/1745691620974772

27. Barth M, Güllich A, Macnamara BN, Hambrick DZ. Predictors of junior versus senior elite performance are opposite: a systematic review and meta-analysis of participation patterns. *Sports Med*. (2022) 52:1399–416. doi: 10.1007/s40279-021-01625-4

28. Hardy L, Laing S, Barlow M, Kincheva L, Evans L, Rees T, et al. *A comparison of the biographies of GB serial medal and non-medalling Olympic athletes*. London: UK Sport (2013).

29. Güllich A, Emrich E. Considering long-term sustainability in the development of world class success. *Eur J Sport Sci*. (2014) 14 Sup1:S383–97. doi: 10.1080/17461391.2012.706320

30. Güllich A. International medallists' and non-medallists' developmental sport activities—a matched-pairs analysis. *J Sports Sci*. (2017) 35:2281–8. doi: 10.1080/02640414.2016.1265662

31. Güllich A. Sport-specific and non-specific practice of strong and weak responders in junior and senior elite athletics—a matched-pairs analysis. *J Sports Sci*. (2018) 36(19):2256–64. doi: 10.1080/02640414.2018.1449089

32. Barth M, Güllich A. Non-linear association of efficiency of practice of adult elite athletes with their youth multi-sport practice. *J Sports Sci*. (2021) 39:915–25. doi: 10.1080/02640414.2020.1851900

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

34. Johnson MB, Tenenbaum G, Edmonds WA. Adaptation to physically and emotionally demanding conditions: the role of deliberate practice. *High Abil Stud*. (2006) 17:117–36. doi: 10.1080/13598130600947184

35. Weissensteiner J, Abernethy B, Farrow D, Müller S. The development of anticipation: a cross-sectional examination of the practice experiences contributing to skill in cricket batting. *J Sport Exerc Psychol*. (2008) 30:663–84. doi: 10.1123/jsep.30.6.663

36. Moesch K, Elbe AM, Hauge ML, Wikman JM. Late specialization: the key to success in centimeters, grams, or seconds (cgs) sports. *Scand J Med Sci Sports*. (2011) 21:e282–90. doi: 10.1111/j.1600-0838.2010.01280.x

37. Hornig M, Aust F, Güllich A. Practice and play in the development of German top-level professional football players. *Eur J Sport Sci*. (2016) 16:96–105. doi: 10.1080/17461391.2014.982204

38. Güllich A. Many roads lead to Rome—developmental paths to Olympic gold in men's field hockey. *Eur J Sport Sci*. (2014) 14:763–71. doi: 10.1080/17461391.2014.905983

39. Güllich A. "Macro-structure" of developmental participation histories and "micro-structure" of practice of German female world-class and national-class football players. *J Sports Sci*. (2019) 37:1347–55. doi: 10.1080/02640414.2018.1558744

40. Güllich A, Kovar P, Zart S, Reimann A. Sport activities differentiating match-play improvement in elite youth footballers—a 2-year longitudinal study. *J Sports Sci*. (2017) 35:207–15. doi: 10.1080/02640414.2016.1161206

41. Güllich A, Cronauer R, Diehl J, Gard L, Miller C. Coach-assessed skill learning progress of youth soccer players correlates with earlier childhood practice in other sports. *Int J Sports Sci Coach*. (2020) 15:285–96. doi: 10.1177/1747954120912351

42. Güllich A, Emrich E. Evaluation of the support of young athletes in the elite sports system. *Eur J Sport Soc*. (2006) 3:85–108. doi: 10.1080/16138171.2006.11687783

43. Güllich A, Cobley S. On the efficacy of talent identification and talent development programmes. In: Baker J, Cobley S, Schorer J, Wattie N, editors. *Routledge handbook of talent identification and development in sport*. London: Routledge (2017). p. 80–98.

44. Malina RM, Rogol AD, Cumming SP, Coelho e Silva MJ, Figueiredo AJ. Biological maturation of youth athletes: assessment and implications. *Br J Sports Med*. (2015) 49:852–9. doi: 10.1136/bjsports-2015-094623

45. Wattie N, Schorer J, Baker J. The relative age effect in sport: a development systems model. *Sports Med*. (2015) 45:83–94. doi: 10.1007/s40279-014-0248-9

46. Barreiros A, Côté J, Fonseca AM. Training and psychosocial patterns during the early development of Portuguese national team athletes. *High Abil Stud*. (2013) 24:49–61. doi: 10.1080/13598139.2013.780965

47. Drake D, Breslin G. Developmental activities and the acquisition of perceptual-cognitive expertise in international field hockey players. *Int J Sports Sci Coach*. (2019) 13:636–42. doi: 10.1177/1747954117711093

48. Ford PR, Williams AM. The developmental activities engaged in by elite youth soccer players who progressed to professional status compared to those who did not. *Psychol Sport Exerc*. (2012) 13:349–52. doi: 10.1016/j.psychsport.2011.09.004

49. Ford PR, Ward P, Hodges NJ, Williams AM. The role of deliberate practice and play in career progression in sport: the early engagement hypothesis. *High Abil Stud*. (2009) 20:65–75. doi: 10.1080/13598130902860721

50. Ford PR, Low J, McRobert AP, Williams AM. Developmental activities that contribute to high or low performance by elite cricket batters when recognizing type of delivery from bowlers' advanced postural cues. *J Sport Exerc Psychol*. (2010) 32:638–54. doi: 10.1123/jsep.32.5.638

51. Güllich A, Emrich E. Elite sport and education in Europe. Brussels: European Commission.

52. Selection GA. de-selection and progression in German football talent promotion. *Eur J Sport Sci*. (2014) 14:530–7. doi: 10.1080/17461391.2013.858371

53. Hendry DT, Hodges NJ. Early majority engagement pathway best defines transitions from youth to adult elite men's soccer in the UK: a three time-point retrospective and prospective study. *Psychol Sport Exerc*. (2018) 36:81–9. doi: 10.1016/j.psychsport.2018.01.009

54. Hendry DT, Crocker PR, Williams AM, Hodges NJ. Tracking and comparing self-determined motivation in elite youth soccer: influence of developmental activities, age, and skill. *Front Psychol*. (2019) 10:304. doi: 10.3389/fpsyg.2019.00304

55. Huijgen BC, Elferink-Gemser MT, Lemmink KA, Visscher C. Multidimensional performance charactristics in selected and deselected talented soccer players. *Eur J Sport Sci*. (2014) 14:2–10. doi: 10.1080/17461391.2012.725102

56. Noon MR, Eyre EL, Ellis M, Myers TD, Morris RO, Mundy PD, et al. The influence of recruitment age and anthropometric and physical characteristics on the development pathway of English academy football players. *Int J Sports Physiol Perform*. (2020) 16:199–207. doi: 10.1123/ijspp.2019-0534

57. Roca A, Williams AM, Ford PR. Developmental activities and the acquisition of superior anticipation and decision making in soccer players. *J Sports Sci*. (2012) 30:1643–52. doi: 10.1080/02640414.2012.701761

58. Schroepf B, Lames M. Career patterns in German football youth national teams—a longitudinal study. *Int J Sport Sci Coach*. (2017) 13:405–14. doi: 10.1177/1747954117729368

59. Gagné F. *Differentiating giftedness from talent. The DMGT perspective on talent development*. New York: Routledge (2021).

60. McCall JJ. Economics of information and job search. *Q J Econ*. (1970) 84:113–26. doi: 10.2307/1879403

61. Neal D. The complexity of job mobility among young men. *J Labor Econ*. (1999) 17:237–61. doi: 10.1086/209919

62. Bransford JD, Schwartz DL. Rethinking transfer: a simple proposal with multiple implications. *Rev Educ Res*. (1999) 24:61. doi: 10.3102/0091732X024001061

63. Araujo D, Fonseca C, Davids K. The role of ecological constraints on expertise development. *Talent Dev Excell*. (2010) 2:165–79.

64. Wrang CM, Rossing NN, Diernæs RM, Hansen CG, Dalgaard-Hansen C, Karbing DS. Relative age effect and the re-selection of danish male handball players for national teams. *J Hum Kinet*. (2018) 63:33–41. doi: 10.2478/hukin-2018-0004

65. Ramos-Filho L, Ferreira MP. The reverse relative age effect in professional soccer: an analysis of the Brazilian national league of 2015. *Eur Sport Manag Q*. (2021) 21:78–93. doi: 10.1080/16184742.2020.1725089

66. Fumarco L, Gibbs BG, Jarvis JA, Rossi G. The relative age effect reversal among the national hockey league elite. *PLoS One*. (2017) 12:e0182827. doi: 10.1371/journal.pone.0182827

67. Duffy LJ, Baluch B, Ericsson AK. Dart performance as a function of facets of practice amongst professional and amateur men and women players. *Int J Sport Psychol*. (2004) 3:232–45.

68. Elferink-Gemser MT, Starkes JL, Medic N, Lemmink KA, Visscher C. What discriminates elite and sub-elite youth field hockey players. *Ann Res Sport Phys Act*. (2011) 1:50–68. doi: 10.14195/2182-7087_1_3

69. Hutchinson CU, Sachs-Ericsson NJ, Ericsson KA. Generalizable aspects of the development of expertise in ballet across countries and cultures: a perspective from the expert-performance approach. *High Abil Stud*. (2013) 24:21–47. doi: 10.1080/13598139.2013.780966

70. Ford PR, Coughlan EK, Hodges NJ, Williams AM. Deliberate practice in sport. In: Baker J, Farrow D, editors. *Routledge handbook of sport expertise*. London: Routledge (2016). p. 347–62.

frontiers | Frontiers in Sports and Active Living

TYPE Systematic Review
PUBLISHED 23 September 2022
DOI 10.3389/fspor.2022.903886

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OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Elite Sports and Performance Enhancement, a section of the journal Frontiers in Sports and Active Living

RECEIVED 24 March 2022
ACCEPTED 24 August 2022
PUBLISHED 23 September 2022

CITATION
Peters CM, Hendry DT and Hodges NJ (2022) A scoping review on developmental activities of girls' and women's sports.
Front. Sports Act. Living 4:903886.
doi: 10.3389/fspor.2022.903886

A scoping review on developmental activities of girls' and women's sports

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We provide a scoping review of research on athlete development in girls' and women's sports. Our emphasis is on pathways to expertise in the context of deliberate practice theory and associated models, such as the Developmental Model of Sport Participation (DMSP). Despite rationale for sex and gender differences in sport development, there are relatively few studies where the developmental pathways of female elite athletes have been evaluated. We sought to map the scope of the literature on this population over the last 30 years, focusing on measures of practice types and amounts. Following an extensive search of the literature, 32 studies were identified that included all female participants or presented sex/gender disaggregated data. Retrospective methods were commonly used to quantify practice, play and specialization. National-level athletes were the most represented, although there was considerable heterogeneity in sport and expertise-level, making general or comparative judgements challenging. We identified some groups that had accumulated high volumes of practice at a young age, particularly in soccer and gymnastics. Across sports and studies, early majority hours of engagement in the primary sport was the norm. Athletes deviated from predictions in the specialization pathway detailed in the DMSP, by continuing to participate in other sports throughout childhood and adolescence. In addition to highlighting the relative paucity of data pertaining to athlete development pathways in female athletes, we show that the data from these groups deviate from predictions detailed in current models of athlete development.

KEYWORDS

expertise, deliberate practice, talent, play, specialization

Introduction

There is a substantial body of literature on the topic of "talent" development in sport and specifically on the question of how sport-specific practice amounts and types, as well as age of engagement, impact on attainment of sport expertise [e.g., (1–3)]. In most of the work on this topic, the developmental experiences of male participants have been the majority focus, or the data has been aggregated across males and females.

Because models of expertise development are dependent on these studies, these models are likely to be skewed in their descriptions and hence predictions about pathways to expertise in women's sports. This knowledge gap was highlighted in a recent scoping review of talent development in sports (1), where only ~10% of the included studies focused solely on female athletes (~45% were exclusively on male participants, ~30% included both male and female participants and ~15% of studies did not report the sex/gender of the participants). In this scoping review, we aim to assess and evaluate the current knowledge of the pathways that are associated with expertise in youth and adult high-level female athletes.

Compared to boys, girls mature biologically and reach ages of peak motor skill development earlier (4, 5). Girls are also less likely to engage in sport and physical activity (6–8) and have fewer opportunities for elite performance [such as paid professional sport leagues (9, 10)]. Some athlete development frameworks include gender specific age ranges for training based on gender differences in peak height velocity (11), where girls reach peak height velocity earlier than boys. Because of these biological differences, interpretations and definitions of early specialization should differ for female and male athletes. Lima et al. suggested that the early specialization of female athletes may be somewhat protective, allowing for better adjustment of athletic performance during pubertal changes (12). Female athletes also show differences in their response to training and to other psychosocial factors, such as their relationships with parents and peers (13), leading us to expect that the developmental pathways to attain expertise may differ between male and female athletes.

In support of the idea that sex/gender impact developmental pathways, differences have been identified in reviews of the relative age effect (14–17). Girls and women do not always exhibit the same advantage for birth month as their male counterparts. Differences have been attributed to biological maturation and socialization factors, where post-pubescent female characteristics (such as shorter legs and wider hips) constrain the athletic development of athletes that mature early (or those born earlier in the year) and social values and norms can deter early maturing female athletes from pursuing sport competitively (16). Moreover, in a review of specialization and diversity in sport, gender was noted as a potential moderator of early specialization with some evidence that girls specialized more than boys (2). However, in only a third of the studies included in this earlier review (2) was specialization defined, primarily based on a descriptor of intense engagement in year-round practice within one sport at the exclusion of others.

Here we discuss sex/gender as a binary concept, focusing on demographically described female participants in research publications. We acknowledge that gender exists on a spectrum and that the experiences of non-binary athletes have been omitted in the current body of literature. We would like to highlight that the terms sex and gender are also not interchangeable, with the former referring to biological and genetic differences and the latter to the roles and relationships ascribed by society (18). Both sex and gender factors likely influence the developmental pathways of female athletes, but we are unable to disentangle the two here.

A key facet of the development of sport expertise is the accumulation of deliberate practice activities (19, 20). According to deliberate practice theory, there is a monotonic relationship between the time engaged in deliberate practice and the level of performance. Deliberate practice is characterized as being effortful, relevant to performance goals, individualized, coach-led, not inherently enjoyable, and has a feedback component [for a recent sport-focused review see (21)]. Originally grounded in music development, there has been some debate as to whether the tenants of deliberate practice, specifically the monotonic benefits assumption, can be generalized to sporting contexts (22–24). However, studies comparing practice histories of skilled and less skilled athletes have shown that the former accumulate more hours in deliberate practice activities across a range of sports and in a somewhat monotonic fashion (25–27).

Approximately a decade after deliberate practice theory was proposed, Côté et al. published work on the Developmental Model of Sport Participation (DMSP), which had two pathways leading to sports expertise (28–30). Based on deliberate practice theory, an early specialization pathway was outlined to include high amounts of practice accumulated from a young age in one sport. In contrast, the early sampling pathway was characterized by early multi-sport involvement, high amounts of play and with later specialization in adolescence. In this second pathway, the sampling years (6–12 yr) were characterized by high volumes of play and participation in many sports. Specialization would not begin until the adolescent years (13–15 yr), where athletes focus on one or two sports and engage in equal amounts of practice and play activities. In the investment years (16–18 yr), athletes increase commitment to one sport and engage in a high volume of deliberate practice (30, 31). The accumulation of diversified sport experiences and play in the early sampling pathway was thought to encourage the broad development of physical and psychosocial skills that benefit future athletic development (32). In contrast, early specialization was thought to benefit the attainment of sports expertise only when peak performance occurs at a young age, such as in gymnastics and figure skating (33, 34).

Although there has been support for some of the predictions emanating from the DMSP, there have been issues in defining specialization and hence determining pathways based only on two categorically distinct pathways (35, 36). Single sport participation, high amounts of deliberate practice, year-round training, exclusion of other sports, and intense training have differentially been used as criteria of specialization across studies (37, 38).

In samples of male soccer players, athletes participated in high volumes of sport specific practice and play at relatively young ages, consistent with the early specialization pathway, but diverged from predictions in that pathway by also sampling other sports in childhood (39–42). Thus, a third pathway has been proposed, characterized by early majority engagement in the primary sport, without limiting participation in other activities (40). This third pathway may offer some "protection" against proposed negative motivational consequences from high amounts of practice, such as burn-out and low intrinsic motivation (43–45).

A provocative idea is that differences in childhood activities which lead to later success take time to show up and hence distinguish across athletes that attain juvenile vs. adult success (46, 47). As such, different pathways might characterize the development of adult and adolescent expertise (46). Indeed, a meta-analysis across multiple sports showed that athletes who attained international success as junior athletes showed a more specialized pathway compared to national or regional athletes, whereas this pattern was reversed for world class adult elite athletes (47). There was more multi-sport participation during development among adult world class elite athletes compared to lesser skilled peers. Although these data are correlational, based on cross-sectional comparisons and aggregated across various sports with different participation rates and ages of peak performance, success at junior levels is not a good predictor of adult success (48) and ∼25% of athletes who attained elite performance as adults in a study of Portuguese athletes did not compete internationally in their youth (49).

In this scoping review, we detail the research (1990 to May 2021) specifying activities undertaken by female "elite" athletes during childhood. In addition to collecting practice, play, and specialization measures, we present key study characteristics and participant demographics to contextualize the results and to highlight gaps in study populations. We sought and evaluated studies that captured female athletes competing at relatively high levels of performance, in both junior and adult groups. Our main aims were to synthesize the data pertaining to childhood activities and demographics of adult and youth female elite athletes to describe and evaluate pathways to expertise in view of current research and models of athlete development.

Methods

Study search and screen

The protocol was set a priori in accordance with current best practices for scoping reviews (50, 51). To inform the search strategy, we reviewed known studies examining girls' and women's sports' participation and scoping and systematic reviews in the field. The primary search was conducted by the first author in SPORTDiscus to identify studies published between January 1990 and May 2021. We chose this period as it slightly pre-dates the seminal study on deliberate practice by Ericsson et al. (20), which resulted in a high volume of research in sport related to pathways of skill development and measures of practice. Boolean search terms were used to combine subject terms and synonyms broadly encompassing the population (high level female/women athletes) and the outcomes of interest (practice, participation, specialization/diversification, and developmental activities). The search was limited to scholarly articles and studies where an English abstract was available. Further searching was done in Google Scholar and manual searching of the reference lists of included studies and several key review papers and books. We also conducted a forward search by reviewing studies that cited the included studies and prominent review papers. The primary search uncovered studies that included both male and female athletes. If there was gender disaggregated data, these were included.

Study screening was done through Covidence (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org). The first author conducted an initial title and abstract screen of the identified studies and the full text screen of the studies selected in the title and abstract screen. An independent reviewer (author two) screened 20% of these studies at both stages. Discrepancies in the title and abstract screen were automatically sent to the full text review and discrepancies in the full text screen were resolved through discussion with all three authors.

Empirical studies were included for review if they included measures of practice, play, multisport participation, or specialization. The scope was limited to capture a relatively elite sample of adult and youth female athletes. We acknowledge that there are issues in defining elite status and to maintain transparency in our definitions we keep descriptors in our analysis to allow better inferences as to "elite" status [e.g., (52–54)]. With respect to inclusion based on "elite" status (as detailed in the data extraction section below), we sought studies with adult participants who were competing at the Varsity/University level or higher, including National team athletes and premier/professional league athletes. For youth (U18) elite athletes, we restricted inclusion to athletes that were part of a national training squad or competing internationally. Studies that did not include participant gender in the abstract were sent to full text review, leading to a large number of studies ($n = 252$) screened at the full-text level. When gender was not reported, these studies were excluded. We included all study design-types, including retrospective, cross-sectional and longitudinal. In some studies, variables of interest, such as practice hours or years of engagement, were reported as demographic measures in the participant's section and not outcome measure. These studies were not included as measures were often poorly defined, leading to ambiguity in how they were obtained.

Data extraction

Results were extracted by the first author using a custom spreadsheet piloted by the first two authors. The second author audited the data extracted from a random sample of 20% of the included studies and no discrepancies were identified. We recorded study details such as the study design, the country in which the data were collected and the sport. We recorded how the authors described the athletes' expertise and categorized them into groups. Adult athletes were categorized by us as "Super Elite" if they were medalists at international level competitions or were ranked highly internationally (i.e., within the top 10). Adult athletes were labeled "National" if they represented their country at an international level of play but did not meet the criteria for Super Elite. Adult athletes that played for a university or college athletic program were classified as "Varsity." We did not distinguish between programs competing at different levels of university competition. Athletes that played their sport as a career and were paid as full-time players were classified as "Professional" and those that played for a high-level club in their country (e.g., premier league) but did not meet any of the above criteria were classified as "Elite Club" (this could include semi-professional athletes). Because in women's sports there are few opportunities for professional play (55), resulting in a paucity of groups in our sample at this level, we collapsed across the Elite Club and Professional categories and termed all as "Elite Adult" in the reporting of data. Groups that comprised athletes who were under 18 years but were competing at an international level or training with a national development squad were included in our analyses and classified as "Youth Elite." Therefore, for descriptive comparisons of the groups, we consider the order of Super Elite, National, Elite Adult, Varsity, and Youth Elite as most expert (Super Elite) to least expert (Youth Elite).

Because we were interested in potential factors leading to adult expertise, we did not include youth or adult club-level athletes (including those competing at a provincial/state level). Participants' current age and the age when measures were taken were also recorded as were definitions of all dependent variables related to time spent in practice and play activities and sport specialization/diversification. When data were presented in figures in extracted studies, a plot digitizer tool (WebPlotDigitizer, https://automeris.io/WebPlotDigitizer) was used to extract numeric values.

Data aggregation and transformations

We reported measures of practice, multisport participation, specialization and play as a function of sport in childhood (6–12 yr), early adolescence (13–15 yr) and late adolescence (16–18 yr) years, corresponding to the sampling, specializing and investment years, respectively (29). In dividing age categories in this way, rather than presenting yearly amounts at each age, we were able to include more studies within an age category and better synthesize the data. Such dividing of data across these age categories also allowed us to compare the data to existing models of athlete development (30, 40). When data were reported across multiple categories (e.g., from ages 14–18 yr), intermediate categories were added spanning the age periods (such as "sampling and specializing"). When authors reported multiple data points within a category of the DMSP (i.e., reported by age), data were averaged or summed depending on the measure (i.e., averaged for hours/year and summed for aggregated hours). When researchers reported data as a proportion of participants (e.g., 50% of the sample started their sport before the age of 10 years), we calculated and reported the median response. In cases where authors reported total years of involvement in the sport rather than start age of primary sport involvement, we subtracted the years of involvement from the current reported age of participants.

Results

Included study characteristics

From the 1,831 papers identified, 32 studies met the inclusion criteria and were included in our analyses as detailed in the PRISMA flow diagram in Figure 1. Of this final set of studies, group level data were extracted ($n = 42$ groups). In 11 cases, data from multiple groups representing different levels of expertise and in some cases different sports were extracted from the same study publication. In determining groups, we noted that some independent publications were based off the same group sample, such that there was the possibility of duplicate reporting of dependent variables. Therefore, although we include all studies in our reporting of study characteristics, we removed duplicate dependent variables in our reporting of outcomes[1]. Table 1

1 Coutinho et al. noted that they used the same participants for their 2016 and 2021 studies. In the 2016 study, age ranges of 8–12, 13–16, and 17–20 yr were reported whereas yearly measures were given from ages 6–12 yr in the 2021 study. Because of the duplicate reporting in the 8–12 yr age range, we only included measures from the 6–12 yr category from the 2021 study, representing a larger age range. We did not include data from Coutinho et al. (56) as the sample characteristics and our measures of interest were identical to those in Coutinho et al. (57). Similarly, Fawver et al. (58), and Cowan et al. (59) used the same sample of participants as reported in De Couto et al. [(60); confirmed via personal communication], such that any duplicate outcomes of interest reported in this work were not included in our final analyses. There was also replication of participants across studies by Johnson et al. (61) and Johnson et al. (62). We have included both Johnson et al. (61) and Johnson et al. (62) in the characteristics of included studies but have omitted duplicated data.

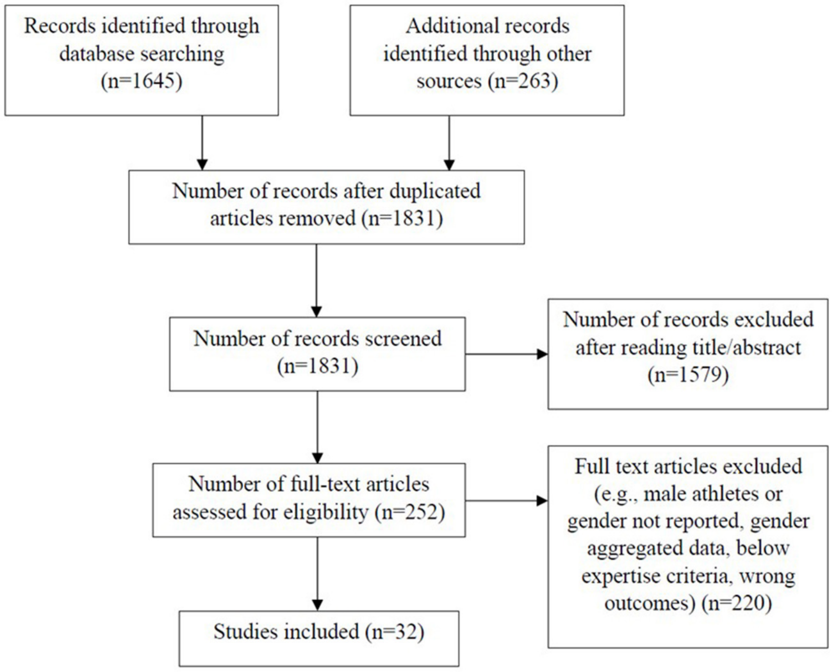

FIGURE 1
PRISMA flow diagram for the scoping review process.

gives details of all included studies including sport, expertise classification, the country where data were collected, group sample size, and outcome measures reported (i.e., practice, play, multisport participation, and specialization).

Practice

Twenty-two studies included broad measures of practice. In Figures 2A–C, respectively, we present practice hours per week, practice hours per year, and accumulated practice hours across what have been termed the sampling years (6–12 yr), the specializing years (13–15 yr) and the investment years (16–18 yr) as a function of sport (30). Intervening categories are presented when data span across sampling and specializing years (e.g., 11–14 yr). As would be expected, practice hours increased across time. However, the so termed specializing and investment years showed little change across time in terms of average hours/week and hours/year of sport-specific practice. Soccer, volleyball and rhythmic gymnastics were the sports most represented in these figures. A few researchers also reported practice hours as a function of years into career and years of involvement (68, 74, 78), but due to the lack of studies, we have not included these data here.

In Figure 3, start age in the main sport (panel A), in main sport practice (panel B), and of specialization (panel C), as a function of sport and expertise, are shown. Data are shown as a function of sport and across the different skill groups given the range of start ages, which was sport and skill dependent. As can be seen in Figure 3A where the data are plotted in order of start age; alpine ski, soccer and gymnastics had early start ages before age 6 yr, whereas rhythmic gymnastics and volleyball had later start ages after age 10 yr. There were only a few sports that had multiple levels of expertise represented, but in general there were no skill-based trends across sports. In gymnastics, National athletes had slightly earlier start ages than Youth-Elite athletes, but this was reversed in rhythmic gymnastics. In soccer, youth athletes were not represented, but among adults, higher level athletes started soccer at an earlier age than the less elite groups. This earlier start age trend was also true for swimming, but here Youth-Elite athletes were represented and they had a slightly later start age than Adult Elite. Few studies reported start age in practice of the primary sport, but consistent with the overall start ages, alpine ski and soccer groups also began practice at a relatively young age (Figure 3B).

Specialization and other sport participation

Eighteen studies included measures of practice and other sport participation and out of these, eleven studies also included

TABLE 1 Included study characteristics.

Study	Country	Sport	Expertise	N	Outcome domains
Baker et al. (63)	Australia	Variety[a]	National	7	Practice, other sport participation
Baker et al. (64)	Germany	Handball	Youth Elite	45	Practice, other sport participation
Barynina and Vaitsekhovskii (65)	USSR	Swimming	National	Not reported	Specialization
Bjørndal et al. (66)	Norway	Handball	Youth Elite	21	Practice, specialization, other sport participation
Blijlevens et al. (67)	The Netherlands	Gymnastics	National	6	Practice
			Youth Elite	4	
Bruce et al. (68)	Australia	Netball	National	19	Practice, play, specialization, other sport participation
			Youth Elite	20	
Buckley et al. (69)	USA	Variety[b]	Varsity	331	Specialization
Coutinho et al. (70)	Portugal	Volleyball	Professional	35	Practice, other sport participation
Coutinho et al. (56)	Portugal	Volleyball	National	15	Practice, specialization, Other sport participation
Coutinho et al. (57)	Portugal	Volleyball	National	15	Play, other sport participation
Coutinho et al. (71)	Portugal	Volleyball	National	15	Play, other sport participation
Cowan et al. (59)	USA	Alpine ski	Youth Elite	91	Practice, play, other sport participation
da Matta (72)	Brazil	Volleyball	Super Elite	10	Practice
			Varied[f]	10	
de Bosscher and de Rycke (73)	Multiple locations	Variety[c]	National	1,253	Practice
DeCouto et al. (60)	USA	Alpine ski	Youth Elite	45	Practice
Duffy et al. (74)	Not reported	Darts	Super Elite	6	Practice, play
Fawver et al. (58)	USA	Alpine ski	Youth Elite	88	Practice, play, other sport participation
Ford et al. (75)	Multiple locations	Soccer	National	86	Practice, play, specialization, other sport participation
Güllich (76)	Germany	Soccer	National	14	Practice, specialization, other sport participation
			Professional	15	
Hendry et al. (77)	Canada	Soccer	National	21	Practice, play, other sport participation
			Varsity	24	
Hodges et al. (78)	Canada	Triathlon	Varied[g]	17	Practice
		Swimming	Elite Club	28	
Hodges et al. (79)	Canada	Triathlon	Varied	17	Practice
Hume et al. (80)	New Zealand	Rhythmic Gymnastics	National	5	Practice, other sport participation
			Youth Elite	25	
Johnson et al. (61)	USA	Swimming	Super Elite	4	Practice, other sport participation
			Varsity	3	
			Youth Elite	2	
Johnson et al. (62)	USA	Swimming	Super Elite	3	Practice
			Varsity	2	
Law et al. (33)	Canada	Rhythmic Gymnastics	Super Elite	6	Practice, specialization, other sport participation
			National	6	
Leite and Sampaio (81)	Portugal	Basketball	National	132	Practice, other sport participation
Naisidou et al. (82)	Greece	Handball	Youth Elite	24	Practice
Post et al. (83)	USA	Variety[d]	Varsity	115	Specialization
Staff et al. (84)	UK	Track & Field	National	28	Practice
Storm et al. (85)	Denmark	Variety[e]	National	10	Specialization, other sport participation
Timmerman et al. (86)	Australia	Field Hockey	Youth Elite	18	Practice, play, other sport participation
			Youth Elite	24	
			Youth Elite	9	

[a] Netball and field hockey.
[b] Collected from a variety of sports.
[c] Collected across 37 different sports.
[d] Basketball, golf, ice hockey, soccer, tennis, softball, and volleyball.
[e] Handball, orienteering, soccer, kayaking, rowing, sailing, swimming and golf.
[f] Five athletes were from club and recreational levels, and five were playing at the Varsity level.
[g] Recruited from a highly ranked club; 5 athletes had competed at the world championship level, 4 at the national level, 1 at the provincial level and 7 at the local level.

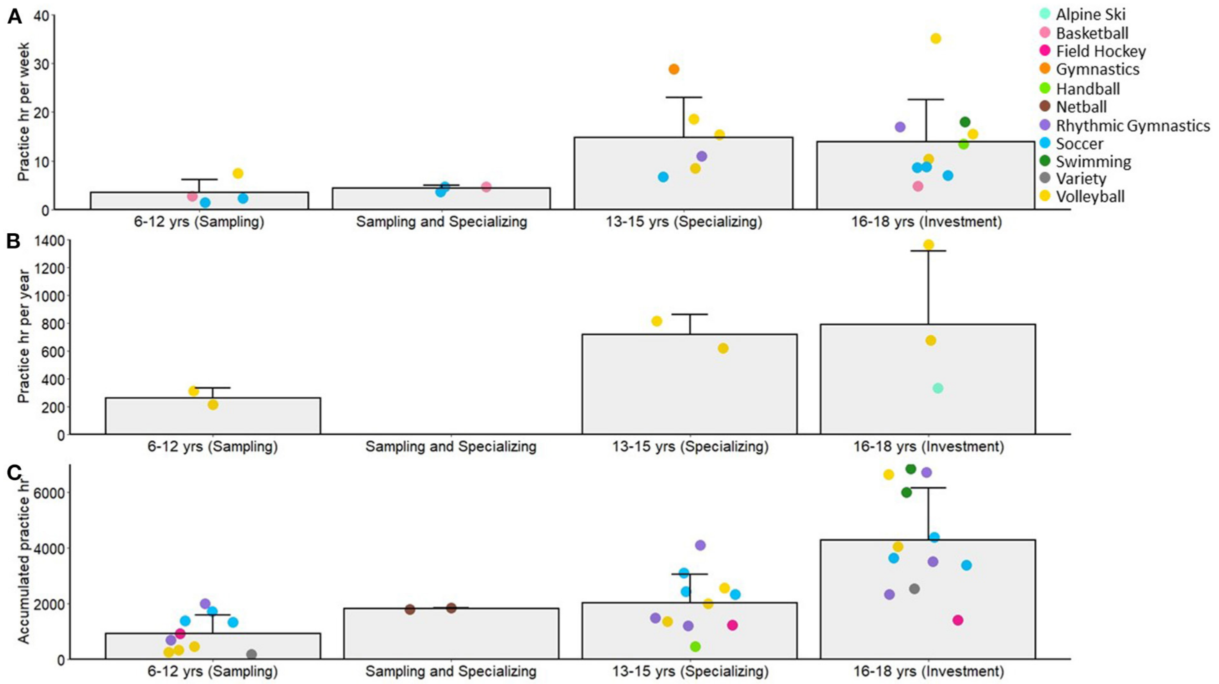

FIGURE 2
Sample (bar) and individual study means (colored circles) across different age categories defined in past literature as the sampling, specializing and investment years, for practice hours per week **(A)**, practice hours per year **(B)**, and accumulated practice hours **(C)**. Error bars represent sample standard deviation, the intermediate category (Sampling and Specializing) contains data that were reported across ages spanning the sampling and specializing years.

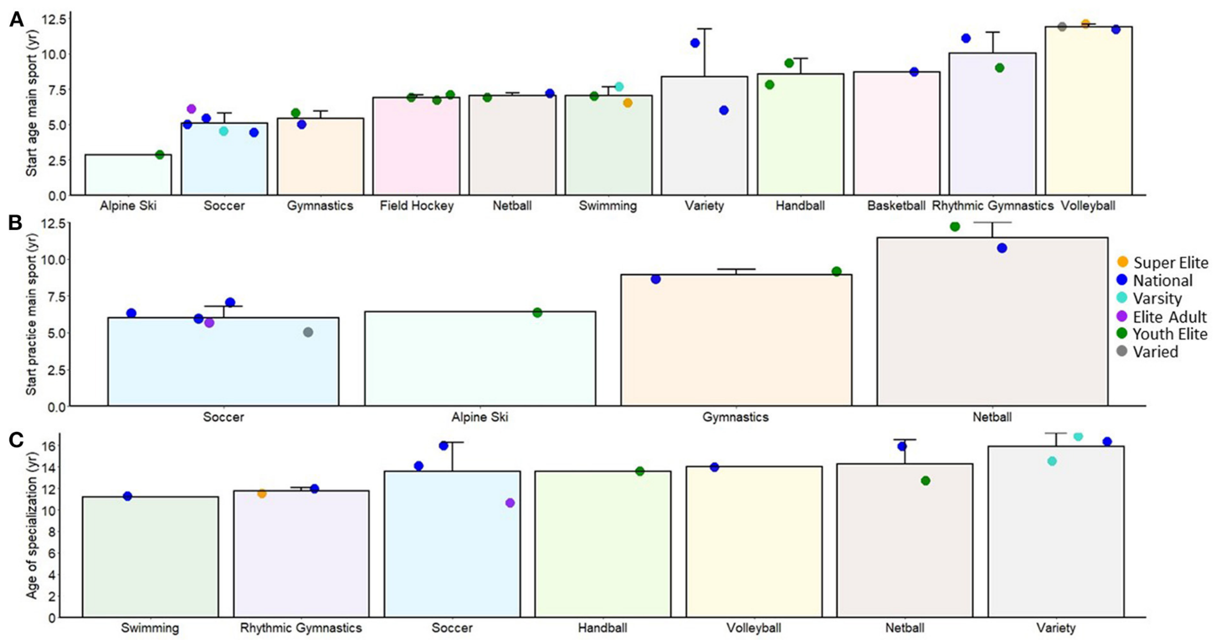

FIGURE 3
Sample (bar) and individual study means (colored circles) across different sports showing start age in the main sport **(A)**, start age in practice **(B)** and start age of specialization **(C)**. The sports are ordered in terms of start age and expertise category is shown in terms of a color coded grouping variable. Error bars show sample standard deviations.

reports regarding age of specialization. Specialization was defined as either exclusive engagement in one sport (33, 56, 66, 68, 69, 75, 76, 87) or age of investment without exclusive specialization (85). As shown in Figure 3C, age of specialization was generally around 14 yr, with the exception of swimming and rhythmic gymnastics (∼10–11 yr). There were a few sports that had data across multiple levels of expertise. In netball and soccer, both the Elite Adult (soccer) and Youth-Elite (netball) athletes specialized earlier than the National-level athletes, but there were no skill-group differences for rhythmic gymnastics.

The average number of other sports played within each age grouping is reported in Figure 4. Although there was a general drop off in sports from age 6–12 yr to 13–15 yr, this number increased for some sports (i.e., alpine ski and soccer) during the transition to the so termed "investment" years, what we have labeled specializing and investing (∼15–16 yr). However, after the age of 16 yr the number of other sports was at its lowest. The number of hours per week and accumulated hours in other sports is presented in Figures 5A,B, respectively[2]. Again, there was a trend for increasing hours in other sports with age, rather than a decrease, especially in the so termed specializing/investment years (13–18 yr) as compared to "sampling" years (6–12 yr). Soccer and netball were the sports most represented showing these trends.

Play amounts

Eight studies (representing two sports) included measures of play in the primary sport, or what were alternatively termed "unstructured activities" (59, 74, 75, 77, 86), as reported in Figure 6. Perhaps somewhat surprisingly, play activities continued to accumulate across development. Data from Youth Elite alpine skiers (age 15.7 yr) were not included (59), because hours/ year were only reported at one time point (∼77 h).

Discussion

Included study characteristics

After an extensive literature search, we retrieved 32 studies representing 13 sports that quantified the practice, play, and specialization pathways of Adult Super Elite, National, Elite-Adult, Varsity, and Youth-Elite female athletes. Only swimming, soccer, volleyball, and rhythmic gymnastics had three or more levels of expertise represented, allowing some commentary on how these pathways differ across groups of elite athletes within a particular sport. In our sample, athletes competing at the adult National and Youth-Elite (national) levels were the most represented in terms of overall proportion of athletes and these athletes were distributed across a range of sports. Relatively few studies included Super Elite athletes (i.e., Olympic medalists), Professional (paid to play), Varsity, or Elite Club-level female athletes. This paucity in studies is somewhat expected for Super Elite athletes, as there are relatively few athletes competing at this high level, posing challenges for recruitment. In the case of female Professional athletes, fewer opportunities for paid play and the presence of a gender pay gap in sport (9) may contribute to the lack of research on these athletes. The lack of research on women University level athletes is more surprising. The sample heterogeneity present for sport and level of expertise makes it challenging to provide either general or comparative judgements about pathways to expertise for female athletes but we have nonetheless attempted to make some general conclusions. Identification of gaps in research with respect to sports, expertise, and outcome measures also allows some statement about directions for future research on women athletes.

Of the included studies, many (81%), reported measures of practice, although less than half (44%) reported measures of practice at multiple time points. In 59% of studies, multisport participation was quantified in some way, with sport specialization (31%) and play (28%) experiences detailed in about a third of the studies, potentially reflecting testable postulates of the DMSP (29). All the included studies originated from Western countries, with large proportions originating from the USA, Portugal, Canada, and Australia. This geographical limitation is likely related to our search being restricted to those published with an English abstract. Environmental constraints, such as socio-cultural factors, have been proposed to interact with the development of expertise in sport (88, 89). Because gender reflects how cultures and societies ascribe roles, characteristics and values to the sexes (18), gender constructs vary cross-culturally (90) and thus our conclusions about developmental pathways are unlikely to generalize outside of "westernized" contexts.

Measures of practice were often framed in the context of the DMSP or deliberate practice theory. There are numerous issues and debates surrounding the definition and subsequent ways of quantifying deliberate practice and potential (mis) interpretations of the definition of deliberate practice (19, 22–24). Ericsson cautioned against conflating general measures of practice, play and competition with deliberate practice (19, 22). However, this has been the norm in many sport-related studies, particularly in team sports, where the criteria for deliberate practice is unlikely to be met at the individual player level in group rather than individual practice settings. In our sample, researchers differed in how they qualified and quantified practice, with some distinguishing team and individual "deliberate practice" and others reporting total hours of general training. The majority of reports of practice were

2 Bruce at al. (68) and Cowan et al. (59) reported hours of other sport participation per year. Values were divided by 52 to convert to a weekly value.

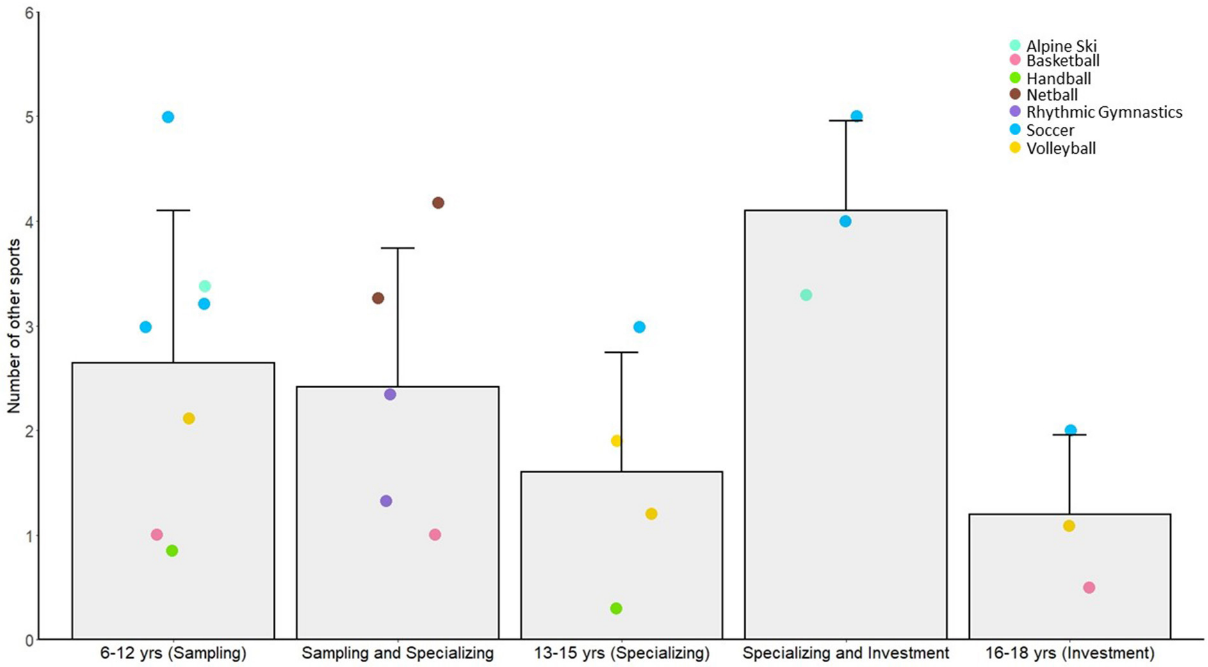

FIGURE 4
Sample (bar) and individual study means (colored circles) across different age categories defined in past literature as the sampling, specializing and investment years, for the average number of other sports participated by athletes. Error bars represent sample SDs and individual colored data points represent different sports and studies.

based on retrospective recall methods (78%; 30% retrospective interviews and 48% retrospective questionnaires), such that there may be tendencies for athletes to overestimate practice hours (91). Over half of the studies included had measures of multisport participation. Some researchers defined other sport participation as regular participation for more than 1 month, while others did not define what constituted other sport participation. As also noted by Mosher et al. (36) there was considerable variability in how researchers defined and reported the number of other sport activities. In only a few studies were measures of play included and there was variability in how this was measured, with some including all sport-related play and others focusing specifically on play in the primary sport.

In the following paragraphs, we outline the general patterns of sport participation pertaining to the age categories detailed in the DMSP; that is ages 6–12 yr (so termed sampling), ages 13–15 yr (so termed specializing) and ages 16–18 yr (so termed investment years) (29, 30). We consider the data with respect to evidence supporting a more diversified or specialized route for female athletes and relate these considerations to the early specialization pathway (which is more in alignment with deliberate practice theory), early majority engagement pathway (40), and the early diversification pathway of the DMSP. Where possible, we consider age and skill-based comparisons in view of a suggested dissociation in patterns of sport involvement that define junior and adult elite athletes (47).

Early childhood (6–12 yr)

In general, the early childhood years were characterized by moderate engagement in practice activities with diversified sport participation. Athletes participated in an average of 2.7 other sports for 1.7 h/week, accumulating 788 h of practice in other sports during the sampling years. Although this is in line with the early diversification pathway of the DMSP (29, 30), there was also significant investment in sport-specific practice activities at a young age; with an average of 3.5 h of practice/week, 260 h of practice/year, and 927 accumulated hours of practice in the primary sport. Notably, the majority of time was spent practicing in the primary sport for these future elite athletes, even in these early childhood years, in line with the early majority engagement pathway (40, 41). Although there were few studies where play amounts were reported, athletes reported relatively high amounts of play during early childhood (M = 390 h accumulated), which translated to ~33% of their sport time spent in play activities relative to practice.

The ages in which athletes began participating in their primary sport was highly varied in our sample, although this variability was mostly between sports rather than between categories of expertise. Within sports there were small differences in the start age in the primary sport across different categories of expertise. In gymnastics and swimming, the adult

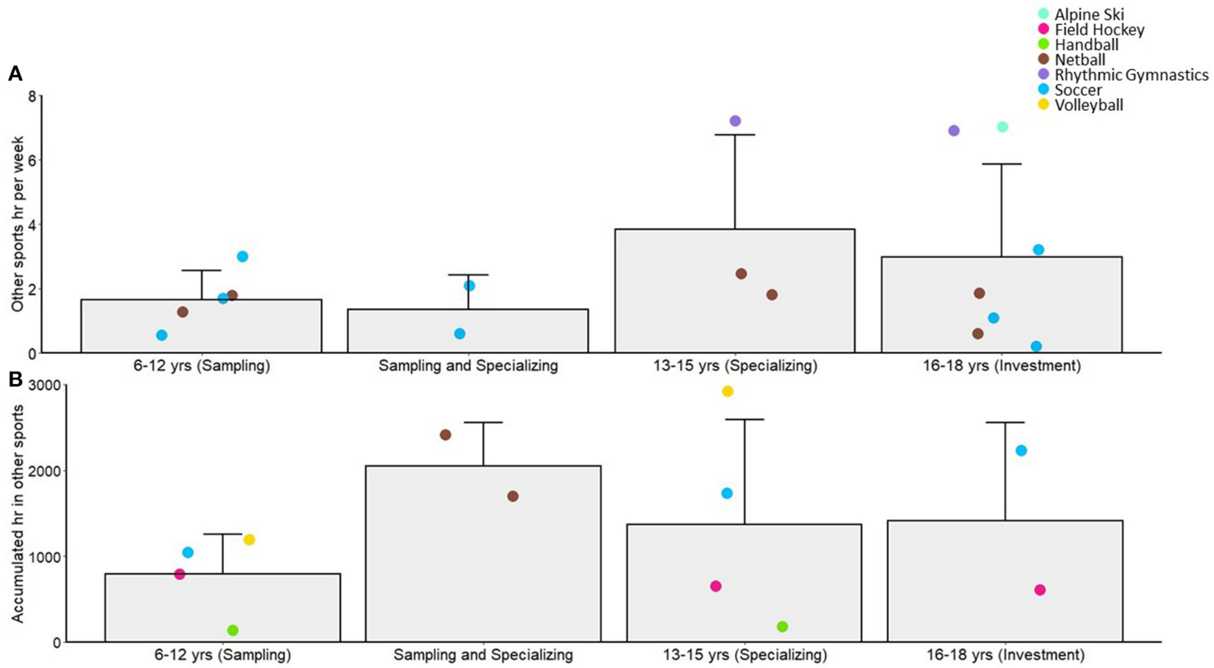

FIGURE 5
Sample (bar) and individual study means (colored circles) across different age categories defined in past literature as the sampling, specializing and investment years, for average hours per week in other sports **(A)** and average accumulated hours in other sports **(B)**. Error bars show standard deviation and colored circles represent individual groups for each sport/study. The "Sampling and Specializing" category represents data that span the ages in those categories.

National and Super Elite athletes, respectively, had earlier start ages than the Youth-Elite groups. In soccer, although youth athletes were not represented, the higher-level adult athletes started earlier than the less elite. Although the data is lacking in women's and girls' sports, the current data does not show evidence supporting a delayed start age for adult elite athletes (47).

In sports such as gymnastics and figure skating, where peak success is often attained in late adolescence/early adulthood, our data were consistent with past research, where early specialized training is shown (10). We also saw data consistent with ideas of late specialization sports, where coordination or physical requirements can hinder early engagement (10). In our sample, several sports, including volleyball, field hockey, handball, netball, and rhythmic gymnastics, had quite late start ages compared to artistic gymnastics, soccer, swimming and alpine skiing (see Figure 3A). It is likely that these first mentioned ball control sports require developed motor skills and physical maturation for successful competition, leading to later sport starting ages. In the case of rhythmic gymnastics, there are coordination requirements that would need to be developed, in addition to fundamental gymnastic skills before athletes can start to use props and engage in this sport. Hence, our data on women and girls serve to further highlight the sport-dependent nature of pathways to expertise, necessitating sport specific recommendations in models of athlete development. These sport-specific data are consistent across male and female contexts because at young ages (before physical maturation), many sports offer mixed-sex/mixed-gender participation and sex differences in biological maturation do not emerge until adolescence.

In summary, elite female athletes engaged early in childhood in high amounts of sport-specific practice, whilst also engaging in approximately three other sports and high play amounts (where detailed). Their early childhood involvement would best be described as one of early majority engagement, rather than either early specialization or diversification.

Early adolescence (13–15 yr)

In what has been termed the specializing years (i.e., 13–15 yr) (30), athletes devoted more time to their primary sport than in the sampling years, but without exclusive specialization. Practice hours were on average 14.8 h/week or 717 h/year. By the age of 15 yr, 2,023 h of practice had been accumulated on average. In these early adolescent years, there was increased variability in practice amounts both within and between sports, reflecting the unique training demands and constraints of the different sports. For the start age of specialization, there was

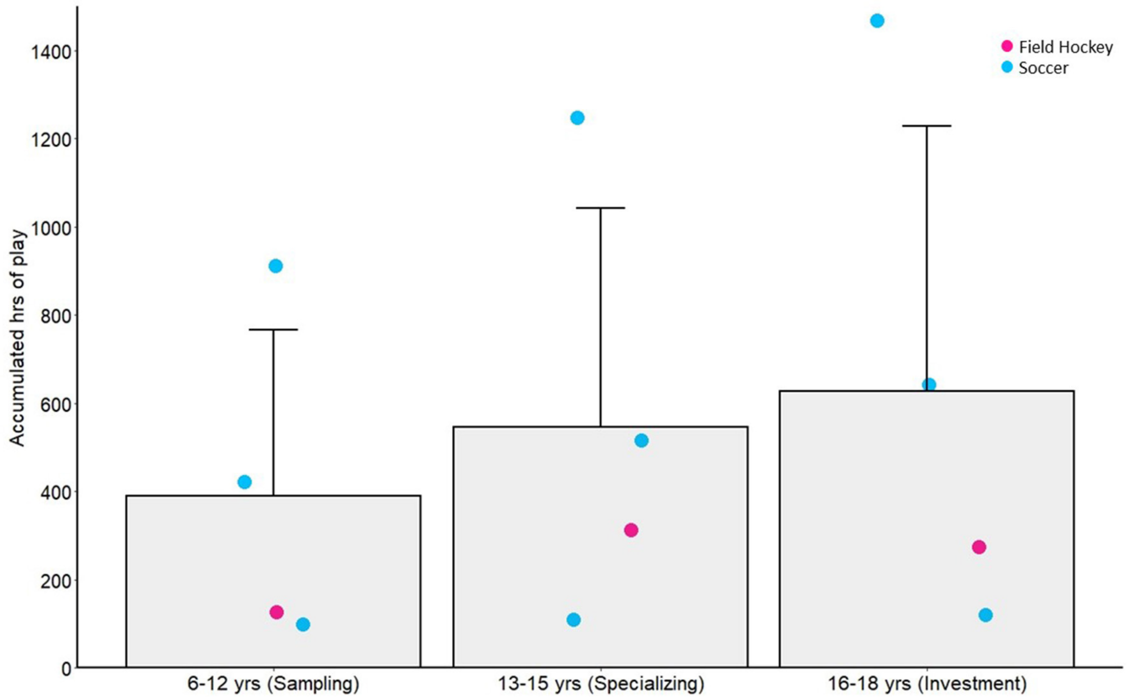

FIGURE 6
Sample (bar) and individual study means (colored circles) across different age categories defined in past literature as the sampling, specializing and investment years, for average accumulated hours of play. Error bars represent sample standard deviation and colored circles represent individual sport groups. The "Specializing and Investment" category represents data that span the ages in those categories.

again some consistency across sports and expertise categories, with the majority of sports showing specialization in this time period ∼14 yr (with the exception of swimming and rhythmic gymnastics at ∼11–12 yr). Soccer showed the largest range across skill groups (with specialization being reported as earlier for Elite Adult vs. Adult National athlete groups). These ages reported in this time period are mostly consistent with what would be expected based on the diversification pathway of the DMSP. Congruent with all developmental pathways, there was a decrease in the amount of time spent in play activities relative to practice during this period (21% of overall sport time).

Deviating from predictions of the early diversification pathway, the female athlete groups from our sample showed only a small reduction in the *number* of other sports in these so termed "specializing" years ($M = 1.6$), compared to the sampling years ($M = 2.7$) and actually increased the *hours* spent in these other sports by ∼2 h from childhood ($M = 3.8$ h/week). Corroborating these data, 63% of a sample of National level soccer athletes participated in other sports in early adolescence (75). However, not all researchers reported other sport participation in the early childhood years and as such the trends in the figures may be misleading (59, 80). Youth-Elite alpine skiers only had data in late adolescence (59, 80) and National level rhythmic gymnasts did not have data represented during childhood (80). For both these athlete groups, there was higher than average (>1 SD above the sample mean) other sport participation in adolescence (59, 80). We do not know why other sport involvement would be so high for these groups, beyond the seasonal nature of skiing or potentially relatively lax definitions of diversified sport participation in these studies. Youth-Elite handball athletes participated in fewer (>1 SD below the mean) additional sports in the childhood and early adolescence years compared to the group mean (64). Because these athletes specialized relatively late at a mean age of 12.7 yr (perhaps reflecting transitions to secondary school or high-school where sport-team practice is regulated by the schools on an almost daily basis), this may partially explain lack of involvement in other sports.

Supporting deliberate practice theory predictions, in both the childhood and early adolescent years, Super-Elite level (international medalist) rhythmic gymnasts accumulated more practice hours than both National-level rhythmic gymnasts and other sport groups (>1 SD above the sample mean) (33). Similarly, groups of Youth-Elite and National-level gymnasts participated in more practice hours per week in gymnastics (>1 SD above the sample mean) than other sports in early and late adolescence, respectively (80). Corroborating these data, a sample of figure skaters started practice at a younger age, but increased practice hours per week at a similar rate as team sport athletes and musicians, indicating that figure skaters were investing in their sport earlier than other groups (92) (note that these data were not included in our sample as the data were not disaggregated for gender).

Late adolescence (15-18 yr)

Late adolescence, termed the "investment" years in the DMSP (30), was characterized by high amounts of practice (M = 13.9 h/week, 790 h/year, 4,508 h accumulated), but with continued participation in diversified sport activities (M = 1.2 other sports, 3.0 h/week). Following the predicted decline in play activities, these athletes spent 12% of sport time in play activities compared to practice in their primary sport.

National and Varsity adult soccer players and Youth-Elite alpine skiers participated in a relatively high number of other sports in the combined specializing and investment years (14–18 yr, M = 4.1 sports). In this category, groups maintained (Varsity soccer players and Youth-Elite alpine skiers) or slightly increased (National soccer players) the number of other sports in comparison to the sampling years (59, 77). In male soccer athletes, diversified sport involvement has also been reported to be relatively high and maintained throughout development (42–45). Moreover, the National soccer players represented in our sample had accumulated more hours of play in early and late adolescence compared to the group mean (>1 SD above the mean), although there were few sports represented with play amounts. National level volleyball players also continued to accumulate high amounts of play activities throughout the so termed specializing and investment years (57, 71). This might reflect the cultural context for these athletes and the capacity for informal play activities in Portuguese volleyball.

Limitations and recommendations

Although we were able to gather developmental data from over 40 groups of elite athletes, the interpretation and generalizability of our findings are limited in several ways. First, there was considerable heterogeneity across sports, across categories of expertise and concerning definitions and types of measures reported. As such, broad statements are difficult to make that represent pathways descriptive of girls and women athletes generally. On the positive, the diversity in sports and categories of expertise captured in this work does allow us to describe a broad range of athlete experiences, providing a strong base for future work. Although others have tried to aggregate across sports based on whether they are team or individual [e.g., (93)], or game sports vs. CGS (centremetre, grams or seconds) sports [e.g., (47)], this variation noted across sports in our review, even within those that might be considered to be of the same category (i.e., soccer and volleyball), illustrates what gets lost or misinterpreted through such aggregation. What we would like to see are more systematic investigations within specific sports amongst girls and women athletes, including longitudinal follow up studies, especially following those athletes who achieved success at the youth/junior levels of sport. This sport-focused investigation coupled with increased specificity in measurement and definitions, will allow for better recommendations about pathways which best engender success and allow for later aggregation of data once such sport-specific nuances are known (91).

In many of the studies in our sample, research questions were posed in the context of the DMSP to discern between groups following what is considered an early specialization or an early sampling pathway. As such, the way data are collected may be biased by the model (i.e., where dichotomous categories are searched for, such as "specializers" or "non-specializers," or data are collected within specific age bands that correspond to an already assumed period of specialization). There have been suggestions to consider practice amount and issues concerning specialization in the context of biological maturation, such that key age ranges for determining practice hours within the primary and in other sports (or non-sport activities) would be different across the sexes (11). Such considerations are consistent with the long-term athlete development model (10) where sex based physical maturation characteristics impact generally on "advice" to progress from a training for fun to training to win level of engagement within a sport. Ideally we would be collecting data from individual athletes concerning their age of pubertal onset, but such individual-based data does raise concern for data collection methods and perhaps underscores a need for physiologists to team up with skill acquisition specialists to best collect data on developmental progressions.

Conclusions

In this scoping review of developmental pathways of elite female athletes, we show some differences in how expertise has been attained in comparison to general pathways proposed in the literature, based predominantly on male athletes. In general, women elite athletes reported increasing practice amounts as they continued in their sport throughout the childhood years but deviated from predicted pathways by continuing participation in other sports throughout adolescence, in what have been proposed to be the specializing and investment years (30, 32). In addition to highlighting differences in pathways, we also highlight a gender gap in our knowledge of developmental pathways leading to expertise in girls' and women's sports. Although the current literature spans a range of sports, the relative paucity of research on female athletes means that there are still not enough data within specific sports and categories of expertise to draw conclusions regarding sport-specific pathways and differences between elite groups. In addition to further study of pathways toward expert performance of elite female athletes, we also recommend collection of data from non-western socio-cultural contexts, longitudinal data throughout the development years (particularly through the adolescence transition) and well-defined definitions of practice, play and specialization to allow better comparisons across studies. It may be that pathways and hence models of elite sport development need to be different for males and females, particularly when opportunities for professional careers are currently limited and where biological and psychosocial differences in maturation exist across sexes and genders. In future, researchers may wish to move beyond testing current dichotomous models of athlete development to explore the upper and lower limits of early engagement (i.e., a continuum of specialization), as well as discerning differential consequences for early patterns of engagement for long-term success and other measures of continued sport participation (such as injury, and psychological wellbeing). Exploring these patterns across defined male and female samples would give researchers and practitioners an evidence-base to create more nuanced athlete development models and programs that offer the next generation of female athletes the opportunity to safely grow, develop and flourish in their future sporting endeavors.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Author contributions

CP performed the study search and data extraction which was audited by DH. All authors contributed to conception and design of the study. All authors contributed to writing and revisions of the submitted manuscript.

Funding

This work was supported by a SSHRC (Social Sciences and Humanities Research Council of Canada) SPRI (Sport Participation Research Initiative) grant awarded to NH (grant # 003385-2017).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Baker J, Wilson S, Johnston K, Dehghansai N, Koenigsberg A, de Vegt S, et al. Talent research in sport 1990–2018: a scoping review. *Front Psychol.* (2020) 11:607710. doi: 10.3389/fpsyg.2020.607710

2. Disanti JS, Erickson K. Youth sport specialization: a multidisciplinary scoping systematic review. *J Sports Sci.* (2019) 37:2094–105. doi: 10.1080/02640414.2019.1621476

3. Turnnidge J, Allan V, Côté J. The development of skill and interest in sport. In: Hodges NJ, Williams AM, editors. *Skill Acquisition in Sport: Research, Theory and Practice.* 3rd ed. London: Routledge (2019). doi: 10.4324/9781351189750-19

4. Viru A, Loko J, Volver A, Laaneots L, Karelson K, Viru M. (1998). Age periods of accelerated improvement of muscle strength, power, speed and endurance in the age interval 6–18 years. *Biol. Sport.* 15:211–27. Available online at: https://www.researchgate.net/publication/282723834.

5. Malina RM, Bouchard C, Bar-Or O. *Growth, Maturation and Physical Activity.* Champaign, IL: Human Kinetics (2004). p. 307–33. doi: 10.5040/9781492596837

6. Craggs C, Corder K, van Sluijs EMF, Griffin SJ. Determinants of change in physical activity in children and adolescents: a systematic review. *Am J Prev Med.* (2011) 40:645. doi: 10.1016/j.amepre.2011.02.025

7. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet.* (2012) 380:247–57. doi: 10.1016/S0140-6736(12)60646-1

8. Berger IE, O'Reilly N, Parent MM, Séguin B, Hernandez T. Determinants of sport participation among Canadian adolescents. *Sport Manag Rev.* (2008) 11:277–307. doi: 10.1016/S1441-3523(08)70113-X

9. Cepeda I. Wage Inequality of women in professional tennis of the leading international tournaments: gender equality vs market discrimination? *J Int Womens Stud.* (2021) 22:407–26. Available online at: https://vc.bridgew.edu/jiws/vol22/iss5/25

10. Wicker P, Breuer C, Dallmeyer S. The gender earnings gap among elite athletes in semi-professional sports. *Manag Sports Leisure.* (2021). doi: 10.1080/23750472.2021.1944819

11. Balyi I, Hamilton A. *Long-Term Athlete Development: Trainability in Childhood and Adolescence* (2004). Victoria, BC: National Coaching Institute British Columbia & Advanced Training and Performance Ltd.

12. Lima AB, Nascimento J v., Leonardi TJ, Soares AL, Paes RR, Gonçalves CE, et al. Deliberate practice, functional performance and psychological characteristics in young basketball players: a Bayesian multilevel analysis. *Int J Environ Res Public Health.* (2020) 17:1–14. doi: 10.3390/ijerph17114078

13. Gledhill A, Harwood C. Developmental experiences of elite female youth soccer players. *Int J Sport Exerc Psychol.* (2014) 12:150–65. doi: 10.1080/1612197X.2014.880259

14. Smith KL, Weir PL, Till K, Romann M, Cobley S. Relative age effects across and within female sport contexts: a systematic review and meta-analysis. *Sports Med.* (2018) 48:1451–78. doi: 10.1007/s40279-018-0890-8

15. Schorer J, Cobley S, Büsch D, Bräutigam H, Baker J. Influences of competition level, gender, player nationality, career stage and playing position on relative age effects. *Scand J Med Sci Sports.* (2009) 19:720–30. doi: 10.1111/j.1600-0838.2008.00838.x

16. Vincent J, Glamser FD. Gender differences in the relative age effect among US Olympic Development Program youth soccer players. *J Sports Sci.* (2006) 24:405–413. doi: 10.1080/02640410500244655

17. Albuquerque MR, Fukuda DH, da Costa VT, Lopes MC, Franchini E. Do weight categories prevent athletes from the relative age effect? A meta-analysis of combat sports. *Sport Sci Health.* (2016) 12:133–9. doi: 10.1007/s11332-016-0282-0

18. Welch V, Puil L, Shea B, Runnels V, Doull M, Tudiver S, et al. *Addressing Sex/Gender in Systematic Reviews: Cochrane Musculoskeletal Group Briefing Note*. Retrieved from: http://equity.cochrane.org/sex-and-gender-analysis (accessed November 15, 2020).

19. Ericsson KA. Towards a science of the acquisition of expert performance in sports: clarifying the differences between deliberate practice and other types of practice. *J Sports Sci.* (2020) 38:159–76. doi: 10.1080/02640414.2019.1688618

20. Ericsson KA, Krampe TT, Tesch-Romer C. The role of deliberate practice in the acquisition of expert performance. *Psychol Rev.* (1993) 100:363–406. doi: 10.1037/0033-295X.100.3.363

21. Ford PR, Coughlan EK. Operationalising deliberate practice for performance improvement in sport. In: Hodges NJ, Williams AM, editors. *Skill Acquisition in Sport: Research, Theory and Practice*. London: Routledge (2020). p. 183–200. doi: 10.4324/9781351189750-10

22. Ericsson KA. Summing up hours of any type of practice versus identifying optimal practice activities: commentary on Macnamara, Moreau, & Hambrick 2016. *Perspect Psychol Sci.* (2016) 11:351–4. doi: 10.1177/1745691616635600

23. Macnamara BN, Hambrick DZ, Moreau D. How important is deliberate practice? Reply to Ericsson (2016). *Perspect Psychol Sci.* (2016) 11:355–8. doi: 10.1177/1745691616635614

24. Macnamara BN, Moreau D, Hambrick DZ. The relationship between deliberate practice and performance in sports: a meta-analysis. *Perspect Psychol Sci.* (2016) 11:333–50. doi: 10.1177/1745691616635591

25. Baker J, Young B. 20 Years later: deliberate practice and the development of expertise in sport. *Int Rev Sport Exerc Psychol.* (2014) 7:135–57. doi: 10.1080/1750984X.2014.896024

26. Ward P, Hodges NJ, Williams AM. Deliberate practice and expert performance: defining the path to excellence. In: Hodges NJ, Williams AM, editors. *Skill Acquisition in Sport: Research, Theory and Practice*. Routledge (2004). p. 255–82. doi: 10.4324/9781351189750

27. Ford PR, Coughlan EK, Hodges NJ, Williams AM. Deliberate practice in sport. In: *Routledge Handbook of Sport Expertise*. London: Routledge (2015). p. 347–62. doi: 10.4324/9781315776675-30

28. Côté J, Baker J, Abernethy B. From play to practice: A developmental framework for the acquisition of expertise in team sport. In Starkes J, Ericsson KA, editors. *Expert Performance in Sports: Advances in Research on Sport Expertise*. Champaign, IL: Human Kinetics (2003) p. 89–113. Available online at: https://canada.humankinetics.com/collections/motor-behavior/products/expert-performance-in-sports

29. Côté J, Vierimaa M. The developmental model of sport participation: 15 years after its first conceptualization. *Sci Sports.* (2014) 29:S63–9. doi: 10.1016/j.scispo.2014.08.133

30. Côté J. The influence of the family in the development of talent in sport. *Sport Psychol.* (1999) 13:395–417. doi: 10.1123/tsp.13.4.395

31. Côté J, and Hay J. Children's involvement in sport: A developmental perspective, in Silva JM, Stevens DE, editors. *Psychological Foundations of Sport.* Boston, MA: Benjamin Cummings (2002). p. 484–502. Available online at: https://www.pearson.ch/HigherEducation/Pearson/EAN/9780205331444/Psychological-Foundations-of-Sport

32. Côté J, Baker J, Abernethy B. Practice and play in the development of sport expertise. In: Tenenbaum G, Eklund RC, editors. *Handbook of Sport Psychology.* (2012). p. 184–202. doi: 10.1002/9781118270011.ch8

33. Law MP, Côté J, Ericsson KA. Characteristics of expert development in rhythmic gymnastics: a retrospective study. *Int J Sport Exerc Psychol.* (2007) 5:82–103. doi: 10.1080/1612197X.2008.9671814

34. Deakin JM, Cobley S. A search for deliberate practice: a developmental framework for the acquisition of expertise in team sports. In: Starkes JL, Ericsson KA, editors. *Expert Performance in Sports: Advances in Research on Sport Expertise.* Champaign, IL: Human Kinetics (2003) p. 115–35.

35. Baker J, Mosher A, Fraser-Thomas J. Is it too early to condemn early sport specialisation? *Br J Sports Med.* (2021) 55:179–80. doi: 10.1136/bjsports-2020-102053

36. Mosher A, Fraser-Thomas J, Baker J. What defines early specialization: a systematic review of literature. *Front Sports Act Living.* (2020) 2:596229. doi: 10.3389/fspor.2020.596229

37. Wiersma LD. Risks and benefits of youth sport specialization: perspectives and recommendations. *Pediatr Exerc Sci.* (2000) 12:13–22. doi: 10.1123/pes.12.1.13

38. Hill GM, Simons J. A study of the sport specialization on high school athletics. *J Sport Soc Issues.* (1989) 13:1–13. doi: 10.1177/019372358901300101

39. Sieghartsleitner R, Zuber C, Zibung M, Conzelmann A. "The early specialised bird catches the worm!" - a specialised sampling model in the development of football talents. *Front Psychol.* (2018) 9:188. doi: 10.3389/fpsyg.2018.00188

40. Ford PR, Ward P, Hodges NJ, Williams AM. The role of deliberate practice and play in career progression in sport: the early engagement hypothesis. *High Ability Stud.* (2009) 20:65–75. doi: 10.1080/13598130902860721

41. Ford PR, Williams AM. The developmental activities engaged in by elite youth soccer players who progressed to professional status compared to those who did not. *Psychol Sport Exerc.* (2012) 13:349–52. doi: 10.1016/j.psychsport.2011.09.004

42. Hendry DT, Hodges NJ. Early majority engagement pathway best defines transitions from youth to adult elite men's soccer in the UK: a three time-point retrospective and prospective study. *Psychol Sport Exerc.* (2018) 36:81–9. doi: 10.1016/j.psychsport.2018.01.009

43. Hendry DT, Hodges NJ. Pathways to expert performance in soccer. *J Expertise.* (2019) 2:1–13. Available online at: https://www.journalofexpertise.org/articles/volume2_issue1/index.html

44. Hendry DT, Crocker PRE, Mark Williams A, Hodges NJ. Tracking and comparing self-determined motivation in elite youth soccer: influence of developmental activities, age, and skill. *Front Psychol.* (2019) 10:1–20. doi: 10.3389/fpsyg.2019.00304

45. Hendry DT, Crocker PRE, Hodges NJ. Practice and play as determinants of self-determined motivation in youth soccer players. *J Sports Sci.* (2014) 32:1091–9. doi: 10.1080/02640414.2014.880792

46. Güllich A, Emrich E. Considering long-term sustainability in the development of world class success. *Eur J Sport Sci.* (2014) 14:383–97. doi: 10.1080/17461391.2012.706320

47. Güllich A, Macnamara BN, Hambrick DZ. What makes a champion? Early Multidisciplinary practice, not early specialization, predicts world-class performance. *Perspect Psychol Sci.* (2022) 17:6–29. doi: 10.1177/1745691620974772

48. Gullich A, Cobley S. On the efficacy of talent identification and talent development programmes. In: Baker J, Cobley S, Schorer J, Wattie N, editors. *The Routledge Handbook of Talent Identification and Development in Sport*. London: Routledge (2017). p. 80–98. doi: 10.4324/9781315668017-7

49. Barreiros AN, Fonseca AM. A retrospective analysis of portuguese elite athletes' involvement in international competitions. *Int J Sports Sci Coach.* (2012) 7:593–600. doi: 10.1260/1747-9541.7.3.593

50. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med.* (2009) 6:e1000097. doi: 10.1371/journal.pmed.1000097

51. Peters MDJ, Marnie C, Tricco AC, Pollock D, Munn Z, Alexander L, et al. Updated methodological guidance for the conduct of scoping reviews. *JBI Evid Implement.* (2021) 19:3–10. doi: 10.1097/XEB.0000000000000277

52. McAuley ABT, Baker J, Kelly AL. Defining "elite" status in sport: from chaos to clarity. *German J Exerc Sport Res.* (2021) 52:193–7. doi: 10.1007/s12662-021-00737-3

53. Williams A, Day S, Stebbings G, Erskine R. (2017). What does 'elite' mean in sport and why does it matter. *Sport Exerc. Scient*. 51:6. Available online at: https://www.iat.uni-leipzig.de/datenbanken/iks/sponet/Record/4056787.

54. Baker J, Wattie N, Schorer J. Defining Expertise: a taxonomy for researchers in skill acquisition and expertise. In: Baker J, Farrow D, editors. *Routledge Handbook of Sport Expertise*. London: Routledge (2015). p. 145–55. doi: 10.4324/9781315776675-13

55. Zerunyan N. Time's up: addressing gender-based wage discrimination in professional sports. *Loyola of Los Angeles Entert Law Rev.* (2018) 38:229–59. Available online at: https://digitalcommons.lmu.edu/elr/vol38/iss3/2

56. Coutinho P, Mesquita I, Fonseca AM, Côté J. Expertise development in volleyball: the role of early sport activities and players' age and height. *Kinesiology.* (2015) 47:215–25. Retrieved from: https://hrcak.srce.hr/150549

57. Coutinho P, Mesquita I, Davids K, Fonseca AM, Côté J. How structured and unstructured sport activities aid the development of expertise in volleyball players. *Psychol Sport Exerc.* (2016) 25:51–9. doi: 10.1016/j.psychsport.2016.04.004

58. Fawver B, Cowan RL, DeCouto BS, Lohse KR, Podlog L, Williams AM. Psychological characteristics, sport engagement, and performance in alpine

skiers. *Psychol Sport Exerc.* (2020) 47:101616. doi: 10.1016/j.psychsport.2019.101616

59. Cowan RL, Fawver B, Lohse KR, Taylor T, Ford PR, Williams AM. Modeling talent development pathways in alpine ski racers. *Psychol Sport Exerc.* (2021) 55:101942. doi: 10.1016/j.psychsport.2021.101942

60. DeCouto BS, Fawver B, Taylor T, Williams AM. Physical fitness is associated with better technical performance in adolescent alpine ski racers after controlling for practice time: a retrospective regression analysis. *J Sports Sci.* (2021) 39:380–7. doi: 10.1080/02640414.2020.1823088

61. Johnson MB, Tenenbaum G, Edmonds WA. Adaptation to physically and emotionally demanding conditions: the role of deliberate practice. *High Ability Stud.* (2006) 17:117–36. doi: 10.1080/13598130600947184

62. Johnson MB, Tenenbaum G, Edmonds WA, Castillo Y. A comparison of the developmental experiences of elite and sub-elite swimmers: similar developmental histories can lead to differences in performance level. *Sport Educ Soc.* (2008) 13:453–75. doi: 10.1080/13573320802445108

63. Baker J, Côté J, Abernethy B. Sport-specific practice and the development of expert decision-making in team ball sports. *J Appl Sport Psychol.* (2003) 15:12–25. doi: 10.1080/10413200305400

64. Schorer J, Baker J, Bagats S, Strauss B. (2012). Training differences and selection in a talent identification system. *Talent Dev Excell.* 4:23–32. Available online at: https://www.researchgate.net/publication/259638507

65. Barynina II, Vaitsekhovskii SM. The aftermath of early sports specialization for highly qualified swimmers. *Fitness Sports Rev Int.* (1992) 27:132.

66. Bjørndal CT, Ronglan LT, Andersen SS. The diversity of developmental paths among youth athletes: a 3-year longitudinal study of Norwegian handball players. *Talent Dev Excell.* (2016) 8:20–32. Available online at: https://www.researchgate.net/publication/315383333

67. Blijlevens SJE, Wylleman P, Bool K, Elferink-Gemser MT, Visscher C. Acquisition and maintenance of excellence: the challenges faced by Dutch top-level gymnasts throughout different stages of athletic development. *Sport Soc.* (2020) 23:577–94. doi: 10.1080/17430437.2018.1524106

68. Bruce L, Farrow D, Raynor A. Performance milestones in the development of expertise: are they critical? *J Appl Sport Psychol.* (2013) 25:281–97. doi: 10.1080/10413200.2012.725704

69. Buckley PS, Bishop M, Kane P, Ciccotti MC, Selverian S, Exume D, et al. Early single-sport specialization a survey of 3090 high school, collegiate, and professional athletes. *Orthop J Sports Med.* (2017) 5:1–7. doi: 10.1177/2325967117703944

70. Coutinho P, Mesquita I, Fonseca AM, de Martin-Silva L. Patterns of sport participation in Portuguese volleyball players according to expertise level and gender. *Int J Sports Sci Coach.* (2014) 9:579–92. doi: 10.1260/1747-9541.9.4.579

71. Coutinho P, Ramos A, Fonseca AM, Davids K, Mesquita I. The nature of formative physical activities and sports in the development of senior volleyball players. *Int J Sports Sci Coach.* (2021) 16:731–40. doi: 10.1177/1747954121992040

72. Da Matta, G. B. (2004). *The influence of deliberate practice and social support systems on the development of expert and intermediate women volleyball players in Brazil* (Doctoral thesis). University of South Carolina, Columbia, SC, United States.

73. de Bosscher V, de Rycke J. Talent development programmes: a retrospective analysis of the age and support services for talented athletes in 15 nations. *Eur Sport Manag Quart.* (2017) 17:590–609. doi: 10.1080/16184742.2017.1324503

74. Duffy LJ, Baluch B, Ericsson KA. Dart performance as a function of facets of practice amongst professional and amateur men and women players. *Int J Sport Psychol.* (2004) 35:232–345. Available online at: https://www.researchgate.net/publication/228794232

75. Ford PR, Hodges NJ, Broadbent D, O'Connor D, Scott D, Datson N, et al. The developmental and professional activities of female international soccer players from five high-performing nations. *J Sports Sci.* (2020) 38:1–9. doi: 10.1080/02640414.2020.1789384

76. Güllich A. "Macro-structure" of developmental participation histories and "micro-structure" of practice of German female world-class and national-class football players. *J Sports Sci.* (2019) 37:1347–55. doi: 10.1080/02640414.2018.1558744

77. Hendry DT, Williams AM, Ford PR, Hodges NJ. Developmental activities and perceptions of challenge for National and Varsity women soccer players in Canada. *Psychol Sport Exerc.* (2019) 43:210–8. doi: 10.1016/j.psychsport.2019.02.008

78. Hodges NJ, Kerr T, Starkes JL, Weir PL, Nananidou A. Predicting performance times from deliberate practice hours for triathletes and swimmers: what, when, and where is practice important? *J Exp Psychol Appl.* (2004) 10:219–37. doi: 10.1037/1076-898X.10.4.219

79. Hodges NJ, Augaitis L, Crocker PRE. Sport commitment and deliberate practice among male and female triathletes. *Int J Sport Psychol.* (2015) 46:652–65. doi: 10.7352/IJSP2015.46

80. Hume PA, Hopkins WG, Robinson DM, Robinson SM, Hollings SC. Predictors of attainment in rhythmic sportive gymnastics. *J Sports Med Phys Fitness.* (1993) 33:367–77. Available online at: https://www.researchgate.net/publication/283517553

81. Leite N, Sampaio JE. Long-term athletic development across different age groups and gender from Portuguese basketball players. *Int J Sports Sci Coach.* (2012) 7:285–300. doi: 10.1260/1747-9541.7.2.285

82. Naisidou S, Kepesidou M, Kontostergiou M, Zapartidis I. Differences of physical abilities between successful and less successful young female athletes. *J Phys Educ Sport.* (2017) 17:294–9. doi: 10.7752/jpes.2017.01044

83. Post EG, Trigsted SM, Riekena JW, Hetzel S, McGuine TA, Brooks MA, et al. The association of sport specialization and training volume with injury history in youth athletes. *Am J Sports Med.* (2017) 45:1405–12. doi: 10.1177/0363546517690848

84. Staff T, Gobet F, Parton A. Investigating the period of practice needed to acquire expertise in Great Britain 2012 track and field olympic athletes. *J Expert.* (2019) 2:148–63. Available online at: https://www.researchgate.net/publication/338544819

85. Storm LK, Kristoffer H, Krogh CM. Specialization pathways among elite Danish athletes: a look at the Developmental Model of Sport Participation from a cultural perspective. *Int J Sport Psychol.* (2012) 43:199–222. doi: 10.7352/IJSP.2012.43.199

86. Timmerman EA, Savelsbergh GJP, Farrow D. Examining the influence of multiple performance characteristics on selection into a representative team in field hockey. *High Ability Stud.* (2021) 1–21. doi: 10.1080/13598139.2021.1885353

87. Post EG, Thein-Nissenbaum JM, Stiffler MR, Brooks MA, Bell DR, Sanfilippo JL, et al. High school sport specialization patterns of current division I athletes. *Sports Health.* (2017) 9:148–53. doi: 10.1177/1941738116675455

88. Baker J, Horton S. A review of primary and secondary influences on sport expertise. *High Ability Stud.* (2004) 15:211–28. doi: 10.1080/1359813042000314781

89. Araujo D, Fonseca C, Davids K. The role of ecological constraints on expertise development. *Talent Dev Excell.* (2010) 2:165–79. Available online at: https://www.researchgate.net/publication/288750954

90. Blackstone AM. Gender roles and society. In: Miller JR, Lerner RM, Schiamberg LB, editors. *Human Ecology: An Encyclopedia of Children, Families, Communities, and Environments.* (2003). p. 335–8. Santa Barbara, CA: ABC-CLIO.

91. Baker J, Hodges NJ, Wilson MJ. Collecting and assessing practice activity data: concurrent, retrospective, and longitudinal approaches. In: *The Cambridge Handbook of Expertise and Expert Performance.* Cambridge: Cambridge University Press (2018). p. 257–70. doi: 10.1017/9781316480748.015

92. Starkes, J. (2000). The road to expertise: Is practice the only determinant? *Int J Sport Psychol.* 31:431–51.

93. Starkes JL, Deakin JM, Allard F, Hodges NJ. Deliberate practice in sports: what is it anyway? In: Ericsson KA, editor. The Road to *Excellence: The Acquisition of Expert Performance in the Arts and Sciences, Sports, and Games.* Mahwah, NJ: Lawrence Erlbaum Associates (1996). p. 81–106. Available online at: https://www.routledge.com/The-Road-To-Excellence-the-Acquisition-of-Expert-Performance-in-the-Arts/Ericsson/p/book/9780805822328

frontiers | Frontiers in Sports and Active Living

TYPE Opinion
PUBLISHED 16 June 2023
DOI 10.3389/fspor.2023.1189355

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OPEN ACCESS

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RECEIVED 19 March 2023
ACCEPTED 05 June 2023
PUBLISHED 16 June 2023

CITATION
Carvalho HM and Gonçalves CE (2023) Mismatches in youth sports talent development.
Front. Sports Act. Living 5:1189355.
doi: 10.3389/fspor.2023.1189355

Mismatches in youth sports talent development

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KEYWORDS
growth, maturation, relative age effect, selection, youth sports

Introduction

The growing pressure to identify and nurture talented athletes for adult competitions has led sports organizations to invest significant efforts in identifying markers of talent at increasingly younger ages (1, 2). Initially, coaches were responsible for this task, but over time, it has shifted towards sport scientists (3, 4). However, in most cases, the final decision regarding the evaluation and development of young prospects still rests with the coaches (5).

A significant challenge in the pursuit of a reliable predictive model for adult performance is the emergence of the "biologic genotype," which suggests that genetics plays a partial role in the physical, physiological, or anthropometric traits necessary for athletic success (6). This phenomenon occurs during childhood and adolescence, coinciding with the period of sport specialization (6, 7). Alongside contextual factors, three major interrelated developmental problems arise when considering a viable model of talent identification and development: growth and maturation, relative age effect, and maturation and training loads. These problems have gained increased awareness in the context of youth sports and talent identification and development (8–10). In particular, there has been a recent discussion emphasizing the importance of maturation and relative age in talent development (11). Here, we extend the discussion to address often overlooked assumptions and their potential implications for researchers and coaches' interpretations.

Growth and maturation

The first process is the phenotypic process of pubertal changes, namely growth and maturation. The significant influence of growth and maturation on body size, physical function and performance, psychological, social, and behavioral characteristics has been widely recognized (8, 12, 13). Young athletes are often considered to have relatively homogeneous maturity status, training experience, body dimensions, functional capacity, and sport-specific skills (13). When a combination of size, strength, power, and endurance are determining factors in sports such as basketball or football, there tends to be an over-representation of early-maturing players (14, 15). On the other hand, in sports where smaller body size and relative strength are determining factors, such as gymnastics, or in sports where late specialization and stature are common, such as volleyball, late-maturing players are more represented (16, 17). The interpretation of the growth and maturation of young athletes is crucial in the selection process, especially in talent development contexts. For example, it has been noted the potential pitfalls of maturity-associated bias on youth selection (15). Nevertheless, there is limited retrospective data in talent development contexts with skeletal maturity assessments.

Likely, open-science practices and data sharing (18) will help to improve the strength of evidence in youth sports research, particularly in talent development contexts.

Longitudinal data monitoring of young athletes' growth and development is scarce, and mostly limited to stature and body mass (19). Interpretations of the occurrence of biological milestones such as peak height velocity or age at menarche require longitudinal observations and advanced modeling techniques. There are several practical problems with longitudinal studies, and even more challenging in applied youth sports settings (20). Recently, several advances have been made in fitting complex longitudinal data, including dealing with imbalanced data, and increased awareness of the strengths, assumptions, and limitations of different modeling approaches (19, 21). These advances have been made possible by increased computational resources, allowing for recent discussions on modeling methods comparisons (21–23).

However, interpretations of the variation in size, performance, and behavior of young athletes associated with growth and maturity are mostly based on cross-sectional data. Prediction-based equations, such as the maturity offset equations (24, 25) or percentage of mature (adult) stature without using skeletal age (26, 27), provide an alternative to having a reference of maturity status when considering cross-sectional observations. These methods are non-invasive and easy to measure. However, the risk of measurement error of anthropometric measures can be a concern in applied settings. On the other hand, these methods were derived from specific populations, mostly North American Caucasians (24–27). Hence, there is limited validity for the use of prediction-based equations in applied youth sports settings, and even more in talent development research. The limitations of prediction-based equations have been discussed (28, 29), also considering contexts of youth sports (30). However, researchers often overlook that these methods are potentially insensitive, and a young athlete may have been assigned to the wrong maturity status category (11, 12).

"Quick fixes" to interpret maturity status and timing based on non-invasive estimates are limited (31), despite their generalized interest and use in youth sports research and applied contexts. Therefore, it is important to exercise care in study designs and measurements, recognize and incorporate method assumptions and limitations, and keep interpretations conservative. Further and deeper development and validation of non-invasive indicators of maturity status and timing remain key issues in youth sports research. In particular, hierarchical/multilevel modeling using a fully Bayesian framework (32, 33) offers a robust and flexible approach to combine available longitudinal data from youth sport-specific samples with well-known shapes and variation in pubertal growth from available growth data (contemporary or otherwise) (19).

Recently, the application of bio-banding in the talent development context of youth sports has been advocated and applied in professional clubs or academies in the search for young "elite" athletes (9). The approach involves grouping and/or evaluating athletes based on their maturity status (and/or body size) rather than chronological age (9). Data-driven interpretations of bio-banding application are becoming more frequent in talent development contexts (particularly in youth football) [e.g., (34–36)]. At face value, the validity of the approach may seem reasonable. However, its application in research and real-world contexts relies on estimated maturity status based on prediction-based equations. Therefore, it is crucial to gather sufficient data on the application of bio-banding in youth sports and examine the accuracy of maturity status estimations in order to engage in meaningful discussions about its validity.

Relative age effect

The second bias is the phenomenon of Relative Age Effect (RAE). Albeit being the object of an extensive body of literature (37–40), RAE persists as coaches continue to be lured by apparent advantages of relative older athletes. RAE bias can appear as early as around 6 years of age in youth football (40). Starting from the onset of sport participation in childhood to early adolescence, around 14–15 years, coaches can engage in a chain of decisions to select or deselect participants based on their date of birth. From a talent development perspective, the exclusion of potential talents or the inclusion of future non achievers represent a negative side effect of a chronologically-based decision.

Unlike maturity status, RAE is easy to assess and offers a field for quantitative studies about the persistence of the phenomenon in adult sport. The observation of the RAE bias in the top levels of competition is highly dependent of the type of sport [e.g., (37–39)]. However, the general trend points to the disappearance of the effect at adult high-level of performance (37).

Our own research (7) revealed that being born in the first quarter of the year did not have an influence on athletic performance. Even when an initial advantage was observed, it diminished rapidly. By late adolescence, typically around 17 years of age, the best scores in any performance test were unrelated to the quarter of birth. These findings provide further evidence that the RAE and maturity status should not be confounded. However, the observations suggest a phenomenological emergence of the "survival of the fittest" (41). As at least for boys, the older individuals, both chronologically and biologically, appear to be more likely to be retained by coaches.

The outcomes are more a consequence of the athletes' responses to the training loads and to the ecologies of practice than determined by a particular characteristic like the birth quarter, maturity status or the year of engagement in talent development programs. Hence, the challenge remains to limit the potential bias associated to RAE on young athletes selection/exclusion, particularly at early ages.

Maturation and training loads

The third bias is represented by the interaction between maturation and the training load. We focus on two issues:

influence of training exposure on developmental changes in performance, and monitoring training loads and maturity status.

Coaches and researchers know that metabolic capacities are altered and enhanced by continued training through biological adaptations. When measuring of developmental changes during the specialization years, the maturation process acts as a confounding factor when interpreting eventual improvements in performance associated to training exposure (42). Furthermore, chronological age, biological age and sport age (accumulated training experience) interact and influence performance development with varying patterns across time (43, 44). It is well known that aerobic capacity, translated in the development of the endurance capabilities, increases through childhood and adolescence (8). The same is true for short-term muscle power outputs, observed and measured as strength or speed. Short-term muscle power outputs increases at the onset of puberty, as the growth of muscle mass is strongly dependent of the maturation process (45). However, data tracking developmental changes in young athletes adjusting for growth, maturation and training exposure is scarce, and merits further study (42), particularly in talent development context.

On the other hand, researchers are well aware of the obstacles raised by the multidimensional nature of performance and by the demands of each specific sport (2, 4, 46). Nevertheless, the pursuit of predicting models to identify those athletes more likely to succeed in adult sport remain a key interest of youth sport researchers (47–49). Multiple sets of tests were designed to measure biological characteristics, and/or functional characteristics at various age groups. However, the results in physical tests are strongly dependent of the accumulated hours of training, and of the respective training load (besides the fact that the assessment is often made downstream of the moment of selection). For instance strength development is connected both to the maturation process of testosterone production and to the participation in organized training sessions. Furthermore, there are different paces in maturation for boys and girls (8).

There is a large body of data describing training loads monitoring in talent development environments, particularly in youth football (50). Recently, the influence of maturation on training loads responses of young athletes in talent development contexts has draw attention [e.g., (51, 52)]. Exposition to high and demanding training loads raises concerns associated to injury risk, particularly during the periods of accelerated pubertal growth (52). As noted earlier, the use of non-invasive predictive equations hinder the potential interpretations. Unfortunately, this has been the case in most of the available research focusing on the relations between maturation and training loads among young athletes in talent development contexts [e.g., (53, 54)].

Future directions

To allow meaningful interpretations of young talented athletes data, we focus our suggestion to researches on three key issues:

(i) Adopting open-science and data sharing practices, allowing to overcome the expected small samples sizes reported, and combination of different sources of information;
(ii) Go beyond statements about the limits of non-invasive predictive methods of somatic maturity status, and explore advanced modeling approaches to include information and critically assess the models and inferences;
(iii) Consider theoretical lenses to frame questions, models and interpretations of potential mismatches between young athletes, and within-athlete development.

The potential biases associated to growth, maturation, RAE and training loads are especially challenging for coaches, who must evaluate their athletes' performances on a daily basis. Furthermore, the decisions made by coaches, as perceived by young athletes, are not limited to selection or exclusion but also involve micro-management of training sessions and competitions (such as playing time, praise and critique, composition of groups, promotion to higher levels, etc). On the other hand, the structures of talent development settings vary in terms of their human resources, sport types, and overall organization. In professional sports, talent development facilities have the capacity to recruit, support, and prepare the best prospects, and professional coaches are likely to benefit from the counseling of a performance analysis team. Even in such situations, the traps of maturity status and RAE are still present and can lead to decisions made without scientific or logical basis.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Gonçalves CE, Rama LM, Figueiredo AB. Talent identification, specialization in sport: an overview of some unanswered questions. *Int J Sports Physiol Perform*. (2012) 7:390–3. doi: 10.1123/ijspp.7.4.390

2. Pearson DT, Naughton GA, Torode M. Predictability of physiological testing, the role of maturation in talent identification for adolescent team sports. *J Sci Med Sport*. (2006) 9:277–87. doi: 10.1016/j.jsams.2006.05.020

3. Abbott A, Collins D. A theoretical, empirical analysis of a 'state of the art' talent identification model. *High Ability Stud*. (2002) 13:157–78. doi: 10.1080/1359813022000048798

4. Reilly T, Williams AM, Nevill A, Franks A. A multidisciplinary approach to talent identification in soccer. *J Sports Sci*. (2000) 18:695–702. doi: 10.1080/02640410050120078

5. Sieghartsleitner R, Zuber C, Zibung M, Conzelmann A. Science or coaches' eye? - both! Beneficial collaboration of multidimensional measurements and coach assessments for efficient talent selection in elite youth football. *J Sports Sci Med*. (2019) 18:32–43. PMCID: PMC6370964.

6. Pickering C, Kiely J, Grgic J, Lucia A, Del Coso J. Can genetic testing identify talent for sport? *Genes*. (2019) 10(12):972. doi: doi: 10.3390/genes10120972

7. Gonçalves CE, Carvalho HM. Revisiting the relative age effect from a multidisciplinary perspective in youth basketball: a Bayesian analysis. *Front Sports Act Living*. (2021) 2. doi: 10.3389/fspor.2020.581845

8. Armstrong N, *Development of the youth athlete*. Abingdon, Oxon: Routledge (2019).

9. Cumming SP, Lloyd RS, Oliver JL, Eisenmann JC, Malina RM. Bio-banding in sport: applications to competition, talent identification,, strength, conditioning of youth athletes. *Strength Cond J*. (2017) 39:34–47. doi: 10.1519/SSC.0000000000000281

10. Malina RM, Rogol AD, Cumming SP, Silva MJCE, Figueiredo AJ. Biological maturation of youth athletes: assessment and implications. *Br J Sports Med*. (2015) 49:852–9. doi: 10.1136/bjsports-2015-094623

11. Sweeney L, Taylor J, MacNamara Á. Push and pull factors: contextualising biological maturation and relative age in talent development systems. *Children (Basel)*. (2023) 10(1):130. doi: 10.3390/children10010130

12. Carvalho HM, Gonçalves CE, Collins D, Paes RR. Growth, functional capacities and motivation for achievement and competitiveness in youth basketball: an interdisciplinary approach. *J Sports Sci*. (2018). doi: 10.1080/02640414.2017.1340654

13. Malina RM. Physical growth, biological maturation of young athletes. *Exerc Sport Sci Rev*. (1994) 22:280–4. doi: 10.1249/00003677-199401000-00012

14. Carvalho HM, Silva MJCE, Figueiredo AJ, Gonçalves CE, Philippaerts RM, Castagna C et al. Predictors of maximal short-term power outputs in basketball players 14–16 years. *Eur J Appl Physiol*. (2011) 111:789–96. doi: 10.1007/s00421-010-1703-4

15. Carvalho HM, Gonçalves CE, Collins D, Paes RR. Growth, functional capacities and motivation for achievement and competitiveness in youth basketball: an interdisciplinary approach. *J Sports Sci*. (2018) 36(7):742–8. doi: doi: 10.1080/02640414.2017.1340654

16. Claessens AL, Lefevre J, Beunen GP, Malina RM. Maturity-associated variation in the body size and proportions of elite female gymnasts 14–17 years of age. *Eur J Pediatr*. (2006) 165:186–92. doi: 10.1007/s00431-005-0017-8

17. Mendes FG, Lima AB, Christofoletti M, Quinaud RT, Collet C, Gonçalves CE et al. Multidimensional characteristics of young Brazilian volleyball players: a Bayesian multilevel analysis. *PLoS ONE*. (2021) 16:e0250953. doi: 10.1371/journal.pone.0250953

18. Mesquida C, Murphy J, Lakens D, Warne J. Replication concerns in sports and exercise science: a narrative review of selected methodological issues in the field. *R Soc Open Sci*. (2022) 9:220946. doi: 10.1098/rsos.220946

19. Lima AB, Quinaud RT, Gonçalves CE, Carvalho HM. Peak height velocity in young athletes: a longitudinal meta-analysis. *J Sports Sci*. (2023) 41:151–63. doi: 10.1080/02640414.2023.2203484

20. Kemper HCG. Longitudinal studies during growth and training: importance and principles. In: Hebestreit H, Bar-Or O (Eds.). *The Young Athlete*. (2007) 469–85. doi: 10.1002/9780470696255.ch34

21. Simpkin AJ, Sayers A, Gilthorpe MS, Heron J, Tilling K. Modelling height in adolescence: a comparison of methods for estimating the age at peak height velocity. *Ann Hum Biol*. (2017) 44:715–22. doi: 10.1080/03014460.2017.1391877

22. Boeyer ME, Middleton KM, Duren DL, Leary EV. Estimating peak height velocity in individuals: a comparison of statistical methods. *Ann Hum Biol*. (2020) 47:434–45. doi: 10.1080/03014460.2020.1763458

23. Cao Z, Hui LL, Wong MY. New approaches to obtaining individual peak height velocity and age at peak height velocity from the SITAR model. *Comput Methods Programs Biomed*. (2018) 163:79–85. doi: 10.1016/j.cmpb.2018.05.030

24. Mirwald RL, Baxter-Jones AD, Bailey DA, Beunen GP. An assessment of maturity from anthropometric measurements. *Med Sci Sports Exerc*. (2002) 34:689–94. doi: 10.1097/00005768-200204000-00020 Available at: http://www.ncbi.nlm.nih.gov/pubmed/11932580

25. Moore SA, McKay HA, Macdonald H, Nettlefold L, Baxter-Jones AD, Cameron N et al. Enhancing a somatic maturity prediction model. *Med Sci Sports Exerc*. (2015) 47:1755–64. doi: 10.1249/MSS.0000000000000588

26. Beunen GP, Malina RM, Lefevre J, Claessens AL, Renson R, Simons J. Prediction of adult stature and noninvasive assessment of biological maturation. *Med Sci Sports Exerc*. (1997) 29:225–30. doi: 10.1097/00005768-199702000-00010

27. Khamis HJ, Roche AF. Predicting adult stature without using skeletal age: the Khamis–Roche method. *Pediatrics*. (1994) 94:504–7. doi: 10.1542/peds.94.4.504

28. Malina RM, Kozieł SM, Králik M, Chrzanowska M, Suder A. Prediction of maturity offset and age at peak height velocity in a longitudinal series of boys and girls. *Am J Hum Biol*. (2020) n/a:e23551. doi: 10.1002/ajhb.23551

29. Teunissen JW, Rommers N, Pion J, Cumming SP, Rössler R, D'Hondt E et al. Accuracy of maturity prediction equations in individual elite male football players. *Ann Hum Biol*. (2020) 47:409–16. doi: 10.1080/03014460.2020.1783360

30. Malina RM, Silva M, Figueiredo AJ, Carling C, Beunen GP. Interrelationships among invasive and non-invasive indicators of biological maturation in adolescent male soccer players. *J Sports Sci*. (2012) 30:1705–17. doi: 10.1080/02640414.2011.639382

31. Malina RM. Top 10 research questions related to growth and maturation of relevance to physical activity, performance, and fitness. *Res Q Exerc Sport*. (2014) 85:157–73. doi: 10.1080/02701367.2014.897592

32. Gelman A, Carlin JB, Stern HS, Dunson DB, Vehtari A, Rubin DB. Bayesian data analysis. *Boca Raton, FL: Chapman Hall/CRC Press* (2013). doi:doi: 10.1201/b16018

33. McElreath R. Statistical rethinking: a Bayesian course with examples in R and stan. 2nd edition. *Boca Raton, FL: Chapman and Hall/CRC Press* (2020)

34. Abbott W, Williams S, Brickley G, Smeeton NJ. Effects of bio-banding upon physical and technical performance during soccer competition: a preliminary analysis. *Sports (Basel)*. (2019) 7:193. doi: 10.3390/sports7080193. Available at: https://www.mdpi.com/2075-4663/7/8/193

35. Bradley B, Johnson D, Hill M, McGee D, Kana-ah A, Sharpin C et al. Bio-banding in academy football: player's perceptions of a maturity matched tournament. *Ann Hum Biol*. (2019) 46:400–8. doi: 10.1080/03014460.2019.1640284

36. Lüdin D, Donath L, Cobley S, Romann M. Effect of bio-banding on physiological and technical-tactical key performance indicators in youth elite soccer. *Eur J Sport Sci*. (2022) 22:1659–67. doi: 10.1080/17461391.2021.1974100

37. García-Rubio J, García-Vallejo A, Arenas-Pareja MdlÁ, López-Sierra P, Ibáñez SJ. From junior to elite in soccer: exploring the relative age effect and talent selection in Spanish youth national teams. *Children*. (2022) 9(10):1543. doi: doi: 10.3390/children9101543

38. Kelly AL, Jackson DT, Taylor JJ, Jeffreys MA, Turnnidge J. "Birthday-banding" as a strategy to moderate the relative age effect: a case study into the England squash talent pathway. *Front Sports Act Living*. (2020) 2. doi: 10.3389/fspor.2020.573890

39. Lupo C, Boccia G, Ungureanu AN, Frati R, Marocco R, Brustio PR. The beginning of senior career in team sport is affected by relative age effect. *Front Psychol*. (2019) 10. doi: 10.3389/fpsyg.2019.01465

40. Patel R, Nevill A, Cloak R, Smith T, Wyon M. Relative age, maturation, anthropometry and physical performance characteristics of players within an elite youth football academy. *Int J Sports Sci Coach*. (2019) 14:714–25. doi: 10.1177/1747954119879348

41. Jones BD, Lawrence GP, Hardy L. New evidence of relative age effects in "super-elite" sportsmen: a case for the survival and evolution of the fittest. *J Sports Sci*. (2018) 36:697–703. doi: 10.1080/02640414.2017.1332420

42. Soares AL, Lima AB, Miguel CG, Galvño LG, Leonardi TJ, Paes RR et al. Does early specialization provide an advantage in physical fitness development in youth basketball? *Front Sports Act Living*. (2023) 4. doi: 10.3389/fspor.2022.1042494

43. Carvalho HM, Leonardi TJ, Soares ALA, Paes RR, Foster C, Gonçalves CE. Longitudinal changes of functional capacities among adolescent female basketball players. *Front Physiol*. (2019) 10. doi: 10.3389/fphys.2019.00339

44. Saal C, Chaabene H, Helm N, Warnke T, Prieske O. Network analysis of associations between anthropometry, physical fitness, and sport-specific performance in young canoe sprint athletes: the role of age and sex. *Front Sports Act Living*. (2022) 4. doi: 10.3389/fspor.2022.1038350

45. Philippaerts RM, Vaeyens R, Janssens M, Renterghem BV, Matthys D, Craen R et al. The relationship between peak height velocity and physical performance in youth soccer players. *J Sports Sci*. (2006) 24:221–30. doi: 10.1080/02640410500189371

46. Carvalho HM, Lekue JA, Gil SM, Bidaurrazaga-Letona I. Pubertal development of body size and soccer-specific functional capacities in adolescent players. *Res Sports Med*. (2017) 25:421–36. doi: 10.1080/15438627.2017.1365301

47. Güllich A. Selection, de-selection and progression in German football talent promotion. *Eur J Sport Sci*. (2014) 14:530–7. doi: 10.1080/17461391.2013.858371

48. Güllich A. Sport-specific and non-specific practice of strong and weak responders in junior and senior elite athletics—a matched-pairs analysis. *J Sports Sci*. (2018) 36:2256–64. doi: 10.1080/02640414.2018.1449089

49. Güllich A, Macnamara BN, Hambrick DZ. What makes a champion? Early multidisciplinary practice, not early specialization, predicts world-class performance. *Perspect Psychol Sci*. (2021) 17:6–29. doi: 10.1177/1745691620974772

50. Murray A. Managing the training load in adolescent athletes. *Int J Sports Physiol Perform*. (2017) 12:S2-42–9. doi: 10.1123/ijspp.2016-0334

51. Nobari H, Eken Ö, Kamiş O, Oliveira R, González PP, Aquino R. Relationships between training load, peak height velocity, muscle soreness and fatigue status in elite-level young soccer players: a competition season study. *BMC Pediatr*. (2023) 23:55. doi: 10.1186/s12887-023-03869-7

52. Salter J, Croix MBADS, Hughes JD, Weston M, Towlson C. Monitoring practices of training load and biological maturity in UK soccer academies. *Int J Sports Physiol Perform*. (2021) 16:395–406. doi: 10.1123/ijspp.2019-0624

53. Nobari H, Aquino R, Clemente FM, Khalafi M, Adsuar JC, Pérez-Gómez J. Description of acute and chronic load, training monotony and strain over a season and its relationships with well-being status: a study in elite under-16 soccer players. *Physiol Behav*. (2020) 225:113117. doi: 10.1016/j.physbeh.2020.113117

54. Salter J, Julian R, Mentzel SV, Hamilton A, Hughes JD, Croix MDS. Maturity status influences perceived training load and neuromuscular performance during an academy soccer season. *Res Sports Med*. (2022) 1–13. doi: 10.1080/15438627.2022.2102916

frontiers | Frontiers in Sports and Active Living

TYPE Mini Review
PUBLISHED 01 November 2022
DOI 10.3389/fspor.2022.975900

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SPECIALTY SECTION
This article was submitted to Elite Sports and Performance Enhancement,
a section of the journal Frontiers in Sports and Active Living

RECEIVED 22 June 2022
ACCEPTED 24 August 2022
PUBLISHED 01 November 2022

CITATION
Wik EH (2022) Growth, maturation and injuries in high-level youth football (soccer): A mini review.
Front. Sports Act. Living 4:975900.
doi: 10.3389/fspor.2022.975900

Growth, maturation and injuries in high-level youth football (soccer): A mini review

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Understanding the challenges football (soccer) players face during adolescence is fundamental to avoid disruptions in their development due to injury. This mini review will describe basic concepts of somatic growth and biological maturity, examine data from 53 prospective epidemiological studies on high-level youth football players and discuss how age, growth and maturity may affect the injury patterns observed. Based on the existing evidence, at least every third player sustains an injury during a football season. The thigh (median for studies of boys: 25%, median for girls: 21%), ankle (b: 18%, g: 30%), knee (b: 17%, g: 18%) and hip/groin (b: 14%, g: 10%) are the body parts injured most often, while muscle strains (b: 31%, g: 25%), sprains (b: 20%, g: 27%) and contusions (b: 17%, g: 16%) are the most common injury types. Injury trends are, however, not consistent throughout adolescence, and players' age, maturity status and position relative to peak height velocity (PHV) have shown to influence the number, type and location of injuries sustained. Despite a high volume of observational injury studies published on high-level youth players, girls (7 studies) and settings outside of Europe (included in 23% of studies) are underrepresented and should receive extra attention in the future. Based on the available epidemiological data, tailored injury reduction programmes can be considered in youth football, alongside application of general training principles such as progression, variation and individualization which may be especially important during vulnerable phases such as the adolescent growth spurt.

KEYWORDS

soccer, sports medicine, growth and development, epidemiology, youth

Introduction

If you have been involved in youth football (soccer) in any capacity – that be as a player, coach, parent, physiotherapist or team coordinator – you probably have at least one story about "that player who grew 10 cm over the summer," "seemingly fully-grown adults playing alongside children" or "the player who could have reached the top if it wasn't for that injury." Stories like these make youth football both interesting and challenging, with some unique obstacles not seen at the senior level.

A general understanding of the changes adolescents experience when transitioning from children to adults [see Malina et al. (1)] is essential for anyone working in youth sports, and awareness around issues relating to injury risk may allow more talents to stay in their sport and develop to their full potential. Injuries keep players out of sessions and disrupt their development, which again may lead to them being dropped from a development programme (2). In some instances, they can have long-term health consequences (3). Although preventing all injuries is near impossible, it is in everyone's interest to limit the frequency and severity of injury. In this mini review, we will explore typical injury patterns in youth football and examine how growth and biological maturation may affect the chances of sustaining one.

Understanding concepts of growth and maturity

Phrases like "the growth spurt," "maturity timing" or "maturity status" can be confusing if used without a clear indication of what they refer to. In research, inconsistent terminology complicates aggregation of findings and in practice it may be a barrier for clear communication within a coaching team or to players and parents. The aim of this first section is therefore to define and clarify some key concepts. Although this review focuses on somatic (bodily) growth and biological maturation, it should be acknowledged that other aspects not covered, such as cognitive, behavioral and social development, or development of motor and psychological skills, also may affect the risk of sustaining injuries (4), which are considered both multifactorial, dynamic and complex (5–7).

Somatic growth and the adolescent spurt

Growth can be defined as a change in the size of the whole body or a body part (1). A player's growth can therefore be assessed by measuring changes in physical dimensions (e.g., height, weight or leg length) over time. Growth in height follows a distinct non-linear pattern from birth to adulthood, with rapid changes observed right after birth, relatively steady growth throughout childhood, a new period of high acceleration during puberty, followed by a deceleration until adult height is reached (8).

The changes around puberty are especially interesting in the context of youth football, as the "adolescent growth spurt" takes off around the age of 8–10 years in girls and 10–12 years in boys (9, 10). The point of maximal acceleration (peak height velocity; PHV), where typical height velocities are around 7–9 cm/year (girls) and 8–10 cm/year (boys), occurs at a younger age in girls (around 11–13 years) compared to boys (around 13–15 years) (9, 10). There is, however, large variation in timing and magnitude between individuals, where age at PHV (timing) can range from 9 to 15 (girls) and 12 to 17 (boys) years, and maximal growth velocities (magnitude) can range from 5 to 10 (girls) and 5–12 (boys) cm/year (9, 10). Variation can also be seen between body parts in the same individual, where distal bones typically reach their peak velocity at a younger age compared to bones located higher up (1).

Adolescents also experience a period of accelerated weight gain: peak weight velocity (PWV). Maximal gains around 7–9 kg/year in girls and 9–11 kg/year in boys are common, around the ages of 12–14 years in girls (range: 11–15) and 13–15 years in boys (range: 13–16) (11). It is worth noting that girls, in general, gain proportionally more fat mass while boys add more lean mass (e.g., muscle and bone) (1). These relatively fast changes in height, weight and body composition at varying ages are important to consider, as they can result in large height and weight differences within age groups (12) and may impact both neuromotor coordination and injury risk negatively (13, 14).

Making sense of biological maturity

The concept of growth can be conceptually easy to grasp; maturation on the other hand, is more complex and refers to the progress toward a mature (adult) state (1). In essence, this implies that a specific biological system has a certain end point (i.e., the mature state), and *maturation* is the journey to reach this endpoint. The end point depends on the system we are looking at; for example, the skeleton starts off as cartilage and matures to ossified bone (skeletal maturity), while sexual maturity is reached with full reproductive function (1, 15).

Adolescence is a phase associated with particularly large changes in different biological systems relating to the onset of puberty (16). The sequence of puberty often follows a typical pattern; however, there will be variation between girls and boys, and between individuals (16). The age at reaching certain maturational landmarks (e.g., PHV or the onset of menstrual cycles) is what we refer to as *maturity timing*. When comparing similar indicators, these are typically reached at a younger age in girls than in boys (1). The rate of change or time between maturational events (*maturity tempo*) also varies, meaning that some will be more advanced than others, even if their chronological age is the same. How far an individual has come at a given time point is what we mean by *maturity status*. In youth football, differences in maturity status are particularly relevant since players most often compete in chronological, not maturity-based, age groups.

Injury patterns in high-level youth football

As mentioned in the introduction, one purpose of reducing the impact of injuries is to maximize developmental opportunities and performance. Understanding injury patterns is therefore fundamental, as we need to know which problems to focus on in order to best mitigate risk (17). The focus in this section will be on high-level adolescent players (e.g., elite, academy, professional club), including data from 53 prospective studies (per March 2022) which reported overall injury outcomes for minimum one season. Although methodological differences (e.g., injury definitions, recorders, classification systems) make comparisons and data aggregation difficult, and relatively few studies have been published on high-level female players, some trends are apparent.

How common and severe are football injuries?

One approach to determining the extent of injuries is to count how many players sustain at least one injury over a season. In boys, this has ranged from 38 to 85% (18–25), with 0.4–2.2 injuries per player per season (19–42). Only one study reported seasonal injury proportion for girls (37%) (43), with another finding an average of 4.3 injuries per player per season (44). The latter also revealed that every second female player experienced an injury problem affecting performance, participation or pain during a given week (44). This suggests that injuries are indeed common in youth football, with a conservative estimate suggesting that at least every third high-level player will be injured once or more during a season.

Counting injuries or calculating the proportion of injured players does not take the time they play football into consideration. This is important, as a team training eight times per week inevitably will see more injuries than a team training once a week; this does not mean that the risk of playing an hour of football is different. Expressing injuries relative to training and match hours is therefore recommended. Using the median of point estimates for reported injury rates (this does not consider the size of each study, nor the uncertainty in their estimates) and keeping methodological differences in mind, the number of injuries per 1,000 h appears similar between genders (Figure 1): around 6.3 (range: 1.3–12.1) for boys (18–20, 24, 26, 27, 29, 31–33, 36, 37, 41, 42, 46–57) and 6.4 (2.1–9.1) for girls (44, 55, 58–60). Matches are consistently associated with greater risk compared to training sessions in both boys (match: 13.4, training: 4.0) and girls (match: 22.4, training: 4.6) (18–20, 24–26, 29, 31–33, 36, 42, 46–50, 53–55, 58, 60–63).

Injury severity is commonly calculated as the number of days elapsed from the day of injury until the day the player returns to full training and/or is available for match selection (64), often presented as the proportion of injuries falling within defined bins (e.g., percentage of all injuries lasting 7–28 days). Although cut-offs vary slightly between studies and the choice of injury definition affects distributions, the combined findings suggest that 38% (7–74%) of injuries in boys last less than a week, another 38% (16–67%) last between a week and a month, while every fifth injury (21%, 2–37%) lasts more than a month (18, 20, 21, 23, 25, 28, 29, 31–37, 39, 41, 46, 48, 49, 53–56, 61). For girls, a larger proportion of "mild" injuries is observed, with around a half (51%, 38–52%) lasting a week or less, a third (36%, 32–41%) between a week and a month, and the remaining 16% (12–20%) more than a month (55, 58, 60).

What are the most common injury locations and types?

Understanding the injury problem in general is an important first step; however, we need to know *which injuries* are the most troublesome to design impactful injury reduction programmes that target specific mechanisms and risk factors. Given the high running demands and frequent kicking and tackling actions observed in youth football (65, 66), it is perhaps not surprising that the lower extremities are the most affected – accounting for approximately four out of five injuries in boys and girls (Figure 2). Breaking it down to specific body parts, thigh injuries are the most common among boys (median of percentages reported in studies: 25% of all injuries, range: 11–39%), with the ankle (18%; 9–31%), knee (17%; 7–23%) and hip/groin (14%; 2–33%) also common. In girls, ankle injuries are the most common (30%; 18–39%), followed by injuries to the thigh (21%; 11–35%), knee (18%; 16–25%) and hip/groin (10%; 10–14%). Three main injury types can be identified, with strains (31%; 14–87%), sprains (20%; 9–40%) and contusions (17%; 3–31%) together accounting for two out of three injuries in boys. Sprains appear more common among girls (27%; 27–61%), although they together with strains (25%; 17–33%) and contusions (16%; 8–17%) also account for roughly two thirds of all injuries reported. Taken together, these patterns are similar to senior players (67, 68), and it could be argued that football players – for the most part – sustain "typical football injuries" regardless of age and gender when proportions are used.

Isolated proportions for body parts and types are of limited value since they do not consider injury severity, nor do they tell us which injury types to focus on within each location or where different types are located. Reporting injury burden (i.e., days lost relative to hours of football exposure) for combinations of body parts and injury types (or specific diagnoses) would therefore represent an advancement in our understanding (69). Few studies provide this, but there

Fist author (year)	Boys age	Country	Duration	Injury definition	Injury recorder	Players	Injuries	Exposure	Overall	Training	Match
Hawkins (1999)	Unclear	England	2.5 years	Time loss (>1d)	Medical staff	n/a	166	Estimated (h)		4.1	37.2
Junge (2000)	14-18 yr.	France/Czech Republic/Germany	1 year	Time-loss tissue damage (>1wk)	Medical staff/Coach	193	131	Individual (h)	2.3		
Peterson (2000)	14-18 yr.	Unclear	1 year	Tissue damage	Medical staff	135	262	Individual (h)	6.3		16.5
Kucera (2005)	U12-18	USA	3 years	Time loss	Coach	928	467	Estimated (AE)	4.3		
Le Gall (2006)	U14-16	France	10 seasons	Time loss (>48h)	Medical staff	528	1152	Estimated (h)	4.8	3.9	11.2
Merron (2006)	16-18 yr.	England	4 years	Time loss (>2d)	Medical staff	112	236	Individual (h)	8.1	6.1	25.0
Johnson (2009)	9-16 yr.	England	6 years	Unclear	Medical staff	292	476	Individual (h)	2.2	1.4	10.5
Brink (2010)	15-18 yr.	Netherlands	2 seasons	Time loss	Medical staff	53	320	Individual (h)		6.7	26.7
Frisch (2011)	13-19 yr.	Luxembourg	1 season	Time loss	Researcher	67	163	Individual (h)	10.4	7.1	23.5
Ergun (2013)	U17-19	Turkey	3 seasons	Time loss	Medical staff	52	44	Individual (h)	12.1	7.4	30.4
Toumy (2014)	U12-20	France	3 seasons	Any complaint	Medical staff	n/a	618	Estimated (h)	4.0	2.6	27.2
van der Sluis (2014)	11.9 yr.	Netherlands	4 seasons	Time loss	Medical staff	26	178	Individual (h)		2.1	12.4
Kemper (2015)	U12-19	Netherlands	1 season	Medical attention (>1d)	Medical staff	101	134	Estimated (h)	5.9	3.3	8.2
Bianco (2016)	13-19 yr.	Italy	1 season	Time loss	Researcher	80	107	Individual (h)	1.3	1.2	2.8
Nilsson (2016)	15-19 yr.	Sweden	2 seasons	Time loss	Medical staff	43	61	Individual (h)	6.8	5.6	15.5
Bacon (2017)	U18-21	England	2 seasons	Unclear	Medical staff	41	85	Individual (h)	10.6	3.7	5.8
Bowen (2017)	U18-21	England	2 seasons	Time loss	Medical staff	32	138	Individual (h)	12.1	7.9	33.5
Bult (2018)	U12-19	Netherlands	3 seasons	Time loss	Medical staff	170	620	Team (h)	8.3		
Tears (2018)	U12-18	England	6 seasons	Medical attention	Medical staff	n/a	882	Estimated (h)	2.5	1.5	24.1
Delecroix (2019)	U19	France	4 seasons	Time loss	Unclear	52	182	Individual (h)	7.6		
Loose (2019)	U19	Germany	1 season	Time loss/Non-time loss	Players/Medical staff	n/a	n/a	Individual (h)	10.4		
Cezarino (2020)	10-20 yr.	Brazil	1 season	Time loss	Medical staff	228	187	Team (h)	1.9	1.4	8.1
Raya-Gonzales (2020)	U14-19	Spain	4 seasons	Time loss	Medical staff	n/a	337	Individual (h)	2.7	2.0	8.8
Sieland (2020)	U12-19	Germany	2 seasons	Time loss	Medical staff	205	125	Individual (h)	2.7	2.3	5.0
Sprouse (2020)	U15-19	England	8 years	Time loss	Medical staff	n/a	319	Individual (h)	7.3	4.0	29.8
Light (2021)	U9-12	England	4 seasons	Time loss	Medical staff	n/a	603	Individual (h)	2.4		
Thiebat (2021)	U9-17	Italy	3 seasons	Time loss	Medical staff	679	975	Team (h)	4.3		
Toselli (2021)	U13-15	Italy	1 season	Time loss	Medical staff	141	83	Individual (h)	3.3	2.8	7.4
Wik (2021)	U13-18	Qatar	4 seasons	Time loss	Medical staff	301	1111	Individual (h)	12.0	8.2	32.0
Hall (2022)	9-23 yr.	England/Spain/Uruguay/Brazil	3 seasons	Time loss (>24h)	Medical staff	501	323	Individual (h)	5.7		
Jaber (2022)	U12-19	Germany	1 season	Time loss (<4d)	Medical staff	138	109	Individual (h)		0.7	6.9

Fist author (year)	Girls age	Country	Duration	Injury definition	Injury recorder	Players	Injuries	Exposure	Overall	Training	Match
Kucera (2005)	U12-18	USA	3 years	Time loss	Coaches	320	320	Estimated (AE)	5.3		
Le Gall (2008)	U15-19	France	8 seasons	Time loss	Medical staff	119	619	Estimated (h)	6.4	4.6	22.4
Clausen (2014)	U18	Denmark	1 season	Time loss	Athlete/Interview	n/a	59	Individual (h)	9.2		
Richardson (2017)	17.2 yr.	Netherlands	1 season	Any complaint	Athletes	23	94	Individual (h)	17.1		
Sprouse (2020)	U15-19	England	8 seasons	Time loss	Medical staff	n/a	326	Individual (h)	6.4	5.0	32.6
Beech (2022)	U10-16	England	1 season	Time loss	Medical staff	375	111	Estimated (h)	2.1	1.1	9.3

FIGURE 1
Overview of studies reporting overall, training and/or match injury rates (per 1,000 h or athletic exposures: AE) in high-level youth football players. Where estimates were only provided for subgroups, the average was used to give an idea of the extent, and where rates were presented using multiple definitions, only the narrowest was included (e.g., time loss > medical attention) as these are more comparable between contexts (45). If datasets were overlapping or used in multiple studies, only the main epidemiological study was included.

First author (year)	Boys age	% Lower ext.	% Hip/Groin	% Thigh	% Knee	% Lower leg	% Ankle	% Foot	% Strain	% Sprain	% Contusion	% Fracture	% Tendon	% Growth
Hawkins (1999)	Unclear		16	23	10	9	17	8	36	20	27	4		
Peterson (2000)	14-18 yr.			13	15		19							
Price (2004)	9-19 yr.	90	12	19	18	10	19	8	31	20		4		
Le Gall (2006)	U14-16	71	2	25	15	5	18	8	15	17	31	6	9	6
Merron (2006)	16-18 yr.	74	7	12	19	7	19	8						
Deehan (2007)	9-18 yr.	86		31	15		18	6	37	18	10		6	
Brink (2010)	15-18 yr.	85							38	25	26			
Frisch (2011)	13-19 yr.	87	4	39	17	3	18	5		22	26	4		
Ergün (2013)	U17-19	80	25	32	7		9	2	61	9		2	20	
Toumy (2014)	U12-20	91	18	28	14	6	15	8						
van der Sluis (2014)	11.9 yr.	82							57	21	13			
Kemper (2015)	U12-19								18	22	28	3	6	19
Bianco (2016)	13-19 yr.		21	34	18	11			87				13	
Nilsson (2016)	15-19 yr.	93	33	26			18		5[illegible]	24				
Renshaw (2016)	9-18 yr.		13	35	17	6	13	4	46	16			13	
Bacon (2017)	U18-21		16	11	16	2	31	7	14	19	12	6		
Bult (2018)	U12-18	85	17	17	17	9	20	7	28	13	28	9	13	
Read (2018)	11-18 yr.	78		16	20		18		21	17		3	4	7
Tears (2018)	U12-18	84	15	20	14	11	15	9	31	20	22	4	12	
Cezarino (2020)	10-20 yr.		12	26	23	4	19	3	26	24	16	7	10	
Hall (2020)	U9-23	75	8	22	20	5	14	6	30	20	9	6	4	9
Raya-Gonzáles (2020)	U14-19		17	23	18	10	23	3	26	37	3	4		
Sieland (2020)	U12-19	81												
Light (2021)	U9-12		9	23	17	8	17	11	29	20	14	7	6	
Mateme (2021)	U9-19	84	13	25	13	12	16	10	24	16	26	6	1	16
Rinaldo (2021)	U9-13	77												
Thiebat (2021)	U9-17			34	18									
Toselli (2021)	U13-15	77							33	36	6			
Wik (2021)	U13-18	83	14	25	13	9	14	8	22	13	17			11
Jaber (2022)	U12-19	81	2	26	21	6	22	11		40	11	14		

First author (year)	Girls age	% Lower ext.	% Hip/Groin	% Thigh	% Knee	% Lower leg	% Ankle	% Foot	% Strain	% Sprain	% Contusion	% Fracture	% Tendon	% Growth
Le Gall (2008)	U15-19	83	10	21	17	5	25	6	25	27	16	3	6	1
Richardson (2017)	17.2 yr.		10	35	25		34	8						
Watson (2017)	15.5 yr.			11	19	3	39	8	17	61	8	3		
Beech (2022)	U10-16	79	14	21	16	5	18	6	33	27	17	5	2	1

FIGURE 2
Reported injury proportions within location and type categories in high-level youth football players. Not all studies used the same classifications, and a best effort was made to place injuries in the most applicable category. In studies reporting subgroup proportions without values for the full sample, the average was entered to give an idea of the overall pattern. Where multiple studies were published with the same or overlapping dataset, only the main epidemiological paper was included.

is evidence to show that it changes our interpretation of surveillance data. As an example, a study of academy boys (24) highlighted that thigh muscle injuries were the most common (16% of all injuries, accounting for 11% of total days lost), but joint sprains to the knee had the greatest impact on player participation (only 3% of injuries, but 18% of days lost). Similarly, contusions, which ranked high in terms of proportions, were of low severity and consequently had a relatively low impact (17% of injuries, but only 5% of days lost). Of particular interest to youth populations, injuries to the skeleton were the most burdensome tissue type in this study (23% of injuries, 34% of days lost), although muscle/tendon injuries were the most common (27% of injuries, 16% of days lost). These insights would be lost if severity was not accounted for.

Do injuries depend on age, growth and maturity?

A wide span in age groups combined with individual differences in timing and tempo of growth and maturation make "youth football players" a heterogeneous population. Some studies will include players closer to childhood, others closer to the senior level, and within age groups there will be variation at the individual level. This section will examine the potential influence age, growth and maturation can have on injury patterns.

Age-related injury patterns

In general, injury rates are not the same across age groups; however, the age-related pattern is not unified based on the available research. Several studies indicate that rates increase with age (24, 25, 28, 31, 34, 35, 41, 54), although others report less clear patterns or bell-shaped relationships peaking around the U15-16 groups (20, 23, 26, 27, 29, 30, 37, 39, 48, 53). Injury severity and burden also appears to be influenced by age, often peaking in the U14-16 age groups (21, 24, 35, 37, 53). While mainly examined in boys, increasing injury incidence and burden with age was also observed in a recent study of girls (60), although contrasted by another showing a lower incidence in U19 players compared to U15 (58). An increased risk with age could potentially be explained by players being stronger, faster and heavier as they grow, mature and accumulate training experience. Furthermore, training sessions and matches may be more intense and carry more significance as competition intensifies. Having sustained a previous injury is also more likely with age, which is a strong risk factor for new injuries (70). Changes associated with the growth spurt (e.g., more fragile growth plates, differences in tissue adaptation, decreased bone-mineral density) (71–74) are often used to explain the higher rate of severe injuries and higher burden observed around the years of expected PHV and PWV. Finally, injury trends differ depending on injury type, with more growth-related injuries observed in younger players and more muscle injuries and joint/ligament sprains in older players (21, 24, 28, 29, 35, 39, 56) – likely influenced by players' absolute maturity status.

Absolute maturity and injury risk

Some tissues may be more prone to injuries prior to reaching their mature state, such as an underdeveloped brain that appears more prone to concussions, thicker and more fragile cartilage, and a growing skeleton (4). Especially the latter has received attention in youth sports, as skeletal conditions (e.g., Osgood-Schlatter disease) are common and can cause problems for years (75). Some injuries (e.g., fractures through, or extreme load on, the growth plate) have the potential to disrupt normal growth patterns if not managed adequately (76).

Absolute maturity (i.e., how close a player is to the mature state) is an interesting concept in terms of injuries. Several studies have demonstrated a pattern where injuries that involve growth areas are less common in players closer to skeletal maturity or adult height (77–79), for whom muscle, joint and ligament injuries are more prominent (78, 79). This likely reflects which tissues and structures represent the "weak link" in the muscle-tendon-skeletal chain; the skeletal attachment site (apophysis) is relatively weaker in immature players, while muscles, ligaments and tendons yield sooner in players with a mature skeleton (80). As consequence, the same mechanisms may lead to different pathologies depending on maturity. For example, a gradual overload may cause apophysitis in an immature athlete but tendinopathy in a mature athlete, and a sudden force may lead to an avulsion in the immature player but a muscle strain in the mature player (80). This theory also aligns with observations that growth-related injuries appear in a bottom-to-top pattern depending on maturity status and age (79, 81), matching the typical distal-to-proximal skeletal maturation process (1, 82).

Relative maturity and injury risk

Relative maturity (i.e., players maturing earlier or later than others; early, average or late maturer) is perhaps the most obvious concern when discussing maturation and injuries, as this comes back to the issue of early and late maturing players training and competing within the same age groups. Intuitively, the later maturing player would seem more injury prone; however, this is not clear in the literature. Early football studies measuring skeletal age found no differences in overall injury risk between relative maturity categories (i.e., early, on time, late) (47, 78), while two recent studies found that early maturing players actually had a greater risk of injury (77, 83). Studies using anthropometric equations also provide conflicting results, with a Dutch study reporting increased overuse injury risk in later maturing players (but only before and during the year around PHV) (84), an English study reporting no difference in non-contact injury risk between early, normal or late maturing players when PHV-period (pre-, circa-, post-PHV) was accounted for (85), and a Spanish study finding a greater burden of overall and growth-related injuries in late vs. normal maturing players (but not compared to early maturing) before PHV, and no differences between relative maturity categories during or after PHV (40).

Rapid growth and injury risk

Although it is difficult to differentiate effects of growth and maturity, higher growth rates (e.g., changes in height, leg length or body mass index) (19, 38, 86, 87) and the circa-PHV period (the months or years around the estimated or observed PHV) (37, 40, 63, 85) have been associated with increased injury risk in high-level youth football. Most studies use relatively broad injury outcomes (e.g., all injuries combined or all overuse injuries), but there is some evidence suggesting that effects of rapid growth are type-dependent, with injury rates for skeletal growth areas particularly elevated during PHV (40). This fits well with the proposed underlying mechanisms for a growth-injury relationship. First, growth plates tend to be thicker and more fragile when growth is at its fastest, making them more susceptible to injuries (71). Second, slower adaptation of tendons and apophyses to a lengthening skeleton compared to muscles may cause increased tension on weaker structures (72). Changes in limb length and mass also increase the force required to move them, which theoretically leads to greater strain on the apophyses (72). Third, delayed bone mineralisation has been observed during rapid growth, coinciding with increased fracture rates; this suggests a period of relative bone fragility (73, 74). Finally, changes in body proportions have been associated with temporarily decreased neuromuscular control ("adolescent awkwardness"), which again may be an injury risk factor (13, 88). While these theories are plausible explanations for players being particularly vulnerable during the adolescent growth spurt, they are rarely included in injury studies and the actual importance of each factor remains unclear.

Summary

It is clear that injuries are common in high-level male and female youth football players, with strains and sprains to the lower limb dominating among both genders. Injury patterns and the type of injuries recorded do, however, depend on the age group observed, players' absolute maturity status and where a player is in relation to the adolescent growth spurt. This warrants age- and maturity-specific prevention programmes, and one can neither assume that all youth players are the same, nor that interventions that work in senior players automatically transfer to age group football.

What are the research gaps?

While our understanding of youth injuries is constantly improving, some areas are still lacking. First, our knowledge originates from a relatively narrow sample. Nine out of ten publications at this playing level report injury data only for boys, and there is little to no data on growth or maturation as risk factors in high-level girls' football. Additionally, epidemiology studies are mainly conducted in European settings (85%). Consequently, there is a demographic and geographic imbalance in the literature, mainly considering data from European boys. Second, there is a need for studies with a larger number of injuries to better understand where injury reduction efforts should be focused. There is now sufficient data to confidently say something about injury proportions for separate body parts and injury types (especially in boys), and future studies should attempt to report these in combination, preferably using burden metrics and differentiating match and training injuries. Third, many studies do not record exposure at the individual level. This is essential for accurate estimates of injury incidence and burden, and a requirement to address risk factors such as growth and maturation.

How can this be used in practice?

Given the pattern of diverse injury locations and types, general prevention programmes (e.g., FIFA 11+ which has been shown to reduce injury risk in young footballers by a third) (89) targeting a large range of potential injuries can be considered appropriate. Keeping the main concepts intact, these can be tailored to suit your specific context (e.g., available time and resources) and increase the chances of successful implementation (90). Detecting and taking pain seriously at an early stage seems important to allow for appropriate management and may limit the time away from sports (91). This may also allow players to continue taking part in sessions, modifying their participation and activities rather than completely removing them from the team (92).

During the adolescent growth spurt and prior to skeletal maturity, it may be necessary to focus more on general movement skills and progressive physical development, being extra careful with increases in load (especially high-impact tasks, such as jumping, acceleration, deceleration) and allowing for sufficient rest and nutrition between sessions (93, 94). Overall load management (e.g., coordinating school, club and regional/national commitments) is particularly challenging, but important, at the youth level (95, 96). Finally, each player must be considered differently. With variations in growth and maturity timing and tempo, individuals will face challenges at different ages. Structured growth and maturity assessments are an option where resources allow it (93, 97); however, observing, talking to, and educating players and parents can perhaps be equally effective. Ultimately, we are all working toward a similar target: to provide players with opportunities to reach their own goals, hopefully enjoying the journey along the way!

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

1. Malina RM, Bouchard C, Bar-Or O. *Growth, Maturation, and Physical Activity. 2nd ed* Champagne, IL: Human Kinetics. (2004).

2. Larruskain J, Lekue JA, Martin-Garetxana I, Barrio I, McCall A, Gil SM. Injuries are negatively associated with player progression in an elite football academy. *Sci Med Football.* (2021) 1—10. doi: 10.1080/24733938.2021.1943756

3. Maffulli N, Longo UG, Gougoulias N, Loppini M, Denaro V. Long-term health outcomes of youth sports injuries. *Br J Sports Med.* (2010) 44:21–5. doi: 10.1136/bjsm.2009.069526

4. McKay D, Broderick C, Steinbeck K. The adolescent athlete: a developmental approach to injury risk. *Pediatr Exerc Sci.* (2016) 28:488–500. doi: 10.1123/pes.2016-0021

5. Meeuwisse WH. Assessing causation in sport injury: a multifactorial model. *Clin J Sport Med.* (1994) 4:166–70. doi: 10.1097/00042752-199407000-00004

6. Meeuwisse WH, Tyreman H, Hagel B, Emery C. A dynamic model of etiology in sport injury: the recursive nature of risk and causation. *Clin J Sport Med.* (2007) 17:215–9. doi: 10.1097/JSM.0b013e3180592a48

7. Bittencourt NFN, Meeuwisse WH, Mendonca LD, Nettel-Aguirre A, Ocarino JM, Fonseca ST. Complex systems approach for sports injuries: moving from risk factor identification to injury pattern recognition-narrative review and new concept. *Br J Sports Med.* (2016) 50:1309–14. doi: 10.1136/bjsports-2015-095850

8. Tanner JM, Whitehouse RH, Takaishi M. Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965. II. *Arch Dis Child.* (1966) 41:613–35. doi: 10.1136/adc.41.220.613

9. Largo RH, Gasser T, Prader A, Stuetzle W, Huber PJ. Analysis of the adolescent growth spurt using smoothing spline functions. *Ann Hum Biol.* (1978) 5:421–34. doi: 10.1080/03014467800003071

10. Preece MA, Baines MJ, A. new family of mathematical models describing the human growth curve. *Ann Hum Biol.* (1978) 5:1–24. doi: 10.1080/03014467800002601

11. Tanner JM, Whitehouse RH, Takaishi M. Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965. I. *Arch Dis Child.* (1966) 41:454–71. doi: 10.1136/adc.41.219.454

12. MacMaster C, Portas M, Parkin G, Cumming S, Wilcox C, Towlson C. The effect of bio-banding on the anthropometric, physical fitness and functional movement characteristics of academy soccer players. *PLoS ONE.* (2021) 16:e0260136. doi: 10.1371/journal.pone.0260136

13. Quatman-Yates CC, Quatman CE, Meszaros AJ, Paterno MV, Hewett TE. A systematic review of sensorimotor function during adolescence: a developmental stage of increased motor awkwardness? *Br J Sports Med.* (2012) 46:649–55. doi: 10.1136/bjsm.2010.079616

14. Swain M, Kamper SJ, Maher CG, Broderick C, McKay D, Henschke N. Relationship between growth, maturation and musculoskeletal conditions in adolescents: a systematic review. *Br J Sports Med.* (2018) 52:1246–52. doi: 10.1136/bjsports-2017-098418

15. Beunen GP, Rogol AD, Malina RM. Indicators of biological maturation and secular changes in biological maturation. *Food Nutr Bull.* (2006) 27(4 Suppl):S244–56. doi: 10.1177/15648265060274S508

16. Wolf RM, Long D. Pubertal development. *Pediatr Rev.* (2016) 37:292–300. doi: 10.1542/pir.2015-0065

17. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med.* (1992) 14:82–99. doi: 10.2165/00007256-199214020-00002

18. Frisch A, Urhausen A, Seil R, Croisier JL, Windal T, Theisen D. Association between preseason functional tests and injuries in youth football: a prospective follow-up. *Scand J Med Sci Sports.* (2011) 21:e468–476. doi: 10.1111/j.1600-0838.2011.01369.x

19. Kemper GL, van der Sluis A, Brink MS, Visscher C, Frencken WG, Elferink-Gemser MT. Anthropometric injury risk factors in elite-standard youth soccer. *Int J Sports Med.* (2015) 36:1112–7. doi: 10.1055/s-0035-1555778

20. Cezarino LG, Gruninger B, Scattone Silva R. Injury profile in a brazilian first-division youth soccer team: a prospective study. *J Athl Train.* (2020) 55:295–302. doi: 10.4085/1062-6050-449-18

21. Hall ECR, Larruskain J, Gil SM, Lekue JA, Baumert P, Rienzi E, et al. An injury audit in high-level male youth soccer players from English, Spanish, Uruguayan and Brazilian academies. *Phys Ther Sport.* (2020) 44:53–60. doi: 10.1016/j.ptsp.2020.04.033

22. Sugimoto D, Loiacono AJ, Blenis A, Morse JM, Borg DR, Meehan WP 3rd. Risk factors in elite, adolescent male soccer players: prospective study. *Clin Pediatr.* (2020) 59:596–605. doi: 10.1177/0009922820916895

23. Rinaldo N, Gualdi-Russo E, Zaccagni L. Influence of size and maturity on injury in young elite soccer players. *Int J Environ Res Public Health.* (2021) 18:3120. doi: 10.3390/ijerph18063120

24. Wik EH, Lolli L, Chamari K, Materne O, Di Salvo V, Gregson W, et al. Injury patterns differ with age in male youth football: a four-season prospective study of 1111 time-loss injuries in an elite national academy. *Br J Sports Med.* (2021) 55:794–800. doi: 10.1136/bjsports-2020-103430

25. Jaber A, Weishorn J, Berrsche G, Ott H, Bangert Y. Injury profile among elite youth male football players in a German Academy. *Int J Sports Med.* (2022) 43:138–44. doi: 10.1055/a-1516-4139

26. Peterson L, Junge A, Chomiak J, Graf-Baumann T, Dvorak J. Incidence of football injuries and complaints in different age groups and skill-level groups. *Am J Sports Med.* (2000) 28:S51–57. doi: 10.1177/28.suppl_5.s-51

27. Junge A, Chomiak J, Dvorak J. Incidence of football injuries in youth players. Comparison of players from two European regions. *Am J Sports Med.* (2000) 28:S47–50. doi: 10.1177/28.suppl_5.s-47

28. Price RJ, Hawkins RD, Hulse MA, Hodson A. The Football Association medical research programme: an audit of injuries in academy youth football. *Br J Sports Med.* (2004) 38:466–71. doi: 10.1136/bjsm.2003.005165

29. Le Gall F, Carling C, Reilly T, Vandewalle H, Church J, Rochcongar P. Incidence of injuries in elite French youth soccer players: a 10-season study. *Am J Sports Med.* (2006) 34:928–38. doi: 10.1177/0363546505283271

30. Deehan DJ, Bell K, McCaskie AW. Adolescent musculoskeletal injuries in a football academy. *J Bone Jt Surg Br.* (2007) 89:5–8. doi: 10.1302/0301-620X.89B1.18427

31. Tourny C, Sangnier S, Cotte T, Langlois R, Coquart J. Epidemiologic study of young soccer player's injuries in U12 to U20. *J Sports Med Phys Fitness.* (2014) 54:526–35.

32. Bianco A, Spedicato M, Petrucci M, Messina G, Thomas E, Nese Sahin F, et al. A prospective analysis of the injury incidence of young male professional football players on artificial turf. *Asian J Sports Med.* (2016) 7:e28425. doi: 10.5812/asjsm.28425

33. Nilsson T, Ostenberg AH, Alricsson M. Injury profile among elite male youth soccer players in a Swedish first league. *J Exerc Rehabil.* (2016) 12:83–9. doi: 10.12965/jer.1632548.274

34. Renshaw A, Goodwin PC. Injury incidence in a Premier League youth soccer academy using the consensus statement: a prospective cohort study. *BMJ Open Sport Exerc Med.* (2016) 2:e000132. doi: 10.1136/bmjsem-2016-000132

35. Read PJ, Oliver JL, De Ste Croix MBA, Myer GD, Lloyd RS. An audit of injuries in six english professional soccer academies. *J Sports Sci.* (2018) 36:1542–8. doi: 10.1080/02640414.2017.1402535

36. Tears C, Chesterton P, Wijnbergen M. The elite player performance plan: the impact of a new national youth development strategy on injury characteristics in a premier league football academy. *J Sports Sci.* (2018) 36:2181–8. doi: 10.1080/02640414.2018.1443746

37. Bult HJ, Barendrecht M, Tak IJR. Injury risk and injury burden are related to age group and peak height velocity among talented male youth soccer players. *Orthop J Sports Med.* (2018) 6:2325967118811042. doi: 10.1177/2325967118811042

38. Rommers N, Rossler R, Goossens L, Vaeyens R, Lenoir M, Witvrouw E, et al. Risk of acute and overuse injuries in youth elite soccer players: Body size and growth matter. *J Sci Med Sport.* (2020) 23:246–51. doi: 10.1016/j.jsams.2019.10.001

39. Materne O, Chamari K, Farooq A, Weir A, Holmich P, Bahr R, et al. Injury incidence and burden in a youth elite football academy: a four-season prospective study of 551 players aged from under 9 to under 19 years. *Br J Sports Med.* (2021) 55:493–500. doi: 10.1136/bjsports-2020-102859

40. Monasterio X, Gil SM, Bidaurrazaga-Letona I, Lekue JA, Santisteban JM, Diaz-Beitia G, et al. The burden of injuries according to maturity status and timing: a two-decade study with 110 growth curves in an elite football academy. *Eur J Sport Sci.* (2021). doi: 10.1080/17461391.2021.2006316. [Epub ahead of print].

41. Thiebat G, Spreafico A, Mazzoni S, Ravasio G, de Girolamo L, Schoenhuber H. Incidence of injuries in young soccer players: epidemiological study in an Italian elite club. *J Sports Med Phys Fitness.* (2021) 61:80–6. doi: 10.23736/S0022-4707.20.11157-5

42. Toselli S, Benedetti L, Di Miceli R, Aiello P, Nanni G. Injury risk and maturity status in Italian elite young football player. *MLTJ.* (2021) 11:592–9. doi: 10.32098/mltj.03.2021.25

43. Watson A, Brickson S, Brooks A, Dunn W. Subjective well-being and training load predict in-season injury and illness risk in female youth soccer players. *Br J Sports Med.* (2017) 51:194–9. doi: 10.1136/bjsports-2016-096584

44. Richardson A, Clarsen B, Verhagen E, Stubbe JH. High prevalence of self-reported injuries and illnesses in talented female athletes. *BMJ Open Sport Exerc Med.* (2017) 3:e000199. doi: 10.1136/bmjsem-2016-000199

45. Wik EH, Materne O, Chamari K, Duque JDP, Horobeanu C, Salcinovic B, et al. Involving research-invested clinicians in data collection affects injury incidence in youth football. *Scand J Med Sci Sports.* (2019) 29:1031–9. doi: 10.1111/sms.13427

46. Merron R, Selfe J, Swire R, Rolf CG. Injuries among professional soccer players of different age groups : a prospective four-year study in an English Premier League Football Club: Research article. *Int Sport Med J.* (2006) 7:266–76.

47. Johnson A, Doherty PJ, Freemont A. Investigation of growth, development, and factors associated with injury in elite schoolboy footballers: prospective study. *BMJ.* (2009) 338:b490. doi: 10.1136/bmj.b490

48. Ergun M, Denerel HN, Binnet MS, Ertat KA. Injuries in elite youth football players: a prospective three-year study. *Acta Orthop Traumatol Turc.* (2013) 47:339–46. doi: 10.3944/AOTT.2013.3177

49. Bacon CS, Mauger AR. Prediction of overuse injuries in professional U18-U21 footballers using metrics of training distance and intensity. *J Strength Cond Res.* (2017) 31:3067–76. doi: 10.1519/JSC.0000000000001744

50. Bowen L, Gross AS, Gimpel M, Li FX. Accumulated workloads and the acute:chronic workload ratio relate to injury risk in elite youth football players. *Br J Sports Med.* (2017) 51:452–9. doi: 10.1136/bjsports-2015-095820

51. Delecroix B, Delaval B, Dawson B, Berthoin S, Dupont G. Workload and injury incidence in elite football academy players. *J Sports Sci.* (2019) 37:2768–73. doi: 10.1080/02640414.2019.1584954

52. Loose O, Fellner B, Lehmann J, Achenbach L, Krutsch V, Gerling S, et al. Injury incidence in semi-professional football claims for increased need of injury prevention in elite junior football. *Knee Surg Sports Traumatol Arthrosc.* (2019) 27:978–84. doi: 10.1007/s00167-018-5119-8

53. Raya-Gonzalez J, Suarez-Arrones L, Navandar A, Balsalobre-Fernandez C, Saez de. Villarreal E. Injury profile of elite male young soccer players in a spanish professional soccer club: a prospective study during 4 consecutive seasons. *J Sport Rehabil.* (2020) 29:801–7. doi: 10.1123/jsr.2019-0113

54. Sieland J, Krause F, Kalo K, Wilke J, Vogt L, Banzer W, et al. Injuries and functional performance status in young elite football players: a prospective 2-year monitoring. *J Sports Med Phys Fitness.* (2020) 60:1363–70. doi: 10.23736/S0022-4707.20.10886-7

55. Sprouse B, Alty J, Kemp S, Cowie C, Mehta R, Tang A, et al. The football association injury and illness surveillance study: the incidence, burden and severity of injuries and illness in men's and women's international football. *Sports Med.* (2020). doi: 10.1007/s40279-020-01411-8. [Epub ahead of print].

56. Light N, Johnson A, Williams S, Smith N, Hale B, Thorborg K. Injuries in youth football and the relationship to player maturation: an analysis of time-loss injuries during four seasons in an English elite male football academy. *Scand J Med Sci Sports.* (2021) 31:1324–34. doi: 10.1111/sms.13933

57. Hall ECR, Larruskain J, Gil SM, Lekue JA, Baumert P, Rienzi E, et al. Injury risk is greater in physically mature versus biologically younger male soccer players from academies in different countries. *Phys Ther Sport.* (2022) 55:111–8. doi: 10.1016/j.ptsp.2022.03.006

58. Le Gall F, Carling C, Reilly T. Injuries in young elite female soccer players: an 8-season prospective study. *Am J Sports Med.* (2008) 36:276–84. doi: 10.1177/0363546507307866

59. Clausen MB, Zebis MK, Moller M, Krustrup P, Holmich P, Wedderkopp N, et al. High injury incidence in adolescent female soccer. *Am J Sports Med.* (2014) 42:2487–94. doi: 10.1177/0363546514541224

60. Beech J, Jones B, King R, Bennett P, Young S, Williams S, et al. The incidence and burden of injuries in elite English youth female soccer players. *Sci Med Footb.* (2022). doi: 10.1080/24733938.2022.2051730. [Epub ahead of print].

61. Hawkins RD, Fuller CW. A prospective epidemiological study of injuries in four English professional football clubs. *Br J Sports Med.* (1999) 33:196–203. doi: 10.1136/bjsm.33.3.196

62. Brink MS, Visscher C, Arends S, Zwerver J, Post WJ, Lemmink KA. Monitoring stress and recovery: new insights for the prevention of injuries and illnesses in elite youth soccer players. *Br J Sports Med.* (2010) 44:809–15. doi: 10.1136/bjsm.2009.069476

63. van der Sluis A, Elferink-Gemser MT, Coelho-e-Silva MJ, Nijboer JA, Brink MS, Visscher C. Sport injuries aligned to peak height velocity in talented pubertal soccer players. *Int J Sports Med.* (2014) 35:351–5. doi: 10.1055/s-0033-1349874

64. Bahr R, Clarsen B, Derman W, Dvorak J, Emery CA, Finch CF, et al. International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020 (including STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS)). *Br J Sports Med.* (2020) 54:372–89. doi: 10.1136/bjsports-2019-101969

65. Varley MC, Gregson W, McMillan K, Bonanno D, Stafford K, Modonutti M, et al. Physical and technical performance of elite youth soccer players during international tournaments: influence of playing position and team success and opponent quality. *Sci Med Football.* (2016) 1:18–29. doi: 10.1080/02640414.2016.1230676

66. Parr J, Winwood K, Hodson-Tole E, Deconinck FJA, Hill JP, Cumming SP. Maturity-associated differences in match running performance in elite male youth soccer players. *Int J Sports Physiol Perform.* (2021) 17:1352–60. doi: 10.1123/ijspp.2020-0950

67. Ekstrand J, Hagglund M, Walden M. Injury incidence and injury patterns in professional football: the UEFA injury study. *Br J Sports Med.* (2011) 45:553–8. doi: 10.1136/bjsm.2009.060582

68. Mayhew L, Johnson MI, Francis P, Lutter C, Alali A, Jones G. Incidence of injury in adult elite women's football: a systematic review and meta-analysis. *BMJ Open Sport Exerc Med.* (2021) 7:e001094. doi: 10.1136/bmjsem-2021-001094

69. Bahr R, Clarsen B, Ekstrand J. Why we should focus on the burden of injuries and illnesses, not just their incidence. *Br J Sports Med.* (2018) 52:1018–21. doi: 10.1136/bjsports-2017-098160

70. Kucera KL, Marshall SW, Kirkendall DT, Marchak PM, Garrett WE Jr. Injury history as a risk factor for incident injury in youth soccer. *Br J Sports Med.* (2005) 39:462. doi: 10.1136/bjsm.2004.013672

71. Caine D, DiFiori J, Maffulli N. Physeal injuries in children's and youth sports: reasons for concern? *Br J Sports Med.* (2006) 40:749–60. doi: 10.1136/bjsm.2005.017822

72. Hawkins D, Metheny J. Overuse injuries in youth sports: biomechanical considerations. *Med Sci Sports Exerc.* (2001) 33:1701–7. doi: 10.1097/00005768-200110000-00014

73. Faulkner RA, Davison KS, Bailey DA, Mirwald RL, Baxter-Jones AD. Size-corrected BMD decreases during peak linear growth: implications for fracture incidence during adolescence. *J Bone Miner Res.* (2006) 21:1864–70. doi: 10.1359/jbmr.060907

74. Blimkie CJ, Lefevre J, Beunen GP, Renson R, Dequeker J, Van Damme P. Fractures, physical activity, and growth velocity in adolescent Belgian boys. *Med Sci Sports Exerc.* (1993) 25:801–8. doi: 10.1249/00005768-199307000-00008

75. Holden S, Olesen JL, Winiarski LM, Krommes K, Thorborg K, Holmich P, et al. Is the Prognosis of Osgood-Schlatter Poorer Than Anticipated? A prospective cohort study with 24-month follow-up. *Orthop J Sports Med.* (2021) 9:23259671211022239. doi: 10.1177/23259671211022239

76. Caine D, Meyers R, Nguyen J, Schoffl V, Maffulli N. Primary periphyseal stress injuries in young athletes: a systematic review. *Sports Med.* (2022) 52:741–72. doi: 10.1007/s40279-021-01511-z

77. Materne O, Chamari K, Farooq A, Weir A, Holmich P, Bahr R, et al. Association of skeletal maturity and injury risk in elite youth soccer players: a 4-season prospective study with survival analysis. *Orthop J Sports Med.* (2021) 9:2325967121999113. doi: 10.1177/2325967121999113

78. Le Gall F, Carling C, Reilly T. Biological maturity and injury in elite youth football. *Scand J Med Sci Sports.* (2007) 17:564–72. doi: 10.1111/j.1600-0838.2006.00594.x

79. Monasterio X, Gil SM, Bidaurrazaga-Letona I, Lekue JA, Santisteban J, Diaz-Beitia G, et al. Injuries according to the percentage of adult height in an elite soccer academy. *J Sci Med Sport.* (2021) 24:218–23. doi: 10.1016/j.jsams.2020.08.004

80. Brukner P, Khan KM. *Brukner & Khan's Clinical Sports Medicine*. 4th ed. New York, NY: McGraw-Hill Medical. (2012).

81. Materne O, Chamari K, Farooq A, Tabben M, Weir A, Holmich P, et al. Shedding light on incidence and burden of physeal injuries in a youth elite football academy: a 4-season prospective study. *Scand J Med Sci Sports.* (2022) 32:165–76. doi: 10.1111/sms.14059

82. Kvist O, Luiza Dallora A, Nilsson O, Anderberg P, Sanmartin Berglund J, Flodmark CE, et al. A cross-sectional magnetic resonance imaging study of factors influencing growth plate closure in adolescents and young adults. *Acta Paediatr.* (2021) 110:1249–1256. doi: 10.1111/apa.15617

83. Monasterio X, Bidaurrazaga-Letona I, Larruskain J, Lekue JA, Diaz-Beitia G, Santisteban JM, et al. Relative skeletal maturity status affects injury burden in U14 elite academy football players. *Scand J Med Sci Sports.* (2022) 32:1400–9. doi: 10.1111/sms.14204

84. van der Sluis A, Elferink-Gemser MT, Brink MS, Visscher C. Importance of peak height velocity timing in terms of injuries in talented soccer players. *Int J Sports Med.* (2015) 36:327–32. doi: 10.1055/s-0034-1385879

85. Johnson DM, Williams S, Bradley B, Sayer S, Murray Fisher J, Cumming S. Growing pains: Maturity associated variation in injury risk in academy football. *Eur J Sport Sci.* (2020) 20:544–52. doi: 10.1080/17461391.2019.1633416

86. Rommers N, Rossler R, Shrier I, Lenoir M, Witvrouw E, D'Hondt E, et al. Motor performance is not related to injury risk in growing elite-level male youth football players. A causal inference approach to injury risk assessment. *J Sci Med Sport.* (2021) 24:881–5. doi: 10.1016/j.jsams.2021.03.004

87. Johnson DM, Cumming SP, Bradley B, Williams S. The influence of exposure, growth and maturation on injury risk in male academy football players. *J Sports Sci.* (2022) 40:1127–36. doi: 10.1080/02640414.2022.2051380

88. Read PJ, Oliver JL, De Ste Croix MB, Myer GD, Lloyd RS. Neuromuscular risk factors for knee and ankle ligament injuries in male youth soccer players. *Sports Med.* (2016) 46:1059–66. doi: 10.1007/s40279-016-0479-z

89. Soligard T, Myklebust G, Steffen K, Holme I, Silvers H, Bizzini M, et al. Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. *BMJ.* (2008) 337:a2469. doi: 10.1136/bmj.a2469

90. O'Brien J, Santner E, Kroll J. Moving beyond one-size-fits-all approaches to injury prevention: evaluating how tailored injury prevention programs are developed and implemented in academy soccer. *J Orthop Sports Phys Ther.* (2021) 51:432–9. doi: 10.2519/jospt.2021.10513

91. DiFiori JP, Benjamin HJ, Brenner JS, Gregory A, Jayanthi N, Landry GL, et al. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. *Br J Sports Med.* (2014) 48:287–8. doi: 10.1136/bjsports-2013-093299

92. Rathleff MS, Winiarski L, Krommes K, Graven-Nielsen T, Holmich P, Olesen JL, et al. Activity modification and knee strengthening for osgood-schlatter disease: a prospective cohort study. *Orthop J Sports Med.* (2020) 8:2325967120911106. doi: 10.1177/2325967120911106

93. Towlson C, Salter J, Ade JD, Enright K, Harper LD, Page RM, et al. Maturity-associated considerations for training load, injury risk, and physical performance in youth soccer: One size does not fit all. *J Sport Health Sci.* (2021) 10:403–12. doi: 10.1016/j.jshs.2020.09.003

94. Bergeron MF, Mountjoy M, Armstrong N, Chia M, Cote J, Emery CA, et al. International Olympic Committee consensus statement on youth athletic development. *Br J Sports Med.* (2015) 49:843–51. doi: 10.1136/bjsports-2015-094962

95. Bjørndal CT, Gjesdal S. The role of sport school programmes in athlete development in Norwegian handball and football. *Eur J Sport Soc.* (2020) 17:374–96. doi: 10.1080/16138171.2020.1792131

96. Johnson DM, Cumming SP, Bradley B, Williams S. How much training do English male academy players really do? Load inside and outside of a football academy. *Int J Sports Sci Coach.* (2022). doi: 10.1177/17479541221101847

97. Lloyd RS, Oliver JL, Faigenbaum AD, Myer GD, De Ste Croix MB. Chronological age vs. biological maturation: implications for exercise programming in youth. *J Strength Cond Res.* (2014) 28:1454–64. doi: 10.1519/JSC.0000000000000391

frontiers | Frontiers in Sports and Active Living

TYPE Opinion
PUBLISHED 02 June 2023
DOI 10.3389/fspor.2023.1190453

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OPEN ACCESS

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RECEIVED 20 March 2023
ACCEPTED 22 May 2023
PUBLISHED 02 June 2023

CITATION
Soares ALA and Carvalho HM (2023) Burnout and dropout associated with talent development in youth sports.
Front. Sports Act. Living 5:1190453.
doi: 10.3389/fspor.2023.1190453

Burnout and dropout associated with talent development in youth sports

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KEYWORDS

youth sports, specialization, injuries, evidence-based & research methodology, selection

Introduction

Dropout and burnout are key issues in youth sports (1–5). However, evidence-based data on this topic is still scarce in literature, and it is important to be aware of its limitations before assuming any unique and conclusive interpretations about the development of young athletes through sports expertise.

Talent development programs in youth sports have been designed, structured, and financed by clubs and governmental bodies to promote conditions for young athletes to achieve high levels of performance, often as early as possible (6, 7). It is generally assumed that early engagement and accumulation of deliberate practice supervised by specialized coaches will improve the development of skills and competencies beyond the effects of normal growth and development needed to perform in high-level competitions (8–10). These programs are mostly based on systematic long-term specific training (e.g., deliberate practice) for athletes to perform in high-level competitions during adulthood (9, 11, 12). Inherent to this model, the attempt to predict potential talented athletes may occur at earlier ages, making the specialization in a single sport a consequent strategy in the practical field. It is assumed that the sooner individuals engage in focused practice, the larger will be the advantage in comparison with others (9, 13–15).

The main counterview to this approach is the Developmental Model of Sports Participation, which advocates participation in a range of sports with the purpose of fun and enjoyment, instead of focusing on dedication and skill acquisition in one sport (16). The model assumes that early specialization may be the reason for many negative issues related to the sports environment, such as an increasing risk of injuries, lack of enjoyment, negative psychosocial effects, and the occurrence of burnout or dropout (3, 16–18), even though the definition of specialization is often unclear (19–21).

The main purpose of this paper is to raise awareness of the limits of the available data and interpretations of dropout and burnout in youth sports, particularly considering the contexts of talent development.

Participation and dropout in talent development

Commitment and engagement in highly demanding tasks, such as deliberate practice, require athletes to be highly motivated, and such accomplishment may determine athletes' achievement in higher or lower levels of youth sports participation, or even lead to dropping out (8). The conceptualization of dropout is not standardized in the scientific literature, particularly considering the varying youth sports contexts studied, which limits comparisons of results and interpretations and guideline proposals. It seems reasonable to assume that dropout refers to youths who leave formal sports program participation. Patterns of progression in youth sports may vary according to the level of competition, participants' age, commitment, achievement, and other external factors within sports participation. Due to the complexity and multifactorial influences in the selection process, young athletes may also have different opportunities and access to engage in specialized programs and better facilities throughout their career development as potential assets (22). For example, data in youth football highlights that talent identification and development is often biased by maturation-related differences in young athletes, which often results in an overrepresentation of early maturers in youth football (7, 23–25).

Several studies have suggested that early specialization is leading practitioners to exclude young athletes, leading to youth sports dropout and further evasion of practice (17, 26–28). Furthermore, the available data considering sports participation trends and dropout in youth sports considers varying levels of sport participation but is scarce when it comes to talent development contexts.

Recent reviews focused on the reasons for dropout in different contexts of youth sports suggested that influential factors leading to dropout were mostly related to psychological issues originating from athletes' personal lives and social relationships, but no evidence indicated that early specialization was a predictor for burnout and dropout (29, 30). It has been noted that the perceived reasons for practitioners dropping out of sports participation were (a) having less support from their coaches, (b) more pressure to succeed in sports than others, and (c) fewer friends in the sport—mostly related to perception of competence and motivation. Athletes' perception of competence may also be influenced by technical skills competence (24), related to their own perceptions as a consequence of the selection process along their career (29, 30). Another key aspect is the athletes' accumulated experience, which brings to a higher perception of the context and influences the level of commitment young athletes have within sport practice (29, 30). All these factors may likely be directly related to other fields than sports in athletes' lives, such as academic and professional perspectives and expectancies (31).

In order to avoid dropout in youth sports, it has been suggested that sports organizations should better understand the causes for athletes' evasion within their contexts to promote adequate strategies, policies, and practical interventions (29). Youth sports programs could promote different levels of participation in both competitive and recreational levels, and practices should stimulate athletes to be focused on learning new skills and developing their abilities while creating good and respectful relationships (29). The available data and synthesis of data highlight that the context and environment athletes are engaged in influence their perceptions and psychological aspects–competitive levels; club or extracurricular programs; competitive or recreational purposes (3, 32–34).

Empirical evidence of selection processes in youth sports is still scarce and lacks more in-depth knowledge about determinants for athletes' progression (or not) along their career. However, recent studies have found that more accumulated experience presented an advantage in youth athletes' progression in their career (25, 32), and the performance in youth ages could influence professional level achievement (35). Satisfying psychological issues might promote a longer period athletes keep engaged in sports practice once the evasion seems to be caused by them. Thus, the assumption that early specialization leads to evasion may be unreliable according to the above-mentioned findings.

Increased injury risk

Pathways to professionalization demand high amounts of training volume and increased loads. The selection process may be determinant for players' achievement of higher levels of competition, and the main stakeholders make decisions based on subjective perspectives of observation of in-game performance (35, 36). Indeed, the risk of injuries may be a key issue and determine young players' career continuity or not into professionalization. Due to the selection process of young players and the continuity of athletes' careers, the risk of injuries is a critical issue. The consequences of injury occurrence may be determinant for athletes' progression, dropout, or achievement of the competitive level. Consequently, a perceived increase in sport-related injuries has become another issue of research frequently assumed to be related to specialization (4, 14, 26, 37).

In general, current consensus statements assume that early specialization and intensive training in youth sports are related to high rates of injury (26, 28). However, interpretations are based on data with varying levels of youth sports exposure and participation, limiting the interpretations. Only recently, prospective data considering a heterogeneous sample of young athletes engaged in talent development contexts noted the contrasting high impacts on injuries and illnesses (38). The same research group noted that early specialization did not increase the risk of injury among young athletes in talent development programs (39). The data contrasts with general observations arguing that the occurrence of injury in specialized athletes, when compared to peers with contrasting youth sports levels (28). It seems reasonable to note that sports programs should adequately adjust the training exposure to athletes' capacities and readiness into training volume and loads (38–40). In order to collaborate with practical intervention and sports programs, the challenge until now is to know the trends of youth development and the impact from multiple dimensions within athletes' careers.

Lack of enjoyment

Early specialization in a single sport has been hypothesized to lead athletes to a lack of enjoyment in sports practice due to the high monotony of routines and the high amount of time spent in specific training (3, 4, 41). Again, the available data considering the links between psychological characteristics and dropout is based on varying contexts of youth sports but is scarce when considering talent development settings.

Nevertheless, some recent findings have shown no substantial effects from the age of specialization on motivation and sources of enjoyment (20). Furthermore, our data (32) suggested that differences could be found according to the competitive level among female basketball players (32). Observations from our research, based on repeated measurements in female young basketball and volleyball players, showed a trend of association of enjoyment with chronological and biological age (distance to menarche), but no relation to accumulated exposure to sport-specific deliberate practice (21). Apparently, enjoyment is potentially linked to the environment athletes are engaged in and biological determinants more than the accumulated time of sport participation. In a sample of young swimmers aged 12–13 years, there were no associations between burnout and dropout with early specialization (4). Thus, different influences, such as coach-athlete relationship, social and parental support, relationships with peers, and alignment of achievement expectancies with personal, professional, and social lives dimensions merit analysis from a more comprehensive perspective (e.g., bioecological approach) to provide deeper insights into the links of dropout and enjoyment in talent development contexts.

Current issues, challenges and future research lines in drop-out research in youth sports and talent development settings

Due to the multiple factors that influence athletes' dropout from sports, research has not considered appropriate analytical approaches to considering not only intra- and inter-individual characteristics but also different structural factors, such as environmental, social, and political contexts in which sports programs are conducted (42). Other empirical and practical variables may be considered, including socio-demographical factors, diverse youth sport participation, age group ranges, and competitive levels athletes have experienced. To accomplish this task, hierarchical/multilevel frameworks should be considered as a default, as noted in other research areas (43, 44).

Research considering dropout in youth sports has been conducted through two different strategies: quantitative, by applying questionnaires related to possible factors associated with dropout on continued participation, and qualitative, through semi-structured interviews conducted to assess the factors and processes involved in dropping out of sports. Both strategies have been applied retrospectively. There is a need for prospective longitudinal designed investigations to describe a follow-up of youth athletes' career progression (25, 29, 30, 32).

Another issue lies in the limitations when comparing different results in dropout studies. The conceptualization of dropout remains unstandardized; therefore, there may be different interpretations of the phenomenon. In general, studies considering dropout in youth sports have the following overlaps when considering dropout: (a) re-registration (or not) for a successive season in the sport context, (b) absent participation for two consecutive years (seasons), and (c) an extended period without practicing the sport. In this sense, it would be key that studies at least state the concept of dropout (4, 29, 30).

Given the highly selective population of youth athletes who aim to achieve professional levels and the boundaries to investigate them longitudinally, many studies have considered small populations and generalized their interpretations (a concern for replication in sports and exercise science (45)). Data collection may occur by convenience in specific clubs or programs, considering small samples of athletes who may or may not achieve higher levels of competition. Limitations and uniqueness of data setting in talent development settings should be assumed and discussed more often. Even considering retrospective findings about high-level athletes' background convergences, there are limits to drawing causal interpretations for expertise attainment.

Prospective design studies, considering the data, context limitations, and multiple sources of information, with clear conceptual and theoretical frameworks, and combined with available advanced modeling approaches, may provide a path to advance the understanding of young athletes within talent development settings and its impacts on young athletes' development.

Conclusion

Most models and recommendations for youth athlete development have been designed to promote a better approach and guide coaches' interventions throughout athletes' career progress. Current consensus statements in youth sports highlight the potential links of sport specialization, particularly early specialization, with dropout and burnout in youth sports, and this is generalized to talent development contexts. However, it is clear that the body of evidence needs to overcome current limits in conceptual, methodological, and analytical approaches to provide better quality information to guide sports programs and coaches' interventions in youth populations.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Funding

ALAS was supported by a grant from the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES (finance code 001).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

1. Petlichkoff LM. Youth sport participation, withdrawal: is it simply a matter of FUN? *Pediatr Exerc Sci.* (1992) 4:105–10. doi: 10.1123/pes.4.2.105

2. Weiss MR, Petlichkoff LM. Children's motivation for participation in, withdrawal from sport: identifying the missing links. *Pediatr Exerc Sci.* (1989) 1:195–211. doi: 10.1123/pes.1.3.195

3. Fraser-Thomas J, Côté J, Deakin J. Understanding dropout and prolonged engagement in adolescent competitive sport. *Psychol Sport Exerc.* (2008) 9:645–62. doi: 10.1016/j.psychsport.2007.08.003

4. Larson HK, Young BW, McHugh TLF, Rodgers WM. Markers of early specialization and their relationships with burnout and dropout in swimming. *J Sport Exerc Psychol.* (2019) 41:46–54. doi: 10.1123/jsep.2018-0305

5. Sorkkila M, Tolvanen A, Aunola K, Ryba TV. The role of resilience in student-athletes' sport and school burnout and dropout: a longitudinal person-oriented study. *Scand J Med Sci Sports.* (2019) 29:1059–67. doi: 10.1111/sms.13422

6. Gonçalves CE, Rama LM, Figueiredo AB. Talent identification and specialization in sport: an overview of some unanswered questions. *Int J Sports Physiol Perform.* (2012) 7:390–3. doi: 10.1123/ijspp.7.4.390

7. Ostojic SM, Castagna C, Calleja-González J, Jukic I, Idrizovic K, Stojanovic M. The biological age of 14-year-old boys and success in adult soccer: Do early maturers predominate in the top-level game? *Res Sports Med.* (2014) 22:398–407. doi: 10.1080/15438627.2014.944303

8. Gonçalves CE, Silva MJCe, Carvalho HM, Gonçalves Â. Why do they engage in such hard programs? The search for excellence in youth basketball. *J Sports Sci Med.* (2011) 10:458–64.

9. Ericsson KA, Krampe RT, Tesch-Römer C. The role of deliberate practice in the acquisition of expert performance. *Psychol Rev.* (1993) 100:363–406. doi: 10.1037/0033-295X.100.3.363

10. Baker J, Young B. 20 years later: deliberate practice, the development of expertise in sport. *Int Rev Sport Exerc Psychol.* (2014) 7:135–57. doi: 10.1080/1750984X.2014.896024

11. Güllich A. Selection, de-selection and progression in German football talent promotion. *Eur J Sport Sci.* (2014) 14:530–7. doi: 10.1080/17461391.2013.858371

12. Peek K, Gatherer D, Bennett KJM, Fransen J, Watsford M. Muscle strength characteristics of the hamstrings and quadriceps in players from a high-level youth football (soccer) academy. *Res Sports Med.* (2018) 26:276–88. doi: 10.1080/15438627.2018.1447475

13. Baker J, Schorer J, Wattie N. Compromising talent: issues in identifying and selecting talent in sport. *Quest.* (2018) 70:48–63. doi: 10.1080/00336297.2017.1333438

14. Baker J, Cobley S, Fraser-Thomas J. What do we know about early sport specialization? Not much! *High Abil Stud.* (2009) 20:77–89. doi: 10.1080/13598130902860507

15. Barreiros A, Côté J, Fonseca AM. From early to adult sport success: analysing athletes' progression in national squads. *Eur J Sport Sci.* (2014) 14:S178–82. doi: 10.1080/17461391.2012.671368

16. Côté J, Vierimaa M. The developmental model of sport participation: 15 years after its first conceptualization. *Sci Sports.* (2014) 29:S63–9. doi: 10.1016/j.scispo.2014.08.133

17. Baker J. Early specialization in youth sport: a requirement for adult expertise? *High Abil Stud.* (2003) 14:85–94. doi: 10.1080/13598130304091

18. DiFiori JP, Benjamin HJ, Brenner JS, Gregory A, Jayanthi N, Landry GL, et al. Overuse injuries and burnout in youth sports: a position statement from the American medical society for sports medicine. *Br J Sports Med.* (2014) 48:287–8. doi: 10.1136/bjsports-2013-093299

19. Mosher A, Fraser-Thomas J, Baker J. What defines early specialization: a systematic review of literature. *Front Sports Active Living.* (2020) 2. doi: 10.3389/fspor.2020.596229

20. Lima AB, Nascimento JV, Leonardi TJ, Soares AL, Paes RR, Gonçalves CE, et al. Deliberate practice, functional performance and psychological characteristics in young basketball players: a Bayesian multilevel analysis. *Int J Environ Res Public Health.* (2020) 17:4078. doi: 10.3390/ijerph17114078

21. Soares ALA, Lima AB, Possamai K, Quinaud RT, Gonçalves CE, Carvalho HM. An ecological approach to sources of enjoyment in young female athletes. *PsyArXiv.* Available at: https://doi.org/10.31234/osf.io/3b5z4.

22. Kalén A, Lundkvist E, Ivarsson A, Rey E, Pérez-Ferreirós A. The influence of initial selection age, relative age effect and country long-term performance on the re-selection process in European basketball youth national teams. *J Sports Sci.* (2021) 39:388–94. doi: 10.1080/02640414.2020.1823109

23. Bidaurrazaga-Letona I, Carvalho HM, Lekue JA, Santos-Concejero J, Figueiredo AJ, Gil SM. Longitudinal field test assessment in a basque soccer youth academy: a multilevel modeling framework to partition effects of maturation. *Int J Sports Med.* (2015) 36:234–40. doi: 10.1055/s-0034-1385881

24. Bidaurrazaga-Letona I, Lekue JA, Amado M, Gil SM. Progression in youth soccer: selection and identification in youth soccer players aged 13–15 years. *J Strength Cond Res.* (2019) 33:2548–58. doi: 10.1519/JSC.0000000000001924

25. Figueiredo AJ, Gonçalves CE, Coelho ESMJ, Malina RM. Characteristics of youth soccer players who drop out, persist or move up. *J Sports Sci.* (2009) 27:883–91. doi: 10.1080/02640410902946469

26. Bergeron MF, Mountjoy M, Armstrong N, Chia M, Côté J, Emery CA, et al. International olympic committee consensus statement on youth athletic development. *Br J Sports Med.* (2015) 49:843–51. doi: 10.1136/bjsports-2015-094962

27. LaPrade RF, Agel J, Baker J, Brenner JS, Cordasco FA, Côté J, et al. AOSSM early sport specialization consensus statement. *Orthop J Sports Med.* (2016) 4:2325967116644241. doi: 10.1177/2325967116644241

28. Jayanthi NA, LaBella CR, Fischer D, Pasulka J, Dugas LR. Sports-specialized intensive training and the risk of injury in young athletes. *Am J Sports Med.* (2015) 43:794–801. doi: 10.1177/0363546514567298

29. Moulds K, Galloway S, Abbott S, Cobley SP. Youth sport dropout according to the process-person-context-time model: a systematic review. *Int Rev Sport Exerc Psychol.* (2022):1–42. doi: 10.1080/1750984X.2021.2012817

30. Back J, Stenling A, Solstad BE, Svedberg P, Johnson U, Ntoumanis N, et al. Psychosocial predictors of drop-out from organised sport: a prospective study in adolescent soccer. *Int J Environ Res Public Health.* (2022) 19(24):16585. doi: 10.3390/ijerph192416585

31. Quinaud RT, Capranica L, Doupona M, Guidotti F. The holistic development of talented sportspersons through dual-career. *Front Sports Active Living.* (2022) 4. doi: 10.3389/fspor.2022.929981

32. Soares ALA, Leonardi TJ, Silva J, Nascimento JV, Paes RR, Gonçalves CE, et al. Performance, motivation, enjoyment in young female basketball players: an interdisciplinary approach. *J Sports Sci.* (2020) 38:873–85. doi: 10.1080/02640414.2020.1736247

33. Eime RM, Young JA, Harvey JT, Charity MJ, Payne WR. A systematic review of the psychological and social benefits of participation in sport for children and adolescents: informing development of a conceptual model of health through sport. *Int J Behav Nutr Phys Act.* (2013) 10:98. doi: 10.1186/1479-5868-10-98

34. Reverdito RS, Carvalho HM, Galatti LR, Scaglia AJ, Gonçalves CE, Paes RR. Effects of youth participation in extra-curricular sport programs on perceived self-efficacy: a multilevel analysis. *Percept Mot Skills.* (2017) 124:569–83. doi: 10.1177/0031512517697069

35. Carvalho HM, Morais CZ, Lima AB, Galvão LG, Grosgeorge B, Gonçalves CE. Participation in the under-18 Euroleague Next Generation Tournament does not predict attaining NBA, Euroleague, or Eurocup. *Int J Sports Sci Coaching.* (2023) 18:523–31. doi: 10.1177/17479541221116881

36. Rogers M, Crozier AJ, Schranz NK, Eston RG, Tomkinson GR. Player profiling and monitoring in basketball: a Delphi study of the most important non-game performance indicators from the perspective of elite athlete coaches. *Sports Med.* (2022) 52:1175–87. doi: 10.1007/s40279-021-01584-w

37. Kaleth AS, Mikesky AE. Impact of early sport specialization. *J Phys Educ Recreation Dance.* (2010) 81:29–37. doi: 10.1080/07303084.2010.10598524

38. Moseid CH, Myklebust G, Fagerland MW, Clarsen B, Bahr R. The prevalence and severity of health problems in youth elite sports: a 6-month prospective cohort study of 320 athletes. *Scand J Med Sci Sports.* (2018) 28:1412–23. doi: 10.1111/sms.13047

39. Moseid CH, Myklebust G, Fagerland MW, Bahr R. The association between early specialization and performance level with injury and illness risk in youth elite athletes. *Scand J Med Sci Sports.* (2019) 29:460–8.doi: 10.1111/sms.13338

40. Moseid CH, Myklebust G, Slaastuen MK, Bar-Yaacov JB, Kristiansen AH, Fagerland MW, et al. The association between physical fitness level and number

and severity of injury and illness in youth elite athletes. *Scand J Med Sci Sports*. (2019) 29:1736–48. doi: 10.1111/sms.13498

41. Boyd MP, Yin Z. Cognitive-affective sources of sport enjoyment in adolescent sport participants. *Adolescence*. (1996) 31:383–95. Available at: http://www.ncbi.nlm.nih.gov/pubmed/8726897

42. Ahmetov II, Fedotovskaya ON. Current progress in sports genomics. In: Makowski GS, editor. *Advances in clinical chemistry*. Elsevier (2015). p. 247–314. doi: 10.1016/bs.acc.2015.03.003

43. McElreath R, *Statistical rethinking: a Bayesian course with examples in R, stan*. Boca Raton, FL: Chapman & Hall/CRC Press (2015).

44. McElreath R. Multilevel regression as default. *Elements of Evolutionary Anthropology* [blog, https://elevanth.org/blog].

45. Mesquida C, Murphy J, Lakens D, Warne J. Replication concerns in sports and exercise science: a narrative review of selected methodological issues in the field. *R Soc Open Sci*. (2022) 9:220946. doi: 10.1098/rsos.220946

frontiers | Frontiers in Sports and Active Living

TYPE Review
PUBLISHED 02 February 2023
DOI 10.3389/fspor.2022.1124234

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Elite Sports and Performance Enhancement, a section of the journal Frontiers in Sports and Active Living

RECEIVED 14 December 2022
ACCEPTED 30 December 2022
PUBLISHED 02 February 2023

CITATION
Weissensteiner JR (2023) The global evolution of talent promotion within Olympic sports: A focus on the national systems and contribution of the former German Democratic Republic, Australia, and the United Kingdom.
Front. Sports Act. Living 4:1124234.
doi: 10.3389/fspor.2022.1124234

The global evolution of talent promotion within Olympic sports: A focus on the national systems and contribution of the former German Democratic Republic, Australia, and the United Kingdom

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In this chapter we chronicle and explore the global evolution of national level talent promotion through the lens and respective journeys of the former German Democratic Republic, Australia and the United Kingdom. Whilst ideologically vastly different, core elements of talent promotion were mirrored and extended within the next national iteration. Key learnings obtained from this historical and comparative exploration serve to provide excellent learnings for policy makers, strategists, practitioners and researchers to support the review and development of current and future national talent promotion systems.

KEYWORDS

systems, policy, strategy, athlete, development, management, national policy approaches

Introduction

The undisputed goal of nations within the "*global sporting arms race*" (1) is finding the right strategic approach to ensure sustainable high-performance outcomes on the world stage, including notably, at the Olympic Games. Central to achieving this objective is talent promotion – the effective recruitment, selection, development, and transition of pre-elite level athletes to a high-performance level.

Recognised as one of the first national talent promotion systems established in the post-war era, the German Democratic Republic achieved rapid and significant Olympic success through the 1970s and 1980s. Albeit veiled by great secrecy and state censorship, the system was admired and emulated globally prior to its dissolution in 1989 and the exposure of its state-sponsored doping of athletes. Notwithstanding this fact, the system and many of its pillars, provided a legacy, directly influencing the build of talent promotion systems within emerging sporting nations such as Australia through the 1970s to 2000s and later, the United Kingdom, contributing to substantial Olympic success for both countries (see **Figure 1**).

Utilising a historical and comparative approach, in this chapter we will examine the chronology and contribution of these three national systems to the broader discipline of talent promotion within Olympic sports. Regardless of their obvious heterogeneity (i.e., ideology, culture, governance etc.) at the core of these systems were commonalities or "homogenous" aspects (i.e., policy, strategy, structures, delivery etc.) that were mirrored, adapted, and extended within the next system and enabled importantly, through the "transfer" of leadership, knowledge, and innovation. As Dennis and Crix (2) share, "*Such a legacy is not to be measured simply in what remains in place in Germany after unification … a legacy can take many forms. It might be ideational, structural or take the shape of an actual*

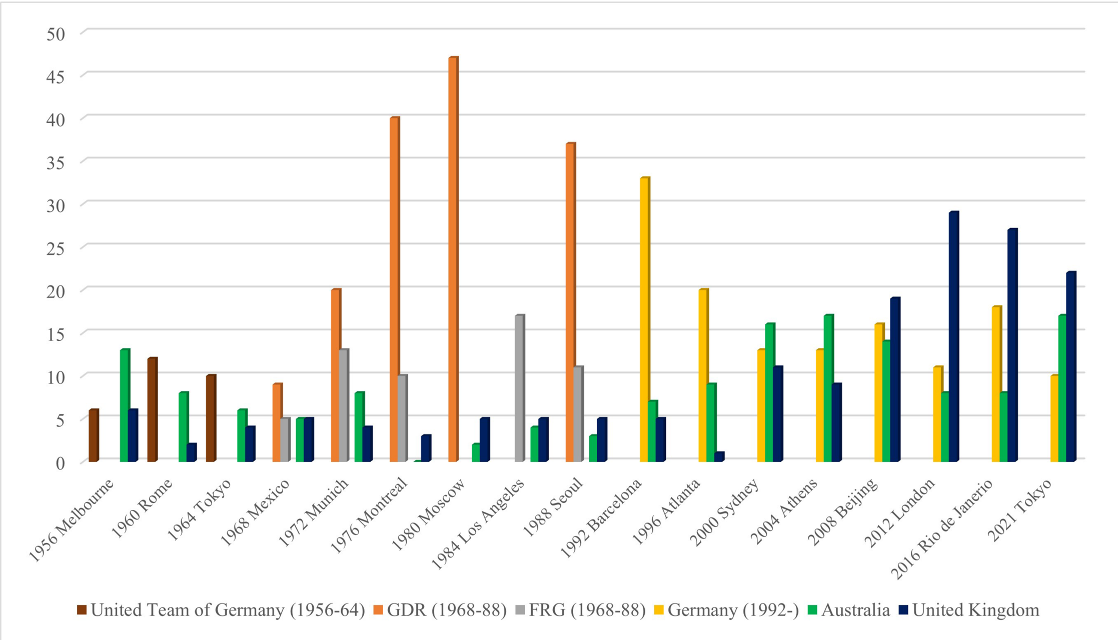

FIGURE 1
Olympic gold medal country tally from Melbourne (1956) to Tokyo (2021) Olympic games. Note: GDR and FRG were part of the United Team of Germany between 1956 and 1964. The FRG boycotted the 1980 Moscow Olympic Games, and the GDR boycotted the 1984 Los Angeles Olympic Games.

person, who brings with them ideas, conventions, technical knowledge, tricks of the trade and so on" (p. 171).

The author is a former athlete and current policy maker, academic and practitioner, who has dedicated the last 20 years of their career to the evolution of talent promotion within Australia and internationally, including providing advice to the International Olympic Committee [see Bergeron et al. (3),]. Reflecting upon the evolution of these systems, provides excellent learnings and impetus for fellow policy makers and practitioners to guide their future planning and implementation.

Former German Democratic Republic (1949–1990)

At the 1976 Montreal Olympics, the world first took notice of the German Democratic Republic, an emerging sporting superpower that doubled its gold medal haul at its home Olympics in Munich in 1972. As Dennis and Crix (2) share, "*Interest in finding out what made up the East German sports system rose sharply after the first international successes of its athletes*." (p. 176). Within the following section, we will explore the genesis, elements and limitations of its national talent promotion system.

Genesis and political context

Following the decimation of Germany after World War II, a key priority of the ruling Socialist Unity Party of Germany (*Sozialistische Einheitspartei Deutschlands* -SED) when it came to power in 1949, was the rebuilding of its entire national high-performance sports system (4–6). Prior to this time, high performance sport was amateur and diversified featuring autonomous sports clubs and associations and worker's sport (2).

Influenced heavily by the communist ideology and sporting success of its occupying force, the USSR (Union of Soviet Socialist Republics) (i.e., the USSR ranked second on the country medal tally at its first Olympics in Helsinki in 1952 and then first at the 1956 Melbourne Olympics), high performance sport became a political instrument of the authoritarian regime. Success on the world sporting stage, was a means of displaying to the world the physical prowess of its citizens, affirm the strength of its socialist ideology and values domestically, and confirm its superiority over its capitalist rivals including the Federal Republic of Germany (West Germany) (2, 5–8).

Specific to mass participation was the regime's "*sport for all*" policy. Walter Ulbricht, the first head of state of the German Democratic Republic, preached "*strength through physical culture and sport*" (7) and demanded that all citizens, young or old, participated in some form of physical activity and this was overseen by the State Committee for Physical Culture and Sport (*Staatliches Komitee für Körperkultur und Sport* - Stako). This was achieved though the prioritisation of physical activity and sport within its school network (including paramilitary disciplines such as close combat and grenade throwing), incentivised physical activity within people's workplaces and the hosting of local and national annual sports festivals (*Spartiakades*).

National governance and priority

High performance sport was centrally governed through the centralist management and control of the SED's Central

Committee Department for Sport and its related policy, planning and monitoring processes including a dedicated national operational plan for each sport, detailed performance targets and biennial monitoring (2). As Dennis and Crix (2) share, "*…the GDR was an authoritarian dictatorship and as such did not suffer the usual problems of interest mediation, lobbying and difficulty with policy implementation in liberal democracies. Given that sport policy was dealt with at the top of the hierarchy, decisions were made, policy was changed and implemented more swiftly and without the need for widespread consensus as is the case in democratic regimes*" (p. 181). Supporting the SED at a national level was the High-Performance Sports Committee (*Leistungssportkomission* - LSK), German National Olympic Committee (NOC) and the German Gymnastics and Sports Association (*Deutscher Turn- und Sportbund der Deutschen Demokratischen Republik* - DTSB) an "umbrella" organisation responsible for providing oversight of its Olympic National Sporting Federations (NSF) (2, 5, 8, 9).

The Stako also provided initial oversight of the German College for Physical Culture (*Deutsche Hochschule für Körperkultur* - DHfK), a national college established in 1950 dedicated to the education of physical education teachers and coaches, and the Research Institute for Physical Culture and Sports (*Forschungsinstitut für Körperkultur und Sport* - FKS), which oversaw research into high-performance sports. Both institutions were situated within the campus of Leipzig University and will be discussed later in this chapter. Other specialist national level institutions included the Research and Development Centre for Sport Equipment (*Forschungs und Entwicklungsstelle für Sportgeräte* -FES), which specialised in the development of sports equipment (e.g., boats, bicycles, skis, bob sleds, luges, speed skates, poles, etc.) and the National Sports-Medical Service (*Sportmedizinischer Dienst der* - SMD) which provided medical services and oversaw sports medical research, inclusive of performance enhancing pharmaceuticals, as will be discussed later.

Talent promotion was central to the SED's national high-performance policy and implementation. The core operational infrastructure of the regime's system was established between 1951 and 1956, including the build of state-of-the-art sporting facilities (e.g., elite training centres) across its territories through its *Golden* and later *Golden East* plans (Hallman et al., 2018), Children and Youth Sports schools (*Kinder und Jugendsportschulen* - KJS) and elite sport clubs such as SC Dynamo Berlin (2). Most sport clubs were state-sponsored and were under the strict control of the army, police, or the "Ministry for State Security" (Stasi - *Staatssicherheit*). It is reported that every tenth citizen of the regime were involved in the surveillance of their own family and friends, and it is alleged that within the sports system, it was more prevalent.

By the mid-1970s and 1980s, the majority of national level sport funding was allocated to the high-performance system including ongoing investment into prioritised "category A" Olympic sports (i.e., sports considered to have substantial medal prospects), its dedicated workforce of coaches and trainers and athletes within its *cadre* system. Ongoing clashes at a bureaucratic level ensued with the Stako insisting that more resources be assigned to support mass participation inclusive of children's and youth sport. However, as Dennis and Crix (2) share, mass sports participation "*…did not survive the voracious appetite for resources of elite sport.*" (*p.* 41) and "*sports for all*" was greatly underserved due to the regime's "*win at all costs*" mentality (2). As Dennis & Crix (2) continue, "*… there was no harmonious, iterative relationship between mass and elite sport: the latter was very clearly demarcated from the former. Over time, the East German authorities were unable to support all areas of sport and as such mass sport provision declined rapidly from the end of the 1970s until the state's collapse in 1989*" (p. 157–158).

Systematic talent identification and development

Considering its relatively small populace (i.e., approximately 16 to 17 million citizens) and the increasing importance placed by the regime on achieving international success, the development of a national system to sift through, select and develop its sporting talent from a young age and enhance the talent pipelines of its prioritised Olympic sports, became an urgent priority of the SED.

Central to achieving this outcome and depicted within **Figure 2**, was the establishment of a systematic and nation-wide process for identifying and developing young and prospective sporting talent which featured three progressive stages:

Stage 1 - 1st and 3rd grade school students were tested and selected for specific sports through a Uniform Inspection and Selection process (*Einheitliche* Sichtung *und Auswahl* -ESA) developed through the FKS and their early sporting development supported through decentralised training centres.

The ESA administered by physical education teachers throughout the school network operated nationally from 1973 until 1990 and resulted in the screening annually of over 200,000 children within grades 1 and 3 for specific sports (10). Prior to the ESA, youth selection relied on informal processes such as coaches eye assessments implemented by locally based trainers and schoolteachers.

Stage 2 - School students aged between 12 and 18 years (and school students aged between 6 and 8 years specific to artistic-composition sports such as gymnastics) were tested and selected into a KJS for intensive and centralised sporting development. The KJS concept was based on the USSR model of elite sport schools and featured an intensified sport curriculum and delivery, with the majority being boarding schools.

Following the 1968 Mexico Olympics, the KJS focussed solely on Olympic sports supporting approximately 10,000 athletes across the network. Each KJS were located strategically in regions with a good match of institutional and infrastructural conditions and were self-sufficient centralised talent promotion facilities, providing its student athlete population with intensive coaching and training support, access to catering and sports medical services. It is notable that the twenty-three KJS within the system—unlike all other schools in the country—were under the direction of the twenty-one sports clubs of the regime, not the educational authorities. Students were required to invest in six hours of sport and only two

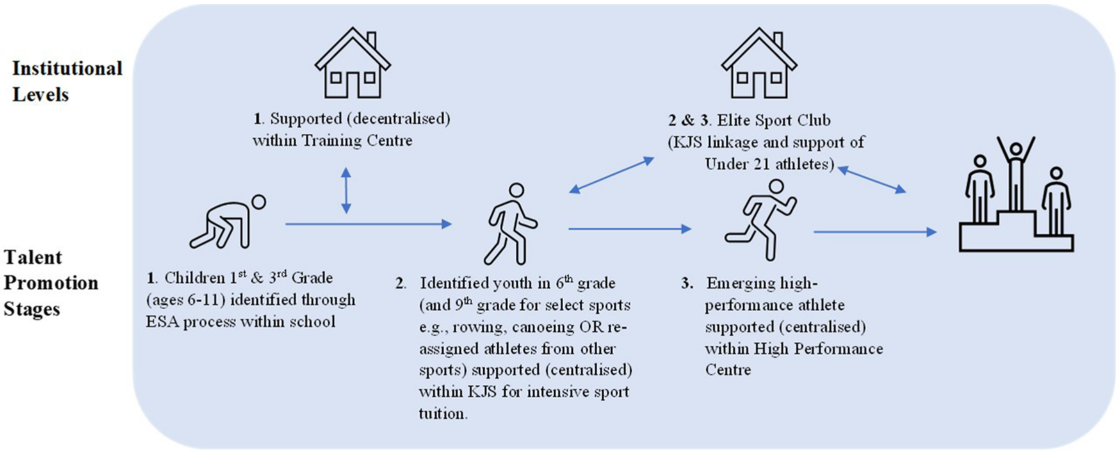

FIGURE 2
Schematic overview of the German Democratic Republic's three-step talent promotion process that existed from 1973 to 1989.

hours of academic tuition each day resulting in severe academic deficits of many athletes for the sake of more available time for sport.

Stage 3 – High-performance athletes received centralised support within one of eight dedicated National high-performance centres which were closely linked to and overseen by an elite sport club. Each of these centres featured state of the art and innovative training facilities and equipment such as treadmills, swimming flumes and hypoxic chambers and athletes had ready access to high-performance coaches, quality daily training environments and equipment, interdisciplinary service support and sports medicine and travel support for competition.

Athletes at this level were able to train fulltime without risking their amateur status for Olympic level competition. Athletes who were successful in being categorised within the *cadre* system received scaled athlete payments (i.e., dependent upon what level they were at) through a dedicated sports foundation and vocational opportunity and support including industry traineeships and jobs.

This systematic approach provided a very structured athlete pathway and eco-system where the delegation, responsibilities, collaboration, and alignment of key stakeholders underpinning an NSF and the role and contribution of talent promotion facilities, was well defined. The capacity of the system was substantial, supporting thousands of athletes annually within each stage (6).

Talent development within each stage was informed by "scientifically based training systems" developed by the FKS which included the "*Framework for Training Concepts*" - set prescriptions of age-related training volumes specific to each type of sport (i.e., aquatic, endurance, combat, strength and power, game sports and acrobatic) (4).

An athlete's development was longitudinally tracked inclusive of their holistic profile, chronological age (and later also biological maturation) and performance outcomes. An athlete's performance prognoses were represented on a 100-point-scale and interpreted in relation to their training age for their sport. In turn, this collective data capture and analyses, was intended by the FKS to inform the further refinement of athletic norms and benchmarks and confirm the prognostic capability of the broader talent promotion approach.

Investment into coach development

Coaches delivering at every level of the system, were required to be university qualified (overseen by the DHfK) and formally accredited by their sport and commit to ongoing professional development. In return, coaches were employed on a full-time basis and renumerated by the state and received rewards (including badges) and bonuses for performance success. Graduate coaches were extremely knowledgeable, skilled, and adept in implementing a strong pedagogical approach to athlete development (including effective periodisation inspired by Russian physiologist Leo Matveyev and later Romanian Tudor Bompa) and comfortably worked side by side within the daily training environment with sport science and sport medicine practitioners to assist their planning and delivery and facilitate the interdisciplinary case management of their athletes.

Learnings and reflections

With the dissolution of the regime and the subsequent release of archived documentation chronicling the system, the ethics and success of the system came under question, when the systematic doping of its athletes even at a young age, was uncovered (6, 7, 11, 12). As Barker (11) shares, "*Often the anabolic steroid 'Oral Turinabol' was administered in little blue pills. Athletes and swimmers were often told that these were 'vitamins'. Sometimes they were forced to sign confidentiality agreements.*" Through the 1980s, the national government in their aggressive pursuit of records and medals no matter the cost, invested over five million German marks annually to investigate doping substances as part of its State Plan 14.25. At the time of reunification in 1990, the FKS was allegedly overseeing twenty-one research projects investigating the effects of different doping substances on athlete performance. The performance differential between genders was significant (i.e., the success of female athletes was seven times that of male athletes), reflecting strong sex-specific variation and impact of doping on performance.

The long-term health and wellbeing of many of its athletes were greatly impacted by long term steroid usage culminating in devastating and irreversible consequences including infertility, birth defects, advanced heart disease, liver failure and gynecomastia (breast growth in males). Consequently, several coaches, administrators, and physicians including the former head of the DTSB and President of the NOC, Manfred Ewald, and Chief Doctor and Vice-Director of the SMD, Manfred Höppner were subsequently convicted of "*intentional bodily harm to athletes and minors*" and served lengthy gaol terms for their involvement (11).

Closer academic scrutiny of the system revealed several other limitations including -

1. its low cost-benefit ratio, dividends, and efficiency [see Güllich et al. (13); Güllich & Emrich (4, 14)]. As Güllich et al. (13) share, "*The system was effective in terms of international medals. On the other hand, its 'tons ideology' was oriented at effectiveness rather than efficiency, and by the 1980s, it had developed extreme requirements of resources*" (p. 58). With the fall of the regime, most of the reported six thousand coaches developed through the system, did not secure further employment domestically or internationally.
2. the selection process, cost-benefit, and impact of the KJS (4, 15). Approximately half of the athlete cohort that represented the German Democratic Republic at the 1988 Seoul Olympics, had failed to meet the selection criteria for admission to a KJS but were recruited anyway, and a similar percentage had initially been selected for a different sport and were later "delegated" to their Olympic sport. Many youth athletes were required to relocate and live on site (board) and contend with very high sporting demands and expectation, enjoyed limited recreational time and autonomy, and had limited connection to their families and social peers, for support.
3. the scientific rationality and rigor of the ESA athlete selection process. The reported prognostic validity of the assessment battery has since been questioned subsequent to allegations that it was empirically falsified. Despite inclusion of estimates of biological maturation to moderate an athlete's results and hence their sport suitability, this only marginally improved the prognostic validity of the test battery which whilst it purported to be "multi-dimensional" was contingent on anthropometric and physical markers. Subsequently, early maturing youth were commonly matched with strength-based sports and late maturing youth, with coordinative-based sports (2). Additionally, errors in data collection were also common (2).
4. the high rates of reported churn (i.e., burn out and drop out of athletes) at each level. Only a very small percentage of athletes that started the journey in their youth, continued within the sport and achieved success at a senior level [see Vaeyans et al. (16)]. Compared to their West German competitors, athletes were characterised by an earlier age of recruitment and specialisation, limited levels of sport sampling, earlier competitive success, and higher intensities of training over shorter developmental timeframes (4, 13). There was a presumption within the system, that early selection and subsequent sport specialisation based on early (junior level) indicators of performance, afforded a longer developmental period and that large volumes of training equated to high performance success but instead it contributed to high injury incidence, athlete burnout and dropout (4, 13, 15).
5. ongoing pressure and high expectations that were placed on athletes and the subsequent impact on their psychological wellbeing and opportunities within the system. Being a communist dictatorship, the system was characteristically restrictive and oppressive. Athletes and their families who were not ideologically conformist were banned from the sport system and devoid of vocational opportunities including attending university. Athletes who did not fulfil performance expectations were not admitted to the university subject they wanted, nor admitted to university at all.

As Dennis and Crix (2) contend, "*It is interesting to note that if the GDR had not collapsed in 1989 and ceased to exist in 1990, the sports 'miracle' is likely to have run aground by its own accord. There is growing evidence of declining resources, declining numbers of children to 'stoke' the system to keep it functioning, growing popular resentment against the extravagance what was the elite sport system and growing evidence that the doping programme had reached its limitations*" (p. 196).

Final comments

Notwithstanding its questionable ethics and efficiency, remnants of the former talent promotion system of the German Democratic Republic including its elite sport schools' network and investment into state-of-the-art research, technology and innovation continue today within the modern German sports system, many decades after its fall. As Dennis and Crix (2) contend, "*… doping was one of the basic ingredients of an already formidable set of integrated elite sport development structures*" (p. 177). At an international level, its systematic approach to talent promotion, served as a legacy influencing the "build" of subsequent national systems through the 1970s and 1980s including Australia. The relative influence and contribution of the system and the subsequent evolution of talent promotion within Australia, will now be discussed.

Australia

The advance in professionalism and subsequent international level success of the German Democratic Republic as well as of China, the USSR and Eastern Bloc countries, caught the attention of Australian bureaucrats, sport administrators and scientists in the early to late 1970s who were at the helm of formulating the blueprint for the modern Australian sporting system. A contributing factor to the collective-level success of the German Democratic Republic, the state-sponsored doping of its athletes, was unbeknownst to these keen observers but would be revealed later, after its fall in 1989.

The Australian high-performance system mirrored several of the key pillars of the former regime albeit not in its entire complexity, nor implemented in such a closed, authoritarian, and ethically questionable way (refer to **Table 1** for a summary). For a country with a relatively small populace [i.e., currently just over 26 million

TABLE 1 Similarities and differences between the national talent promotion systems of the former German Democratic Republic and Australia.

Similarities	Dedicated federal policy and funding specific to high-performance
	Establishment of a National Institute of Sport and subsequent satellite network of state and territory high-performance institutes and academies
	Substantial federal investment into the build of state-of-the-art infrastructure and facilities
	Targeted federal level investment into prioritised Olympic sports
	Systematic athlete profiling and talent identification and development
	Provision of centralised daily training environments inclusive of quality coaching, sport science/medicine service provision, testing and individualised planning for athletes
	Scholarships and direct funding to athletes
	Investment into coach education, professional development and accreditation
	Investment into sport science/sport medicine research and innovation and integrated service provision for athletes
Points of difference	Lack of authoritarian and rigid governance, organisational and personal implications for poor Olympic performance
	Talent pathways and promotion not central to federal high-performance policy, implementation, and evaluation
	Nil state-sponsored implementation of athlete doping
	Diversified and complex talent pathways
	Coaching workforce not directly renumerated by the state
	Smaller cohort of sports schools but not central to national talent promotion strategy
	Non-professional club system which is not state sponsored

citizens and ranked 52nd highest globally according to the website Population Australia (17)], "*punching above its weight*" on the international sporting stage, has long been synonymous with Australia's national identity and culture since its colonisation. Australia based on per capita of population, is considered one of the most successful national high-performance systems in the modern era of Olympic sport (i.e., for every 832,000 of its citizens, Australia achieves an Olympic medal) (18).

Today, Australia's high-performance system comprises a network of formally recognised National Sporting Organisations that are funded and supported by the federal agencies of sport including the national Office of Sport, the Australian Sports Commission (ASC), the newly formed Sport Integrity Australia, the Australian Institute of Sport, Australian Olympic Committee, Paralympics Australia, and the Australian Commonwealth Games Association. National Sporting Organisations (NSOs) are supported by a network of State Sporting Organisations (SSOs) funded and supported by their respective state or territory government departments, who in turn have oversight of a state institute or academy, regional level sport associations and academies, local amateur clubs and schools including public, catholic and independent schools and a small number of state sports schools (e.g., NSW Sports High Schools Association established in 2014 includes seven sports high schools, six of which are situated in the city of Sydney). This complex and diverse sports system as will be discussed later, provides an ongoing challenge with respect to the effective choreography and governance of talent promotion within Australia.

In this section we will chronicle the evolution and adaptation of Australia's national talent promotion system specific to Olympic sports.

Genesis of Australia's high-performance system

Being a liberal democracy, Australia has enjoyed an open and diversified society and since 1901, possesses a federated system of national government, inclusive of six states and two territories, each with their own heads of government and underpinning network of metropolitan, regional, and remote local government areas and councils.

In post-war Australia, high performance sport was amateur, with minimal financial assistance at a state and federal level of government (19). Pockets of organic talent promotion through small club and coach-led programs had proven successful. At its first home Olympics in Melbourne in 1956, Australia placed second on the medal tally and gold medal winning athletes Betty Cuthbert, Shirley Strickland and Dawn Fraser became "*Aussie*" Olympic legends. Athletics coach, Percy Cerutty who's self-developed and unconventional "*Stotan*" training program embracing a holistic regime of natural diets, mental stimulation and resistance training to exhaustion within the sand dunes near his Portsea base in Victoria, was incredibly effective, nurturing a squad of world-class middle-distance runners including Betty Cuthbert but also Olympic champion and world record holder Herb Elliott and Olympic bronze medallist John Landy (20).

By the early 1970s however, Australia's amateur approach was quickly falling behind and unable to keep pace with the dedicated national systems and professional approach of the USSR, the German Democratic Republic and its Eastern Bloc allies, including Romania and Hungary (Bloomfield, 2003).

In direct response, the late John Bloomfield recognised as the chief architect of the modern Australian sports system and a longstanding and respected advocate, was commissioned in 1973 by the then Labor government and Australia's first federal sports minister Frank Stewart, to prepare a report titled "*The role, scope and development of recreation in Australia*" based on his keen observations and critique of international systems. Bloomfield's key recommendations included the establishment of a national sporting institute envisioned as a national centre of excellence, structures, and processes specific to effective athlete identification and development and federal investment into coaching and sports science/sports medicine disciplines. Bloomfield was also adamant that grass roots programs be established within the school and community sport network to facilitate the physical activity and fitness of youth. These collective recommendations were in accordance with then Prime Minister Gough Whitlam's view of sport as a vehicle for improving the overall welfare of the nation and "*a legitimate focus for public policy*" (21). However, due to a change in government in 1975, this plan was not realised immediately. Allan Coles in 1975 was commissioned by the subsequent Liberal government led by Prime Minister Malcolm Fraser to chair the development of the "*Report of the Australian Sports Institute Study Group*".

At the subsequent Olympic games in Montreal, Canada in 1976, Australia failed to win a gold medal, placing 32nd on the medal tally. At the following Commonwealth Games in 1978 in Edmonton, Canada, Australia finished third behind the host nation and England. These collective poor performances "*thrust sport into the glare of the political spotlight*" [see Nihill & Drane (22) p. 13] and provided the urgency and catalyst for change commencing with substantial federal investment into Australia's high-performance system (21). The late Bob Ellicott, a minister within Malcolm Fraser's Liberal government decreed in 1980 with strong bipartisan support, that the Australian Institute of Sport (AIS) be established in Australia's capital city of Canberra, considered to be "*an investment in the nation and…. the future of Australian sport*" (21).

The AIS opened its doors soon after in 1981 and state of the art facilities were built on the campus including the National Indoor Sports Centre, a track and field stadium and later, a tennis hall, swimming centre and gymnastics centre. Soon after a dedicated sports science/medicine centre, administration building, national sport information centre (the first of its kind in the world) and residential complex were completed. Soon after, the AIS for a time, also served as a national training centre for non-residential sports such as Indoor Volleyball (the author was a joint Australian Volleyball/AIS scholarship holder in 1986, relocating to Canberra from Port Macquarie in regional New South Wales).

In 1985, the Australian Sports Commission was established, its role being to "*…fulfil the role of a coordinating body for sport—to foster cooperation, to allow for greater involvement of sports bodies in decision-making about sport and to broaden the financial base for sport*" [Jolly (21) p. 10].

The initial intake of AIS athletes comprised of one hundred and fifty-three athletes across eight sports, basketball, gymnastics, netball, soccer, swimming, tennis, athletics, and weightlifting. At its peak, the AIS managed thirty-five separate programs within twenty-six sports, and the typical makeup of squads, were a mix of mature international-level performers and promising, emerging athletes. For these emerging athletes, particularly the many that originated from regional and rural Australia (23) the AIS offered a well-resourced and supportive centralised high-performance daily training environment and critical "steppingstone" to national representation (see **Figure 3**).

Each scholarship provided residential accommodation (initially a few short kilometres from the campus, but later within the AIS campus), high quality coaching, access to state-of-the-art training and competition facilities and equipment, interdisciplinary sport science-medicine service support (including education, individualised testing, planning, and monitoring), uniforms, meals, academic tutoring, travel, and domestic and international competition. For younger athletes in residence such as gymnasts, house parents, supervisors and mentors were assigned to chaperone and support. A requirement of each AIS scholarship was that athletes were expected to commit to concurrent educational or vocational training or work part-time. A dedicated sports studies faculty offering sport science/coaching, administration, and journalism, was established at the nearby Canberra College of Advanced Education (CCAE now known as the University of Canberra) under the leadership of renowned academic and sport scientist, the late Frank Pyke. Many scholarship athletes and their coaches within the AIS sports programs undertook these courses. There was strong linkage

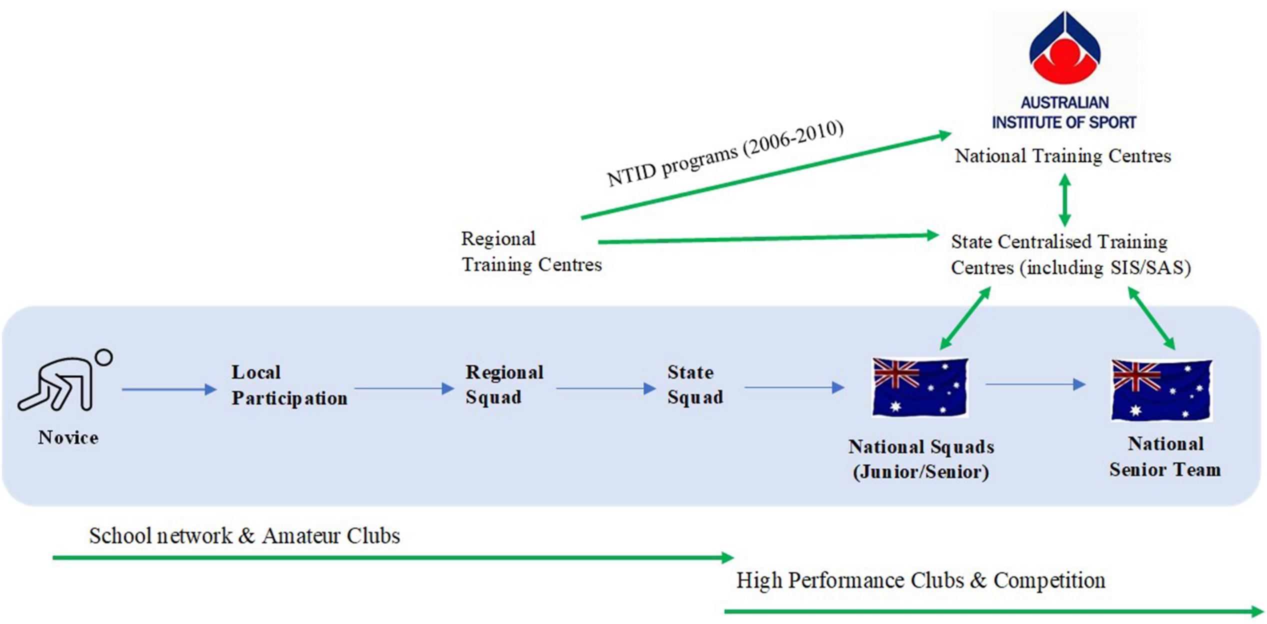

FIGURE 3
Talent promotion pathways within Australia pre-2014.

between these courses with practicums routinely taking place within the AIS environment and connection with its practitioners. Many graduate coaches, sport scientists and administrators from this college (the author being one of them), progressed to working within the AIS, the broader Australian system and internationally.

After the announcement in 1993 by the IOC that Australia had secured the hosting of the 2000 Olympics in Sydney, the federal government substantially increased its high-performance funding through its Olympic Athlete Program (OAP) which was administered by the AIS. Through the OAP, athletes were provided direct financial assistance, and were able to access more interdisciplinary sports science/medicine service support, professional coaching and dedicated career and educational support. The National Athlete Career and Education (ACE) program (later adapted into Personal Excellence and currently known as Athlete Wellbeing and Engagement) initially developed at the Victorian Institute of Sport, was delivered throughout the AIS and SIS/SAS network from the mid-1990s and was a world-first initiative dedicated to supporting an athlete's educational and vocational training and sport-life balance (24) and was later emulated by the United Kingdom.

Supporting an athlete's development (and importantly their coach), was a world-class and integrated sport science/sports medicine workforce within the AIS. The founding departments of the AIS featured expert and passionate scientists and practitioners and comprised of physiology, sports medicine, sport psychology, physical therapies and biomechanics. Later the disciplines of sports nutrition, performance analysis and skill acquisition were added. This vibrant eco-system embraced an unwavering culture of excellence, working collaboratively to provide servicing to its athletes, guide and support its coaches, and lead innovative research, providing an ongoing legacy for these disciplines across the national high-performance network and internationally for many decades to come. For instance, its Physiology department led the implementation of Australia's first talent identification program and later the Talent Search program (both of which will be discussed a little later), developed cooling jacket technology to support recovery, a detection test for erythropoietin stimulating agents, altitude adaptation (including a custom-built altitude house) and wearable micro technologies providing real time monitoring and feedback to athletes and their coaches. Internationally acclaimed sports nutritionist Louise Burke established its Sport Nutrition department, one of the first in the world, which has since been emulated across the globe.

The AIS's inaugural director was internationally renowned swimming coach, the late Don Talbot who had coached more than thirty Olympic and world record swimmers internationally (Canada and the United States of America) and within Australia including Olympic swimming twins, Ilsa and John Konrads (25). Drawing upon his personal learnings from working within the United States and Canadian systems, Don oversaw the prioritisation of quality coaching within the AIS including the provision of "apprenticeship" positions. Coaches were renumerated, benefitted from ongoing professional development, networking and learning from other AIS coaches, and were supported within the daily training environment by sports science/sports medicine practitioners (25).

The AIS also drew the attention of many international coaches including from Romania (e.g., Reinhold Batschi, inaugural AIS Rowing director) and the former German Democratic Republic. Internationally renowned cycling coach, the late Heiko Salzwedel who was both a cyclist and coach developed through the former system, became the inaugural head coach of the AIS's road cycling program from 1991 to 1998 (26, 27). Heiko like his East German coaching compatriots, brought with him a strong pedagogical and professional approach to coaching characterised by meticulous athlete planning and periodization.

Between 1982 and 1996, a satellite network of State and Territory Sporting Institutes and Academies (SIS/SAS) were established to support the decentralisation of some AIS programs including hockey (Perth, Western Australia), cycling (Adelaide, South Australia) and squash, canoeing and diving (Brisbane, Queensland).

The contribution of the AIS and SIS/SAS in supporting the effective talent promotion and subsequent international success of many of Australia's finest Olympic athletes, cannot be understated. For example, at the Sydney 2000 Olympics, the majority of athletes representing Australia were or had been supported through either an AIS, SIS/SAS, or co-badged scholarships (28). As Nihill and Drane (22) share, "*It (the AIS) took hold of the undeniable talent of Australian athletes, witnessed many times before, and applied a structured, supportive, and professional approach to the ongoing development of sport. It introduced Australians to professionalism in sport. It recruited coaches. It built infrastructure. It embraced sport science – Australian style, not Eastern Bloc. It exposed elite athletes to international competition. And it nurtured talent, opening up pathways for young elite athletes through a scholarship system designed to make them not just better athletes but better Australian citizens in life after competition.*" (p. 10).

Transformative period of talent identification and development

To support Australia's sustainable Olympic success, it was imperative that innovative approaches to "flush" the pipelines of Olympic sports (including AIS and SIS/SAS scholarship programs) with prospective talent, became a key focus of the early AIS to lead on behalf of the national sport system. Prior to this time, the predominant approach was through talent selection from within a sport (29).

Following in the footsteps of Bloomfield and colleagues who implemented a scientific approach to talent identification in swimming in the early 1970s and 1980s inspired by those adopted within the German Democratic Republic and Eastern Bloc [see Bloomfield & Blanksby (30) and Bloomfield (31)], Allan Hahn, AIS physiologist and coach Peter Shakespear, drew inspiration and insights from the then Romanian women's rowing program, which won five gold medals at both the 1980 Moscow and 1984 Los Angeles Olympics (32–34). Allan and Peter established alongside AIS colleagues including the late Doug Tumilty, Australia's first talent detection program in 1987 in the sport of rowing. The initiative was fundamentally a "*proof of concept*" project – an opportunity to apply a scientific and detection approach to talent identification (i.e., source youth athletes from outside the sport) like Romania and the German Democratic Republic and confirm its viability within the Australian context [see Gulbin (29) and Hahn (32)].

In addition to supplementing the talent pipelines of rowing within Australia with numerous athletes gaining full AIS scholarships and achieving national representation at World Championship level between 1989 and 2004, the pinnacle achievement of the program was the successful pairing of Megan Still (now Marcks) and established rower Kate Slatter (now Allen) who became the first female crew to win gold for Australia at the 1996 Atlanta Olympics. The achievements of this initiative were not limited to the athletes it unearthed but also the coaching expertise it nurtured. Paul Thompson, the coach of Megan Still and Kate Slatter and a former elite rower himself, went onto achieve further world-class success within the United Kingdom system.

The success of the AIS rowing initiative within a relatively short time frame, fuelled great interest from other sports and led to the establishment of a similar initiative within the South Australian Sports Institute (SASI) in 1993 in partnership with Cycling Australia. Like the AIS rowing initiative, this program achieved international success quickly with podium success at the 1996 Junior World Championships, gold at the 1998 Kuala Lumpur Commonwealth Games and two top ten finishes at the 2000 Sydney Olympics.

These "concept" initiatives were pivotal for Australian Olympic sport, signalling the start of a *transformative* evolution of innovative talent identification and development led by the AIS over the next two to three decades. The progressive phases constituting this transformative period are well described by Gulbin (29) as "*concept*", "*growth*", "*refinement and maturation*", and "*investment*". This fruitful period included the innovative computer-based "sport counselling" program *Sport Search* and subsequent National *Talent Search* program led by Deborah Hoare (now Latouf) which recruited school-aged children through talent detection and relied on state and national sporting organisations to manage an athlete's daily training environment, and the *National Talent Identification and Development* (NTID) program led by Jason Gulbin and informed by the learnings from *Talent Search* that incorporated diversified approaches for talent identification (i.e., selection, detection, transfer and re-integration of older aged established athletes) and expanded in capacity and capability through partnership with over 40 Universities and an electronic recruitment platform (eTID) and dedicated development programs on behalf of fourteen Olympic sports overseen by a workforce of NTID practitioners and coaches. Adapted from Gulbin (29), we provide in **Figure 4** an overview this transformative period in talent identification and development, led by the AIS.

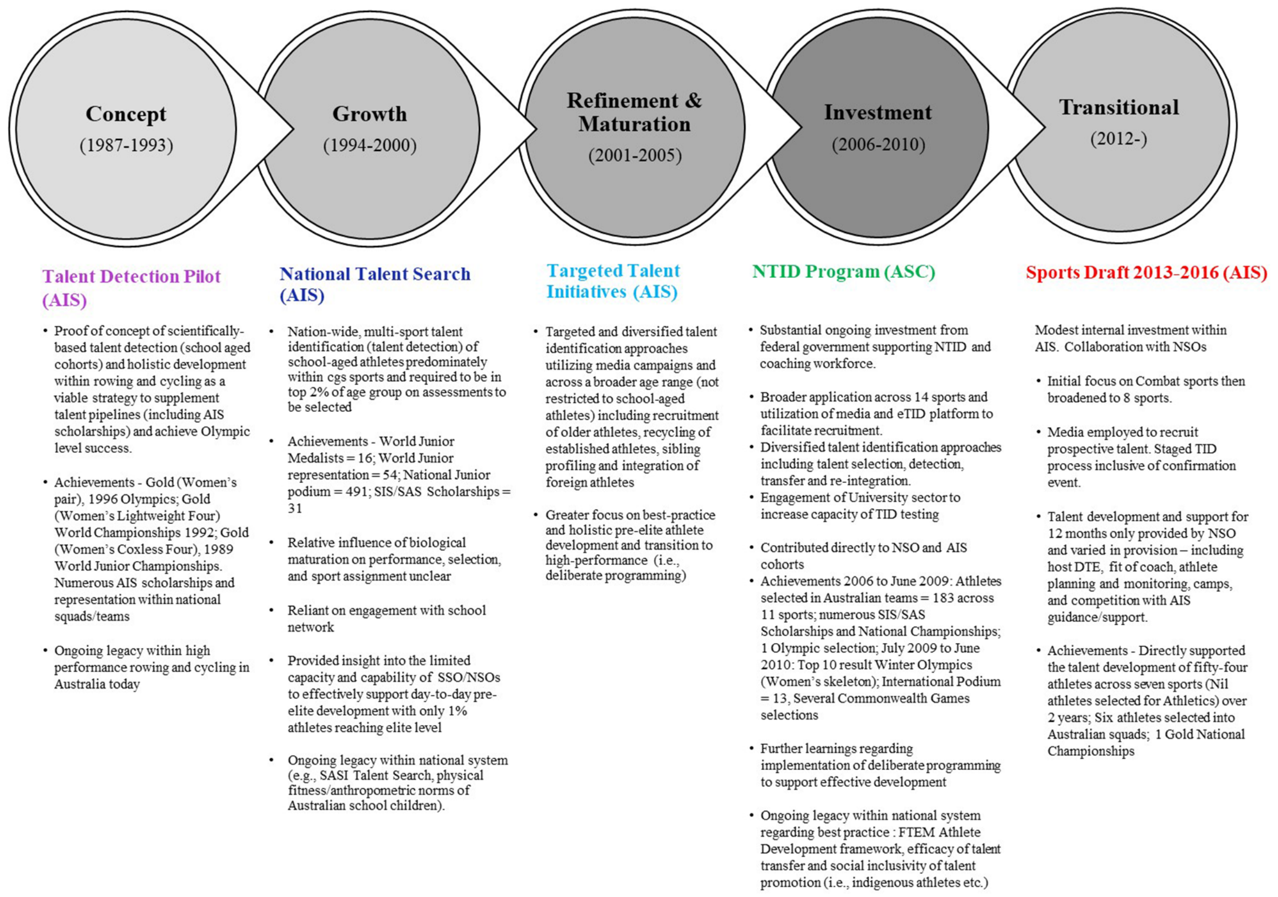

FIGURE 4
Evolution of talent identification and development under the leadership of the AIS (1987 to 2016). Contributing References: Abbott (35); Australian Institute of Sport (36); Australian Sports Commission (37–40); Ferguson (24); Gulbin (29); Gulbin et al. (41); Hahn (32, 33); Hoare (42, 43); Tomkinson et al. (44).

It is noteworthy, that these initiatives operated concurrent to and may have benefitted from, the implementation of the internationally recognised *Aussie Sports* program, delivered by the ASC as part of its *Active Australia* strategy between 1986 and 2003 (24, 45). *Aussie Sports* not only empowered the physical literacy and positive sport development of children and youth through participation within modified sports and games (i.e., the program developed over forty modified formats) and dedicated education and mentoring, it also directly supported the professional development of community level coaches (including volunteer parents) and teachers across the national network of primary schools to bolster the foundational levels of sport (24, 46). The contribution and legacy of this ground-breaking program to Australian sport at all levels, cannot be understated.

Change in national system and impact on talent promotion

Since late 2012 and the advent of the federal government's *Winning Edge* policy in response to Australia's poor performance at the London Olympics (47), national talent identification within Australia is best described as *transitional* (29) and has occurred in direct response to a change in role of the AIS, rather than a transformational progression within the discipline. Apart from the short-lived *AIS Sports Draft* (2013–2016), national-level identification and development has been the responsibility of NSOs and their partner SSOs and SIS/SAS to implement within their respective systems. For instance, the state government of Queensland recently increased their investment into the Queensland Academy of Sport, to drive and manage state-based talent identification and development programs (including several sport science/medicine and coaching roles) in the lead-up to the 2032 Brisbane Olympics through its *Youfor2032* initiative launched in early 2022 by its Chief Executive and former UK Sport director, Chelsea Warr (48). Chelsea's contribution to the growth of talent promotion within the United Kingdom will be addressed in the next section.

Another major change bestowed by the *Winning Edge* policy, was the decision that the AIS would no longer deliver and manage high-performance programs and provide athlete scholarships, and funding would instead be "put back in the hands" of prioritised NSOs to administer and manage. Furthermore, in May 2018, the dedicated sports science and medicine workforce located within the AIS hub in Canberra was significantly reduced, leading to the firm contention, that the AIS no longer resembled the vibrant and world leading institution, envisioned and realised through the 80s, 90s and 2000s (49, 50). As renowned AIS historian and scholar Greg Blood (51) shared, "*It (AIS) has now changed from an elite sport training centre with the mantra of 'athlete- centred, coach-driven' to a centre where sports and their coaches and athletes are clients or customers to AIS facilities and services.*" The current AIS model which garners substantial federal funding despite not delivering sport programs and offering athlete scholarships, continues to administer federal funding and hosts "user-pay" camps for NSOs, features a small cohort of "national discipline leads" specific to each sport science/sports medicine discipline who provide guidance across the broader network of providers within NSOs and the SIS/SAS, and provides guidance and grants specific to high performance coaching, performance pathways and athlete wellbeing and engagement which is limited to recognised sports and nationally categorised athletes, and not below (52).

High-performance funding for recognised Olympic NSOs overseen by the AIS, is over a four-year span in accordance with the Olympic cycle and the collective investment is smaller in magnitude than the United Kingdom, as will be discussed later. NSOs are required to submit annual plans to the AIS and report on their achievement of key performance indicators specific to their high-performance operations only (e.g., international level performances) and not inclusive of their underpinning but critically important talent pathways and operations. To support the achievement of these short-term high-performance targets and ensure ongoing federal funding, the predominant spend of NSOs are within the high-performance levels inclusive of its *performance pathways* that supports nationally categorised athletes only, and not supporting sustainable talent promotion of emerging athletes below a nationally categorised level.

Additionally, NSO's are required to align and coordinate several underpinning state and territory, regional and local level organisational partners and across the sport continuum from early participation to high performance [see **Figure 5** specific to the sporting landscape within the state of New South Wales]. Without an effective and evolving "whole of sport" strategy and the compliance, alignment, and collaboration of system stakeholders, it can be challenging and inefficient. Since the advent of the *Winning Edge* policy, the *FTEM* (Foundation, Talent, Elite and Mastery) athlete development framework (41, 54) developed within the AIS and operationalised through the 3D-AD (Three Dimensional Athlete Development) model [see Gulbin and Weissensteiner (55) and Weissensteiner (54, 56) for more information], has been utilised extensively by many national, state, and regional sporting organisations, to inform the review and refinement of their "whole of sport" planning, implementation and evaluation inclusive of talent promotion [see Weissensteiner (54),]. A notable adopter of this approach is Swimming Australia. Since 2014, Swimming Australia has implemented and evolved the *Australian Swimming Framework* (ASF) to support its operational alignment, effectiveness and success (57). At the recent 2021 Tokyo Olympics Australian swimmers won nine gold medals, more than half of Australia's overall tally of seventeen (58). Whilst Swimming Australia amongst other NSOs have embraced and committed to this "whole of sport" planning approach, it is not a mandated requirement by the AIS, nor Sport Australia for recognised sports.

At a federal policy level, Australia has lacked for some time a dedicated national coaching strategy spanning the *trichotomy* of sport (i.e., participation, talent, and high performance). Like the current federal sport strategy *Sport 2030: Participation, Performance, Integrity, Industry* (59) and funding of NSOs, there has remained for some time, an uncomfortable juxtaposition between supporting the community base of coaching and high-performance, with coaches within the critical talent pathways lacking advocacy, funding, resources, and support. The ASC has recently re-invigorated its approach to educating and supporting community level coaches which shows great promise. The AIS

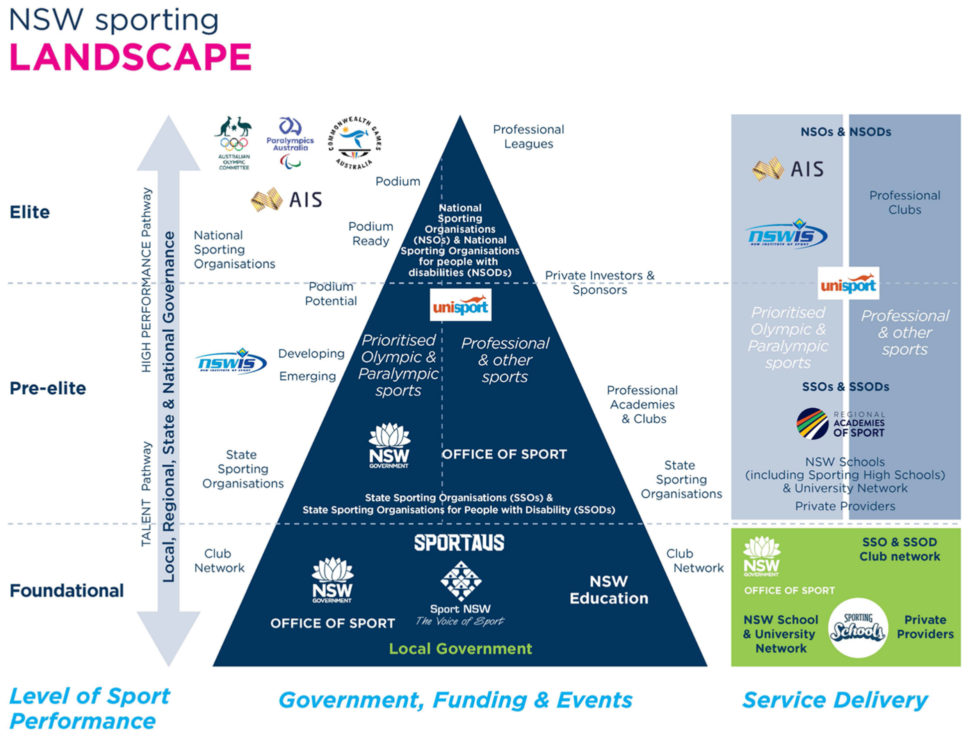

FIGURE 5
Sporting sector landscape of New South Wales (53). Image reproduced courtesy of New South Wales Office of Sport.

currently provides grants to NSOs to support the acquisition of coaches within its performance pathway and high-performance levels and grants to support coach professional development, but this is limited to coaches of nationally categorised athletes and not below that. Coaches within the critical talent levels operating at a local, regional, and state level are commonly poorly renumerated or volunteer, work mostly on a part-time or casual capacity, and have limited access to ongoing professional development. Within the state of New South Wales and guided by *the FTEM NSW Participant and Athlete Development Framework* (60, 61), the NSW Office of Sport released its *Future Champions* strategy in December 2019 (53) and in early 2022 it's *Phase One Action Plan* (62) - the first state-level, systems strategy dedicated to building and sustaining the foundational and talent pathways of sports. A key priority of this initiative alongside facilitating system leadership and a best practice approach to talent promotion is boosting the capability and capacity of coaching talent within NSW.

Closing comments

With Australia's next home Olympics, Brisbane 2032 on the horizon, enthusiastic discussion specific to revisiting its national approach to talent promotion has been re-invigorated. Former Chief Executive of the Australian Sports Commission and respected advocate Jim Ferguson, contends that the ASC and the AIS must return to the roles defined for them in the Australian Sports Commission Act 1989 and that NSOs be supported in developing and implementing "whole of sport" plans and strategies inclusive of best practice talent promotion [see Ferguson (63, 64)]. Further discussion specific to the viability of National Lottery funding (much like that of the United Kingdom) to further invest into Olympic talent and performance pathways may be reinvigorated (65, 66).

A keen observer (amongst many) of Australia's journey has been the United Kingdom. In the next section, we chronicle the evolution of its national talent promotion system and its linkage with the former systems.

United Kingdom

Empowered through strong leadership, shared vision, sustainable investment, effective coordination and firm governance and benefitting from learnings stemming from the Australian system (which was in turn influenced by the former German Democratic Republic), the United Kingdom possesses arguably one of the most advanced and successful talent promotion systems in the world, contributing to its perennial high-performance success over the last four Olympic cycles (see **Figure 1**). As Dennis and Crix (2) observed, "*While no commentators would agree that the contemporary UK elite sport system is based upon or moving towards a version of the East German one, many would concede that the UK looked for inspiration to the successful Australian system, which was itself modelled to a great extent on the GDR template. Thus, we have the 'transfer' of ideas, techniques, and structures – such as the need for a systematic talent identification programme – that derive from the GDR, are then interpreted and* *implemented in Australia, and later influence and are incorporated into the UK's understanding of what it takes to achieve elite success*" (p. 175).

In the following section, we chronicle the evolution and highlight the core components of this leading national talent promotion system.

Historical background and genesis

Like Australia, the impetus for change and the need for direct national governmental intervention to systemise talent promotion in the United Kingdom, was declining Olympic level performance. At the 1996 Atlanta Olympics, the United Kingdom won a solitary gold medal and placed 36th on the medal table. In direct response, then Prime Minister, John Major oversaw a substantial review and restructure of the sports system including the establishment of its high-performance agency, UK Sport, in January 1997 and home nation sport councils.

Further justification for change, came in July 2005 when the United Kingdom was successful in its bid to host the 2012 London Olympics. In 2006, UK Sport under the leadership of its inaugural chair, Sue Campbell established and committed to operating and mandating its *World Class Performance Pathway* inclusive of progressive levels, *World-Class Talent* (i.e., athletes considered to be eight years away from reaching podium), *World-Class Development* (i.e., athletes four to six years away from podium) and *World-Class Podium* (i.e., athletes four years and less from podium) and a "*no-compromise*" approach to funding its numerous Olympic and Paralympic National Governing Bodies (NGBs) contingent upon strict planning and review requirements, results from the prior Olympics, its competitive track record, projected medal capability and demonstrated ability to produce athletes through the pathway inclusive of the talent levels, articulated more recently within its *Code for Sports Governance* (67). Sue Campbell proclaimed, "*… UK Sport will take full responsibility for identifying and then supporting our most talented athletes, streamlining the system, and giving all Olympic and Paralympic sports a 'single front door' for funding and support. In a devolved world that is as close to the single agency model as you are ever going to get*" (68).

It is pertinent to note that concurrent to her role as chair of UK Sport, Sue Campbell, a former teacher who was equally passionate about the role that schools play in facilitating physical literacy and its contribution to "academic literacy", was the inaugural Chief Executive of the Youth Sport Trust (YST), a charity championing youth engagement in physical education and sport in schools and clubs. Like its Australian predecessor *Aussie Sport*, the program featured a dedicated national physical education curriculum implemented across the national school network, provided ongoing professional development opportunities for teachers and coaches, and established an athlete leadership program *Our Changing Lives* (69). Additionally, the YST developed and implemented the *National Physical Literacy Framework* and award-winning *Girls Active campaign* in 2014 and continues to host the *UK School Games* a four-day multi-sport national event for emerging school-aged athletes (69).

Since 2006, UK Sport has served as the leading high-performance agency in the United Kingdom, providing centralised strategic support on behalf of the system, oversees the establishment and periodic review of an NGB's "*whole of sport*" operational plan inclusive of its talent strategy, development of world-class coaches and pathway managers and delivery of targeted talent identification and development campaigns, all of which will be discussed in detail later in this section. It's "*no compromise approach*" received criticism domestically, with critics saying it (the United Kingdom system) had "*…gone too far and (was) damaging grassroots sport*" particularly in sports such as basketball that historically received less funding and support (70).

Affiliates of UK Sport from within each of the four home nations include Sport England, Sport Scotland, Sport Wales and Sport Northern Ireland all of which support grass roots participation and community sport but also talent pathways and high-performance through their respective national centres of excellence (e.g., English Institute of Sport, Scottish Institute of Sport, Northern Irish Institute of Sport and the Welsh Institute of Sport) who in turn, support a network of underpinning regionally based institutes or academies. UK Sport and each of these home country agencies are entrusted with managing the United Kingdom's governmental investment into the sport system sourced from its exchequer (tax) and the National Lottery (71). This ongoing investment funds the operations of UK Sport including its coaching and performance pathways initiatives, is administered as grants for recognised NGBs and payments to athletes including the Athlete Personal Award (APA) and supports multi-disciplinary sport science/medicine and performance lifestyle support for athletes.

Funding to prioritised NGBs is spread over the four-year Olympic cycle but within the context of a twelve-year projection to support long-term system sustainability and growth. Unlike the Australian system, the allocated investment into the talent and performance pathways levels of Olympic NGB's is effectively "ring fenced" - dedicated solely to supporting this critical and recognised component of the high-performance system.

In establishing its system, UK Sport fervently recruited "expertise" - administrators, sports scientists, and coaches from across the globe, including from Australia. Notable appointments included Wilma Shakespear, former head coach of the AIS netball program and director of the Queensland Academy of Sport who became the inaugural director of the English Institute of Sport, her husband Peter Shakespear recognised earlier, who established British Rowing's highly successful *World Class Start* talent identification and development program, former AIS head swimming coach Bill Sweetenham who became national performance director of British Swimming (2000–2007), his successor at British Swimming (2007–2013) former AIS director (2001–2005) and inaugural director of the NSW Institute of Sport, Michael Scott, talent practitioner Chelsea Warr a physiologist who formerly worked within Australia's National Talent Search program [see Hoare and Warr (72)] and rowing coach Paul Thompson recognised earlier within this chapter.

The national sport agency of each home nation in partnership with its high-performance institute, oversee the implementation of their respective talent pathways plans (*Performance Foundations*) which underpins and contributes directly to UK Sport's

Performance Pathway (see Sport England's 2018 released *Talent Plan for England – Creating the world's best talent system* as an example).

Unlike the Australian system, the investment into each home country's talent system and plan is substantial. For instance, within Sport England's Talent Plan (73), £85 million pounds were invested into its talent system (2017–2021 funding cycle) which directly supported England Talent Pathways (ETPs) that contribute to both national and commonwealth high-performance outcomes, within forty-three sports. The scale and breadth of operations is substantial - supporting approximately 60,000 athletes directly within ETP programmes and 200,000 emerging youth athletes within its underpinning entry level talent programs who receive coaching and competition support (73). Athletes supported through the ETP, are eligible for the Talented Athlete Scholarship Scheme (TASS), a Sport England-funded partnership between NGBs and educational institutions to provide dual career support.

Supporting the talent pathway within each home nation, are their network of schools (including a small number of specialised sports schools), colleges and universities which provide athletes with valuable participation and competitive opportunities within their respective sports clubs and teams and access to facilities and coaching. Additionally, each NGB has a network of affiliated clubs that "…*provide and facilitate the 'daily training' facilities, camaraderie, coaching and governance structures necessary to support talented athletes*" (73).

Consolidated talent identification and development strategy

After working within British Swimming as a Talent Identification manager, Australian Chelsea Warr joined UK Sport in 2005 and led the formulation of its *Talent Identification and Performance Pathways* section, later becoming Director of Performance. Through Chelsea's leadership and exploration of expertise within other "performance" domains such as medicine, the team established and mandated across the system, a methodical multi-staged process for supporting effective talent identification and development (comparable to that advocated through the talent levels of Australia's FTEM Athlete Development Framework).

Following successful submission of their application, athletes were required to attend one of many dedicated testing centres and undergo two phases of *talent identification.* The first phase involved anthropometric and physiological testing and consideration of an athlete's training and competitive history. The second phase, involved follow-up sport-specific testing to ascertain an athlete's sport suitability, undergo a functional movement screening, and psychological and behavioural assessments. The successful athlete was then required to go through a dedicated *confirmation* phase whereby they were formally inducted and embedded within a dedicated daily training environment for their sport for 6–12 months to verify their readiness, commitment, and developmental and performance potential. Progressing from this phase, emerging athletes were supported through a longer *development* phase in which they received individualised athlete planning, access to quality coaching and core sport science/medicine services, athlete education, career mentoring and "*performance lifestyle*" support, and access to progressive competition.

Adopting this approach since 2007, UK Sport has successfully delivered seventeen talent initiatives featuring both traditional (i.e., selection of existing talent within a sport) and non-traditional talent recruitment approaches (i.e., talent detection and transfer).

Following Australia's lead, talent transfer or "reassignment" of high-performance athletes into another sport after exiting their prior sport, has proved to be a very fruitful strategy that has translated into "fast tracked" and substantial Olympic success for the United Kingdom. The *Girls4Gold* program was UK Sport's inaugural talent transfer program launched in 2008, whereby British female athletes aged between 17 and 24 years of age, who possessed the attributes of power, strength, speed, and mental toughness, were recruited. Successful athletes were then embedded into well resourced, dedicated developmental programs within the sports of skeleton, canoeing, modern pentathlon, rowing, and sailing. Several Olympic champions have been unearthed through this approach including two-time gold medallist rower Helen Glover who was a former national level athletics representative and hockey player, and fellow rower and former equestrian showjumper Victoria Thornley, who competed at the 2012 London Olympics five years after she was talent identified and won a silver medal at the 2016 Rio de Janeiro Olympics (74). Another notable athlete discovered through the *Girls4Gold* program was former heptathlete Lizzy Yarnold, who became the United Kingdom's most successful Winter Olympian in the sliding sport of skeleton. Lizzy commenced competition in skeleton in 2010, became Junior World Champion in 2013 and then won back-to-back gold medals at the 2014 Sochi and 2018 PyeongChang Winter Olympics (75).

Dedicated tools and ongoing review

UK Sport's Performance Pathways personnel established the dedicated benchmarking tool and evaluative process, known as the *Pathway Health Check*. This tool administered every four years, serves to benchmark against "world's best," identify gaps and opportunities within the sport, which in turn, facilitate discussion and the workshopping of viable solutions with NGB Pathway staff. The focus areas of the tool include "*a gap analysis, athlete profiling, junior to senior transition, retention/attrition rates of athletes in the pathway, confirmation processes and the effectiveness of the development curriculum the athlete receives*" (76). As well as guiding an NGB's pathways strategy and operations, it also provides critical intelligence of the sector for UK Sport to further inform and refine their overarching high-performance strategy and prioritisation. The AIS through its former Athlete Pathways and Development section, developed a similar tool in 2013, the *NSO Pathway Healthcheck* to support the review and refinement of an NSO's pathway strategy and implementation [see Weissensteiner (54)]. A point of difference, however, is that unlike the United Kingdom's tool, there are no funding implications for Australian NSOs.

Dedicated ongoing investment into talent promotion workforce

Supporting the effective implementation, alignment and growth of UK Sport's talent promotion strategy is its ongoing investment into its dedicated "talent workforce" (i.e., NGB pathway managers and coaches) and the fruitful ongoing partnership with its university sector. For many years, UK Sport has directly supported the professional development and support of NGB pathways managers through its dedicated talent curriculum (e.g., *World Class Talent, Confirmation and Development – A framework for talent managers and coaches*), educational and networking opportunities such as pathway symposiums and masterclasses, to instil a best-practice and progressive approach to talent promotion and grow the capability of its workforce. More recently, UK Sport has established an online *Performance Pathways Learning Hub* to support ongoing education.

Coaching is recognised as a central pillar of the United Kingdom's talent promotion system. In 2008, the *UK Coaching Framework* was launched to support an increase in the capability and capacity of coaches at all levels of sport. Sue Campbell declared at its inception in 2008, that "…*its implementation will raise the standard and sustainability of coaching in the UK, promoting a clear pathway for the development of world-class coaching expertise from grassroots to elite level*" (77). Since this time, substantial, ongoing investment into the professional development of its coaching workforce inclusive of those within the talent and performance pathways in its progressive *Foundation, Apprenticeship* and *Elite* programs, has ensued [see UK Sport (77)]. All coaches aligned and supported through the strategy receive individualised education and development, on the job training and feedback, ongoing mentoring, and access to periodic networking opportunities such as conferences and events (77). Concurrently, *UK Coaching*, an active charity which currently supports three million coaches across the United Kingdom, provides best practice education and training, aligned research, and maintains industry standards across sports, communities and NGBs (78). The *Coach Learning Framework* is an exemplary ecological and practical tool developed by UK Coaching to directly support coaching capability and includes advice specific to athlete development but also self -reflective practices, lifestyle, and wellbeing tips (79).

Extending upon the engagement with the university sector that featured within Australia's former National Talent Identification and Development program's "*talent assessment centres*", the United Kingdom's talent promotion system features strong linkage and expansive contribution from its university sector including access to quality sporting infrastructure, training facilities and equipment, athlete testing and personnel, ongoing research and innovation and delivery of core sport science/sports medicine services. The EIS high-performance centre at Loughborough University for instance, supports athletes from a wide range of sports and provides sports science/sports medicine services across the East Midlands of Great Britain in partnership with the Holme Pierrepont Sports Centre in Nottingham (80). Similarly, the EIS high-performance centre based at the University of Bath is the training base for several sports including modern pentathlon, bobsleigh, skeleton, and swimming and supports the delivery of sport science/sports medicine services across the southwest of Great Britain complementing services provided in Weymouth (sailing) and Plymouth (diving) (80).

Research and innovation informing strategy and practice

UK Sport has invested substantially into ongoing research and innovation to enhance its approach and delivery of talent promotion. For example, the *Great British Medallists* research project, commissioned by UK Sport and led by Bangor University's Institute for the Psychology of Elite Performance, was implemented to gain an evidence-based understanding of world class athlete development by exploring the developmental histories of thirty-two former British Olympic athletes, half of which were categorised as "*super elite*" (i.e., won an Olympic or World Championship gold medal and another medal at that level) and the other half, "*elite*" athletes (i.e., had not won a medal at that level but were recognised and supported high performance athletes) [see Rees et al. (81)]. Insights garnered from the project further informed UK Sport's pathway strategies and implementation including the professional development of its coaches, performance directors, pathway managers, and other officials supported through the World Class Programme.

Final comments

Capitalising on the keen observations and learnings from the former German Democratic Republic and Australian systems and unashamedly reliant upon substantial ongoing federal government investment, the United Kingdom through its enduring and effective leadership and structures, firm governance, dedicated high performance plans inclusive of the underpinning talent pathways and coordinated and collaborative capable network, has developed a world-class system of sustainable talent promotion, admired across the globe.

Discussion – looking to the future

In this chapter we explored the growth of national level talent promotion by chronicling the emergence and contributions of the former German Democratic Republic, Australia and the United Kingdom. As our exploration revealed, despite their apparent differences in political ideology, intent and ethics, there were key strategic and operational similarities and linkage between the systems. Whilst it is quite evident that this transference or "mirroring" of policy and operational elements has occurred between these national systems, successful adaptation and implementation within the "recipient" country is contingent upon and enabled through, the "right fit" of leadership (and courage!), expertise and innovation. As Gulbin (29) states, "…*international sporting systems are becoming more uniform than different. This suggests that there are few secrets in elite sport, but rather the point of differentiation being a nation's ability to optimally coordinate these common components*" (p. 147).

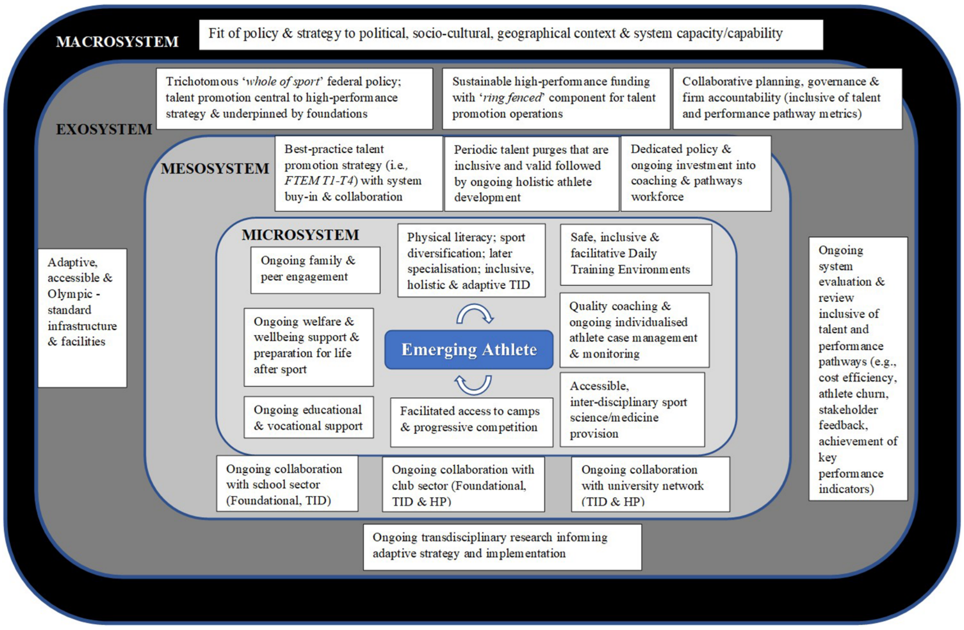

FIGURE 6
System level and integrated framework to support effective national talent promotion.

Declining physical literacy and youth sport participation incurred by the Covid-19 global pandemic (82) present ongoing challenges for current and future talent promotion, that must be recognised, and future policy and implementation must consequently be adaptive.

In addition to analyses of efficiency and cost-benefit at a national level [see Güllich & Emrich (4, 14)], it is strongly advocated that future researchers adopt ethnographic, ecological, and transdisciplinary approaches [see Toohey et al. (83)] to evaluate national-level talent promotion from a systems-management perspective (i.e., in their operational entirety inclusive of each level and relative integration) and not compartmentalised (i.e., focussed on one discrete aspect within one level).

Whilst this chapter has focussed on well-resourced nations characterised by substantial capacity, we contend that its key learnings, offer good guidance for any policy makers and practitioners assisting with the review and refinement of their respective national systems. Based on our collective learnings of the prior system and considerate of contemporary issues, we provide in **Figure 6** for consideration, a systems framework outlining key aspects (i.e., strategic, operational etc.) at a macro, exo, meso and micro level to support effective and sustainable national-level talent promotion.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Acknowledgments

The preceding chapter is dedicated to the founding pioneers of the modern Australian sport system – the late Bob Ellicott, the late Frank Stewart, the late John Daly, the late John Bloomfield, Jim Ferguson, the late Frank Pyke, the late Don Talbot, Greg Hartung, Frank Cotton, Peter Fricker, Allan Hahn, Dick Telford, Jeff Bond, Bruce Mason, Craig Purdham, Louise Burke, the late Doug Tumilty, Deborah Latouf (nee Hoare), Jason Gulbin, Chelsea Warr, David Martin, Damian Farrow, the late Heiko Salzwedel and the late Keith Lyons. Thank-you to Andrew Putt, Mia Jenkins, Phil Hamdorf, Andrew Logan and Todd Faulds for your advice and support.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

1. De Bosscher V, Bingham J, Shibli S, van Bottenburg MD, Knop P. *The global sporting arms race: An international comparative study on sports policy factors leading to international sporting success*. Oxford, UK: Meyer & Meyer Sport (UK). Ltd (2008).

2. Dennis M, Crix J. *Sport under communism: behind the east German 'miracle'*. England: Palgrave Macmillan: Hampshire (2012).

3. Bergeron MF, Mountjoy M, Armstrong N, Chia M, Côté J, Emery CA, et al. International Olympic committee consensus statement on youth athletic development. *Br J Sports Med*. (2015) 49:843–51. doi: 10.1136/bjsports-2015-094962

4. Güllich A, Emrich E. Investment patterns in the careers of elite athletes in east and west Germany. *Eur J Sport Soc*. (2013) 10(3):191–214. doi: 10.1080/16138171.2013.11687919

5. Pfister G. A world power in women's sport – women without power in sport: Gender, power, and sport in East Germany (2003). Available at: www.idrottsforum.org (Retrieved June 16, 2022)

6. Sandner H. Core elements of successful elite sport systems - The example of GDR elite sport and modern national elite sport systems of today (2004). Available at: https://www.jpnsport.go.jp/jiss/portals/0/jiss-conf-2004/pdf/p0087-p0136_sandner.pdf (Retrieved June 16, 2022).

7. Coles B.C. *The east German sport system: image and reality* [*Doctoral dissertation*]. Texas: Texas Tech University (2000). Available at: http://hdl.handle.net/2346/21865 (Retrieved April 15, 2022).

8. Petry K, Steinbach D, Burk V. Germany. In: B Houlihan, M Green, editors. *Comparative elite sport development: systems, structures, and public policy*. Oxford, United Kingdom: Butterworth-Heinemann (2008). p. 115–46.

9. Hallmann K, Breuer C, Disch J, Giel T, Nowy T. The German sport industry. In: JJ Zhang, H Huang, J Nauright, editors. *Sports business in leading economies*. United Kingdom: Emerald Publishing (2018). p. 165–203.

10. Güllich A. Evaluation of institutional support programmes for young athletes in elite sport systems. In: R Valleala, editor. *Science for Success – The Way to the Top*. Jyvaeskylae: KIHU (2011). p. 26–30.

11. Barker P. The German Democratic machine that ruled the world (2019). Available at: https://www.insidethegames.biz/articles/1086540/german-democratic-republic-fall (Retrieved August 3, 2022).

12. Pitsch W, Emrich E, Klein M. Doping in elite sports in Germany: results of a www survey. *Eur J Sport Soc*. (2007) 4(2):89–102. doi: 10.1080/16138171.2007.11687797

13. Güllich A, Flatau J, Emrich E. *Effectiveness versus efficiency: orientation in the athletic careers of east and west German elite athletes. 9th Conference of the European association for sociology of sport. Book of abstracts* (2012). p. 58

14. Güllich A, Emrich E. Evaluation of the support of young athletes in the elite sports system. *Eur J Sport Soc*. (2006) 3(2):85–108. doi: 10.1080/16138171.2006.11687783

15. Emrich E, Fröhlich M, Klein M, Pitsch W. Evaluation of the elite schools of sport: empirical findings from an individual and collective point of view. *Int Rev Sociol Sport*. (2009) 44:15. doi: 10.1177/1012690209104797

16. Vaeyens R, Güllich A, Warr CR, Philippaerts R. Talent identification and promotion programmes of Olympic athletes. *J Sports Sci*. (2009) 27(13):1367–80. doi: 10.1080/02640410903110974

17. Population Australia. Australia Population, 2022 (2022). Available at: https://www.population.net.au/ (Retrieved June 29, 2022).

18. Thomas S. Which Olympic nations are doing best on the per capita medal tally (2021). Available at: https://www.theroar.com.au/2021/08/03/which-olympic-nations-are-doing-best-on-the-per-capita-medal-tally (Retrieved November 21, 2021).

19. Bloomfield J. *Australia's sporting success: the inside story*. Sydney, Australia: University of NSW Press Ltd (2003).

20. Sport Australia Hall of Fame. Percy Cerutty (2022). Available at: https://sahof.org.au/hall-of-fame-member/percy-cerutty/ (Retrieved June 29, 2022).

21. Jolly R. *Sports funding: federal balancing act*. Parliament of Australia: Parliamentary Library (2013).

22. Nihill G, Drane R. *Australian Institute of sport: celebrating excellence*. Bondi, NSW, Australia: Focus Publishing (2006).

23. Blood G. History of AIS support of regional athletes in Australia. Australian Sport Reflections (2021). Available at: https://australiansportreflections.com/2021/02/09/history-of-ais-support-of-regional-athletes-in-australia/ (Retrieved November 21, 2021).

24. Ferguson J. *More than sunshine & vegemite: success the Australian way*. Broadway, New South Wales, Australia: Halstead Press (2007).

25. Blood G. Contribution of Overseas Coaches to the AIS and Australian Sport. Australian Sport Reflection (2020). Available at: https://australiansportreflections.com/2020/08/11/contribution-of-overseas-coaches-to-the-ais-and-australian-sport/ (Retrieved April 16, 2022).

26. Arnold R. Remembering Heiko Salzwedel: A coach to many and a champion of cycling. Sydney, Australia: Ride Media (2021). Available at: https://www.ridemedia.com.au/features/remembering-heiko-salzwedel-a-coach-to-many-and-a-champion-of-cycling/ (Retrieved May 9, 2022).

27. Blood G. The Australian Institute of Sport Story 1981-2013. Australian Sport Reflections (2020). Available at: https://australiansportreflections.com/2020/04/29/the-australian-institute-of-sport-story-1981-2013/ (Retrieved April 16, 2022).

28. News Limited. *2000 Australian Olympic team handbook and Media guide*. Sydney, Australia: Harper Collins Publishers (2000).

29. Gulbin JP. Applying talent identification programs at a system-wide level: the evolution of Australia's National program. In: J Baker, S Cobley, J Schorer, editors. *Talent identification and development in sport: international perspectives*. London: Routledge (2012). p. 147–65.

30. Bloomfield J, Blanksby BA. Strength flexibility and anthropometric measurements: a comparison of highly successful male university swimmers and normal university students. *Aust J Sport Med*. (1971) 3:8–15.

31. Bloomfield J. Talent identification and profiling. In: J Bloomfield, PA Fricker, KD Fitch, editors. *Textbook of science and medicine in sport*. 1st ed. Melbourne: Blackwell Scientific Publications (1992). p. 187–98.

32. Hahn A. Identification and selection of talent in Australian rowing. *Excel*. (1990) 6 (3):5–11. ISSN: 0817-4792

33. Hahn A. *Lesson learnt from rowing TID – AIS performance research centre. Presentation delivered at NTID national conference, Australian institute of sport* (2010).

34. Slot O, Timson S, Warr C. *The talent lab: how to turn potential into world-beating success*. Random house, United Kingdom: Ebury Press (2018).

35. Abbott AJ. *Talent identification and development in sport* [*Doctoral dissertation*]. Scotland: The University of Edinburgh (2006).

36. Australian Institute of Sport. AIS Sports Draft 2013-2016 Review: Recommendations to Improve Talent Transfer Initiatives within Australian Sport. [Stakeholder report] (2016).

37. Australian Sports Commission. *Sport search: the search is over. A sports counselling program*. Canberra, Australia: Australian Sports Commission (1993).

38. Australian Sports Commission. Establishment of the National Talent Identification & Development Program: July 2006 to August 2007. [Stakeholder report] (2007).

39. Australian Sports Commission. National Talent Identification and Development in Three: A three-year snapshot of the NTID program 2006-07 to 2008-09. [Stakeholder report] (2009).

40. Australian Sports Commission. NTID Year in Review: July 2009-June 2010. [Stakeholder report] (2010).

41. Gulbin JP, Croser MJ, Morley E, Weissensteiner JR. An integrated framework for the optimisation of sport and athlete development: a practitioner approach. *J Sports Sci*. (2013) 31(12):1319–31. doi: 10.1080/02640414.2013.781661

42. Hoare D. Talent search: the national talent identification and development program. *Sport Health*. (1995) 13(2):10–2. ISSN: 1032-5662

43. Hoare D. The Australian national talent search program. *Coaching Director*. (1996) 8(3):33–5. ISSN: 0814-7752

44. Tomkinson GR, Olds TS, Gulbin J. Secular trends in physical performance of Australian children: evidence from the talent search program. *J Sports Med Phys Fitness*. (2003) 43(1):90–8. ISSN: 0022-4707

45. Australian Sports Commission. *Aussie sports: developing young people through sport*. 2nd ed. Canberra, Australia: Australian Sports Commission (1993).

46. Australian Sports Commission. Aussie Sports. Clearinghouse for Sport (2020). Available at: https://www.clearinghouseforsport.gov.au/kb/aussie-sports (Retrieved November 20, 2022).

47. Australian Sports Commission. Australia's Winning Edge: 2012-2022: Our game plan for moving from world class to world best. [Policy document] (2012).

48. Queensland Academy of Sport. Youfor2032 (2022). Available at: https://youfor2032.initiatives.qld.gov.au (Retrieved July 1, 2022).

49. Harvey R. Further reflections on the AIS (2021). Available at: https://australiansportreflections.com/2021/03/01/further-reflections-on-the-ais/ (Retrieved November 21, 2021).

50. Lowry T. AIS begins 'painful' journey to change, as jobs go in bid for more Olympic success. ABC News (2018). Available at: https://www.abc.net.au/news/2018-05-08/ais-jobs-go-in-the-bid-for-more-olympic-success/9737256 (Retrieved April 18, 2022).

51. Blood G. Australian Sport Reflections (2022). Available at: https://australiansportreflections.com/ (Retrieved November 21, 2021).

52. Australian Institute of Sport. New AIS grant program a learning pathway to success (2020). Available at: https://www.ais.gov.au/media-centre/news/new-ais-grant-program-a-learning-pathway-to-success (Retrieved on April 18, 2022).

53. NSW Office of Sport. Future Champions strategy (2022). Available at: https://www.sport.nsw.gov.au/sites/default/files/2021-04/future-champions-strategy-full-version_0.pdf (Retrieved April 16, 2022).

54. Weissensteiner JR. How contemporary international perspectives have consolidated a best-practice approach for identifying and developing sporting talent.

In: J Baker, S Cobley, J Schorer, N Wattie, editors. *Routledge handbook of talent identification and development in sport*. London: Routledge (2017). p. 131–47.

55. Gulbin JP, Weissensteiner JR. Functional sport expertise systems. In: D Farrow, J Baker, C MacMahon, editors. *Developing sport expertise: researchers and coaches put theory into practice*. 2nd ed. London: Routledge (2013). p. 45–67.

56. Weissensteiner JR. Method in the madness - working towards a viable 'paradigm' for better understanding and supporting the athlete pathway. In: J Baker, S Cobley, J Schorer, N Wattie, editors. *Routledge handbook of talent identification and development in sport*. London: Routledge (2017). p. 50–67.

57. Swimming Australia (2022). Australian Swimmers Framework. https://www.swimming.org.au/community-1/coaches/australian-swimming-framework (Retrieved February 14, 2022).

58. Graham B. Kieren Perkins explains the stunning resurrection of Australian swimming after historic Tokyo Olympics gold rush. Nine Wide World of Sports (2021). Available at: https://wwos.nine.com.au/olympics/tokyo-olympics-2021-australian-swimming-emma-mckeon-ariarne-titmus-kieren-perkins-exclusive/2222aa21-0674-4648-9f43-bded1a994d59 (Retrieved July 2, 2022).

59. Australian Government. *Sport 2030: participation, performance, integrity, industry*. Canberra, Australia: Department of Health, Commonwealth of Australia (2018). [Policy document].

60. NSW Office of Sport. FTEM NSW (2022). Available at: https://www.sport.nsw.gov.au/pathways-and-development/ftem-nsw (Retrieved April 16, 2022).

61. Weissensteiner J.R. The FTEM NSW Participant and Athlete Framework: System Guidelines and Considerations - The Talent Levels (2021). Available at: https://www.sport.nsw.gov.au/pathways-anddevelopment/FTEM-NSW (Retrieved November 22, 2022).

62. NSW Office of Sport. Future Champions Phase One Action Plan (2022). Available at: https://www.sport.nsw.gov.au/sites/default/files/2022-03/Future%20Champions%20Phase%20One%20Action%20plan%20220222.pdf (Retrieved April 29, 2022).

63. Ferguson J. Effective sporting organisations: a Practitioner's Perspective. *Open J Soc Sci*. (2021) 9:167–211. https://doi.org/10.4236/jss.2021.912013. doi: 10.4236/jss.2021.912013

64. Ferguson J. Effective Sporting Organisations: Nine Pillars, 138 Critical Success Factors using the SPLISS Model. Australian Sport Reflections (2022). Available at: https://australiansportreflections.com/2022/03/16/effective-sporting-organisations/ (Retrieved June 27, 2022).

65. Fairfax Media. ASC boss John Wylie pushes 'responsible' lottery to fund Olympic success. Sydney, Australia: The Sydney Morning Herald (2018). Available at: https://www.smh.com.au/sport/asc-boss-john-wylie-pushes-responsible-lottery-to-fund-olympic-success-20161128-gsytq0.html (Retrieved June 29, 2022).

66. Hartung G. The idea of an Australian national sports lottery has a long and disappointing history … but history has proved no impediment to old arguments in the quest for the non-government dollar. Australian Sport Reflections (2022). Available at: https://australiansportreflections.com/2022/02/14/sports-lottery/ (Retrieved June 27, 2022).

67. UK Sport. A code for sports governance (2022). Available at: https://www.uksport.gov.uk/resources/a-code-for-sports-governance (Retrieved May 9, 2022).

68. UK Sport. UK Sport response to raising the bar (2006). Available at: https://www.uksport.gov.uk/news/2005/09/22/uk-sport-response-to-raising-the-bar (Retrieved November 21, 2022).

69. Youth Sport Trust. Our story (2020). Available at: https://www.youthsporttrust.org/about/what-we-do/our-story (Retrieved April 18, 2022).

70. Halliday J. Brutal but effective – Why team GB is winning so many Olympic medals. The Guardian (2016). Available at: www.theguardian.com/sport/2016/aug/15/brutal-but-effective-why-team-gb-is-winning-so-many-olympic-medals (Retrieved May 8, 2022).

71. UK Sport. How UK Sport Funding Works (2022). Available at: https://www.uksport.gov.uk/our-work/investing-in-sport/how-uk-sport-funding-works (Retrieved May 9, 2022).

72. Hoare D, Warr CR. Talent identification and women's Soccer: an Australian experience. *J Sports Sci*. (2000) 18:751–8. doi: 10.1080/02640410050120122

73. Sport England. The talent plan for England and creating the world's best talent system (2018). Available at: the-talent-plan-for-england.pdf (sportengland-production-files.s3.eu-west-2.amazonaws.com) (Retrieved July 3, 2022).

74. UK Sport. First 'Sporting Giants' selected for Team GB in Rowing (2012). Available at: https://www.uksport.gov.uk/news/2012/06/06/first-sporting-giants-selected-for-team-gb-in-rowing (Retrieved May 9, 2022).

75. UK Sport. Olympic Champion Lizzy Yarnold launches search for future (2013). Available at: https://www.uksport.gov.uk/news/2014/03/03/olympic-champion-lizzy-yarnold-launches-search-for-future-skeleton-stars (Retrieved May 9, 2022).

76. UK Sport. UK Coaching Framework launched (2008). Available at: https://www.uksport.gov.uk/news/2008/04/22/uk-coaching-framework-launched (Retrieved November 21, 2022).

77. UK Sport. Coaching (2022). Available at: https://www.uksport.gov.uk/our-work/coaching (Retrieved May 10, 2022).

78. UK Coaching. About UK Coaching (2022). Available at: https://www.ukcoaching.org/about/about-us (Retrieved July 3, 2022).

79. UK Coaching. Coach Learning Framework (2022). Available at: https://www.ukcoaching.org/coach-learning-framework (Retrieved November 18, 2022).

80. English Institute of Sport. EIS Centres (2022). Available at: https://eis2win.co.uk/services/centres/ (Retrieved July 3, 2022).

81. Rees T, Hardy L, Güllich A, et al. The great British medallists project: a review of current knowledge on the development of the world's Best sporting talent. *Sports Med*. (2016) 46:1041–58. doi: 10.1007/s40279-016-0476-2

82. Eime R., Westerbeek H. *Latest sport participation trends and the focus for recovery from COVID-19. Presentation on behalf of VICSPORT* (May 5, 2022).

83. Toohey K, MacMahon C, Weissensteiner J, Thomson A, Auld C, Beaton A, et al. Using transdisciplinary research to examine talent identification and development in sport. *Res Methodol Sport Scholarship. Sport in Society*. (2018) 21(2):356–75. doi: 10.1080/17430437.2017.1310199

TYPE Original Research
PUBLISHED 06 October 2022
DOI 10.3389/fspor.2022.1031227

OPEN ACCESS

EDITED BY
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SPECIALTY SECTION
This article was submitted to Elite Sports and Performance Enhancement, a section of the journal Frontiers in Sports and Active Living

RECEIVED 29 August 2022
ACCEPTED 20 September 2022
PUBLISHED 06 October 2022

CITATION
Hancock DJ, Vierimaa M and Newman A (2022) The geography of talent development. *Front. Sports Act. Living* 4:1031227. doi: 10.3389/fspor.2022.1031227

The geography of talent development

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Geography (i.e., birthplace) is one of many factors that influence talent development. When one's birthplace leads to advantages in sport participation or performance, it is called a birthplace effect. Nearly two decades of committed research has revealed that birthplace effects are pervasive across sports and countries. Recently, researchers have attempted to better understand birthplace effects by considering various metrics that serve as proxies for birth advantages; for instance, population size, population density, and proximity to sport clubs. Underlying mechanisms that explain birthplace effects include infrastructure (e.g., environment and facilities) and social structure (e.g., family and safety), though contextual differences across existing research (e.g., sports and countries) make it difficult to fully explain the effects. Herein, we provide more depth regarding these elements of birthplace effects, while also presenting new data on "talent hotspots"; that is, communities with optimal population *and* density for talent development.

KEYWORDS
birth, birthplace, youth, community, social

Introduction

When considering the factors that influence elite talent development in sport, most would point to genetics, intrinsic motivation, passion, and work ethic. Perhaps fewer people might identify other contributing factors such as coaching and birthdate. Often overlooked, albeit quite important, is the influence that geography (i.e., birthplace) has on talent development. A seminal study by Côté et al. (1) firmly placed birthplace effects on sport scientists' research agendas, leading to dozens of studies on the topic conducted since then. In this chapter, we will outline some of these studies to showcase what is known about birthplace effects in sport. Following, we will describe some of the variability in birthplace effects results, identify weaknesses and gaps related to birthplace effects research, and explain some recent findings on "talent hotspots."

The birthplace effect

The process to identify birthplace effects is relatively simple. First, a sample of athletes is selected for examination (e.g., handball players in Spain). Second, the athletes are placed into various categories, based on the population of their birthplaces (e.g., 25,000–49,999). Next, the percentage of athletes in each category is calculated (e.g., 12% of athletes in the sample were born in the 25,000–49,999 category). Following, the percentage of the general population born in each population category is calculated (e.g., 5% of the general population is born in the 25,000–49,999 category). Finally, across each population category, the distribution of athletes is compared to the distribution of the general population (e.g., 12 vs. 5% in the 25,000–49,999 category). The mathematical calculations to identify if the distribution differences are "significant" or "meaningful" require more depth of understanding, which goes beyond the necessary description for this chapter. Suffice to say, these steps allow one to conclude if athletes born in a certain population category are (1) more, (2) less, or (3) no more likely to achieve elite sport status.

Though one's birthplace is rather arbitrary, researchers have uncovered birthplace effects spanning countries and sports. Côté et al. (1) conducted one of the earliest studies on birthplace effects, exploring American athletes who reached professional leagues in ice hockey, basketball, baseball, and golf. Regardless of sport, their findings indicated that, compared to any other population category, people born in communities of 50,000–99,999 residents were much more likely to attain professional athlete status (11 times more likely for basketball and golf; 19 times more likely for ice hockey; and 21 times more likely for baseball). Meanwhile, across all sports, people born in cities of 500,000 or more residents were far less likely to attain professional athlete status. Given the findings, the authors proposed that the nature of smaller cities must offer advantages for talent development that are absent in other population categories. They further suggested that the nature of sport in large cities (i.e., stratified competitions, time commitments, expenses, etc…) actually inhibits talent development.

In the years following Côté et al.'s (1) study, there was an influx of research on birthplace effects. Mainly, sport scientists aimed to understand the pervasiveness of the effect to better catalog the role of geography in athletic talent development. Baker and Logan (2), for instance, uncovered birthplace effects for Canadian- and American-born athletes who were drafted into the National Hockey League. Other sports with noted birthplace effects based on population size include volleyball (3), soccer (4), handball (5), gridiron football (6), and cricket (7). Whereas most research focused on male athletes, the effect has been discovered among female athletes as well, specifically for athletes in soccer, golf, basketball, handball, and volleyball (4, 8). Likewise, while most researchers focus on birthplace as a conduit to elite athletic success, other studies have noted the influence of one's place of birth on sport dropout [i.e., more likely to drop out of ice hockey if born in cities with 500,000 or more residents; (9)] and participation [i.e., more likely to participate in team and individual sports if born in communities of 10,000–100,000 residents; (10)]. Strengthening the case that birthplace effects are pervasive, this effect has been found in several countries including Canada (9), United States (1), Portugal (3), Israel (8), Brazil (11), United Kingdom (7), and Germany (10), to name a few.

Variations in birthplace effects

Whereas birthplace effects (as measured by population size) are fairly consistent, there is considerable variability in the advantaged population categories across existing studies. For instance, some studies show optimal birthplaces being communities of 50,000–99,999 residents (1), with others indicating 200,000–399,999 residents (3) or 500,000 or more residents (6) as optimal. Variations in findings are not surprising as the structure of communities varies greatly by continent (e.g., comparing North American and European community structures), and even within one continent (e.g., comparing German and Norwegian community structures). Such variations have spurred birthplace effects researchers to use different metrics to examine trends. One such method is considering population density as opposed to absolute population size, which might be more reflective of the structure of one's community. Hancock et al. (3) advocated for this approach, noting an example comparing Paris and Toronto, which share similar population sizes, but Paris has four times the population density.

Rossing et al. (12) explored birthplace effects among elite male (12 years old and younger) Danish soccer and handball players, using population density as a metric. Therein, the authors reported that soccer players were more likely to be born in high-density communities (>1,000 residents/km^2), yet handball players were more likely to be born in less-dense communities (100–250 residents/km^2). Rossing et al. (13) continued this research by studying elite male (15–21 years old) Danish soccer players, again finding that that high-density communities (>1,000 residents/km^2) produced more players. Similarly, van Nieuwstadt et al. (14) noted that increased urbanity (i.e., population density of one's community) elevates the likelihood of attaining professional status in Dutch male soccer, though the authors noted other variables (e.g., migration status and income) might influence the strength of urbanity effects. Switching sports, Hancock et al. (3) explored professional and semi-professional Portuguese volleyball players. For female players, being born in communities of differing population density did not influence their resulting competitive levels. For male players, however, being born in communities with lower population density (∼300 residents/km^2) increased the likelihood of achieving the highest competitive divisions compared to athletes born in communities with higher population density (∼400 residents/km^2).

Though population density might better reflect community structures, it still seems that results differ based on sport and country. As such, researchers have continued to employ other metrics to explore birthplace effects. These include considering proximity to the nearest soccer clubs (12), the concentration of basketball clubs in a region (11), and distance to larger cities that house developmental ice hockey teams (15). These and previously discussed metrics all yield the same conclusions: it evident that one's birthplace influences talent development in sport—even if the key demographic is different across sports and countries. Thus, it is imperative to understand the mechanisms that underpin the effect.

Hancock et al. (3), and later on Hancock (16), offered two mechanisms to explain birthplace effects. First, *infrastructure* captured environmental structures available to youth athletes that might facilitate talent development. Examples include training facilities, competition venues, available parks and green spaces for unstructured play, and teams or clubs that focus on development rather than winning. Of note, training and competition venues need not be state-of-the-art (often the case in large cities); rather, the venues merely need to be nearby and available for frequent use. Second, *social structure* centers on family and community factors that yield positive sport outcomes. The authors posited that social structure includes autonomy-supportive coaches, involved (but not over-involved) and caring parents, environments where unsupervised youth feel safe, and sport programs that promote positive youth development. The notion that optimal social structures yield favorable birthplace effects was previously intimated by Hancock and Côté (17), who stated that social agents (i.e., parents, coaches, and athletes) significantly influenced birthplace effects through mechanisms related to the self-fulfilling prophecy. Ultimately, communities that offer beneficial infrastructures and social structures are believed to produce more athletes, both at the elite and recreational levels. The proposed explanations—which are guided by logic and critical analysis of literature in similar research fields—provide some insights into birthplace effects. Nevertheless, they lack direct empirical support. To overcome our limited understanding of birthplace effects, it is vital to address the methodologies used in this research field.

Weaknesses and gaps in birthplace methods

In any research venture, robust and varied methods are required to elucidate reliable and meaningful results that lead to strong conclusions regarding the data. The field of birthplace effects, however, suffers from many weaknesses and gaps that render it difficult to extract precise meaning from the research. Several factors contribute to this issue, which are explained herein.

The first such factor is the term "birthplace" itself. Likely due to ease of analysis, birthplace is the accepted proxy from which researchers draw conclusions regarding talent development. This presents several concerns, though developing superior and feasible alternatives has yet to happen. In many sports, it takes 10 or more years of athletic development to attain elite status. For some athletes, their birthplace and their community during the formative developmental years are one and the same. Many other athletes, however, are born in one community and then move to a different community before the age of entry into sport. Similarly, it is not uncommon to hear of athletes who begin their sport careers while living in one community, but then move to a different community after one, five, or even 10 years of development. For all these reasons, the nature of birthplace effects research has inherent limitations. Compounding this, birthplace is typically self-reported. In writing this chapter, the first author asked his son, "What do you consider to be your birthplace?" His son stated one city (population ~1,000,000), though we moved to a different city (population ~125,000) before he was 6-weeks-old. If asked again in 10 years, he might state the latter city as his birthplace, likening it more to a "home town." Since the populations of these two cities are quite different, his response to that question could lead to different interpretations—similar to what one would expect of athlete populations when asked the same question. Not only is birthplace self-reported, but in most instances, data are collected by sport organizations, not researchers. Since there would rarely be a need for sport organizations to differentiate between birthplace and community of development, it likely means that little guidance is given to athletes about what constitutes birthplace. The nature of birthplace as defined and measured in the literature has several limitations that contribute to our lack of understanding of birthplace effects. Researchers would be wise to acknowledge these issues, while also seeking data collection techniques that rely on direct information from participants rather than archival methods.

A second concern relates to the community sizes that constitute each population category in birthplace effects research. Across the globe, many municipal governments have amalgamated to form larger cities with fewer administrative costs and streamlined—or at least centralized—community services. This raises a concern for birthplace effects researchers, who must deliberate on the population categorizations of amalgamated cities. Going back to the first author's son, his actual birthplace was a suburb of the larger city, which had a population of ~25,000. This brings into question what his assigned birthplace population size should be: 25,000 (the size of the suburb) or 1,000,000 (the size of the amalgamated city)? Typically, more accurate results come from specifying suburbs and amalgamated regions, though when reliant on sport organizations to provide birthplace data, researchers must accept whatever data were collected, even if they are not ideal. Again, this points to the need for researchers in this field to consider direct data collection measures, along with clear decision processes for categorizing various community sizes, to improve the validity of their findings.

Recent research overseen by Wattie (15, 18, 19) highlight a third issue with birthplace effects research: assuming cities of equal size and density are homogeneous. Wattie et al. (18) identified that, in 1996, 36% of residents in the Canadian province of Ontario lived in cities of greater than 250,000 people. Meanwhile, in Canada's four Atlantic provinces at that time, no cities existed of that size. In essence, what is considered a medium city in one region could be viewed as a large city in another. Extending this principle, small communities should not be deemed homogeneous simply because they exist in the same country. To illustrate this point, consider the cities of Shelburne, Ontario (~8,000 residents) and Estevan, Saskatchewan (~13,000 residents). Shelburne is certainly a small community, but residents are a two-hour drive or less (assuming little traffic) to nine other centers with 100,000 or more residents. Meanwhile, Estevan is also a small community, but is slightly more than a two-hour drive to the nearest center with 100,000 or more residents. As Wattie et al. (18) and Farah et al. (19) rightly indicated, it is because of differences such as these that communities of equal size should not be treated homogeneously. Instead, researchers must endeavor to explore the underlying infrastructures and social structures that drive birthplace effects, grouping communities together for analysis only when their structures are truly homogeneous.

A final weakness related to birthplace effects is the type of research that is typically conducted. Most often, researchers employ archival methods (e.g., collecting birthplaces from websites) to explore birthplace effects. Such approaches have been vital in identifying the presence of birthplace effects across sports and countries, but they have been less useful for contributing to our understanding of why birthplace effects exist. Instead, researchers ought to seek varied methods for future research including direct participant interactions (as noted above), longitudinal or quasi-longitudinal designs (to track changes over time and shifts in the communities in which athletes live), and qualitative methods (learning about participants' experiences in small, medium, and large communities).

The fact that this section is longer than the preceding ones speaks volumes to how limited our knowledge is of birthplace effects. This is partially because it is a field still in its infancy, but also because several weaknesses in researchers' approaches render it challenging to draw firm conclusions about the field. Hopefully those reading this chapter (students or researchers) take it as a call to action and are inspired to create research designs with the goal of standardizing birthplace effects measures/metrics that lead to meaningful conclusions.

Talent hotspots in North American basketball

The following section aims to draw further attention to some of the gaps in the birthplace effect literature identified above. In response to critiques challenging the homogeneity of communities of particular sizes (18, 19), we present data from a study which investigated potential birthplace effects in men's and women's basketball in the United States at both the collegiate and professional levels.[1] Through the examination of birthplace effects in terms of both absolute population and population density, we aim to identify potential "talent hotspots" that can be used to further advance discussions of the underlying mechanisms driving birthplace effects. In addition, the investigation of birthplace effects in a single sport in both male and female and collegiate and professional levels of competition will help to better understand how the birthplace effect manifests across sport contexts.

Participants

A total of 8,740 American professional and collegiate basketball players were included in the study. Places of birth were collected from the official websites of the National Basketball Association (NBA; $n = 382$), Women's National Basketball Association (WNBA; $n = 120$), Men's Division I National Collegiate Athletic Association (MNCAA; $n = 4{,}030$), and Women's Division I National Collegiate Athletic Association (WNCAA; $n = 4{,}208$) using each team's 2018 rosters.

Procedure

Birthplace data were collected for each of the four leagues, and individuals born outside of the United States were excluded from the analyses. United States census statistics were then used to compare athletes' birthplace information with the general population for both community size and density. To account for the average age differential between the professional and collegiate samples, two separate sets of census data were collected. The 2000 United States census (20) was used for the NBA and WNBA datasets, while the 2010 United States census (21) was used for both the MNCAA and WNCAA.

Data analysis

Communities were categorized into eight groups based on population size: (1) <50,000 residents, (2) 50,000–99,999 residents, (3) 100,000–249,999 residents, (4) 250,000–499,999 residents, (5) 500,000–999,999 residents, (6) 1,000,000–2,499,999 residents, (7) 2,500,000–4,999,999 residents, and (8) ≥5,000,000 residents. For population density, eight groups were used: (1) <50 residents/km^2, (2) 50–99 residents/km^2, (3) 100–249 residents/km^2, (4) 250–499 residents/km^2, (5) 500–999 residents/km^2, (6) 1,000–2,499 residents/km^2, (7) 2,500- 4,999 residents/km^2, and (8) ≥5,000 residents/km^2.

1 In the United States, professional basketball players are drafted from the collegiate ranks.

TABLE 1 Odds ratios (ORs) and confidence intervals (CIs) across city size categories for collegiate athletes.

Community size	US (%)	MNCAA (%)	OR	CI	WNCAA (%)	OR	CI
≥5,000,000	2.58	0.25	0.09	0.05–0.18	1.00	0.38	0.28–0.52
2,500,000–4,999999	4.47	4.15	0.92	0.79–1.08	2.28	0.50	0.41–0.61
1,000,000–2,499,999	7.50	6.63	0.88	0.77–0.99	4.52	0.58	0.50–0.67
500,000–999,999	7.73	10.75	1.44	1.30–1.59	7.73	1.03	0.92–1.16
250,000–499,999	6.03	11.05	1.94	1.75–2.14	10.31	1.79	1.62–1.98
100,000–249,999	11.82	15.35	1.35	1.24–1.47	15.02	1.32	1.21–1.44
50,000–99,999	13.13	12.91	0.98	0.89–1.08	13.36	1.02	0.93–1.11
<50,000	46.74	38.91	0.73	0.68–0.77	44.75	0.92	0.87–0.98

Odds ratios (ORs) were calculated across the different population sizes and densities for each group. ORs and 95% confidence intervals (CIs) were calculated by dividing the chance of being a part of the sample group from a population size or density (e.g., an NBA athlete) by the chance of being from a specific community with that population size or density based on the general population (i.e., Census data). ORs were interpreted based on their positioning above or below 1. An OR above 1 implies that an athlete in that population size or density has a greater likelihood of participating at elite levels compared to an individual from a different population size or density. Conversely, ORs less than 1 means that an athlete is less likely to achieve success from a certain population size or density than someone from another area. If the CI contains the 1, those ORs are deemed not statistically significant.

Results

Collegiate athletes

There was a significant over-representation of both male and female NCAA athletes from two community size categories, ranging from 100,000 to 499,999 residents (Table 1). This effect was the strongest for athletes born in cities of 250,000–499,999, with 11.05% of male NCAA athletes and 10.31% of female NCAA athletes compared to just 6.03% of the general US population ($OR_{MNCAA} = 1.94$, $CI_{MNCAA} = 1.75–2.14$; $OR_{WNCAA} = 1.79$, $CI_{WNCAA} = 1.62–1.98$). While the specific ORs differed slightly across male and female NCAA athletes, the overall trends in relation to community size were consistent across genders.

As for population density, there was a significant over-representation of male and female collegiate athletes from moderately dense cities between 500 and 2,499 residents/km^2 (Table 2), with the largest ORs observed for the 1,000–2,499 residents/km^2 category ($OR_{MNCAA} = 1.38$, $CI_{MNCAA} = 1.30–1.47$; $OR_{WNCAA} = 1.36$, $CI_{WNCAA} = 1.23–1.40$). Similar to the community size data, ORs followed similar trends across density categories in both male and female NCAA athletes.

Professional athletes

Among both NBA and WNBA datasets, there was a significant over-representation of male and female participants from three community size categories ranging from 100,000 to 999,999 residents (see Table 3). For the NBA, this relationship was the strongest for athletes from cities ranging from 250,000 to 499,999 residents ($OR_{NBA} = 2.90$, $CI_{NBA} = 2.20–3.81$), while the WNBA showed the largest over-representation in the 500,000–999,999 residents category ($OR_{WNBA} = 3.12$, $CI_{WNBA} = 1.96–4.95$). Besides the ranges noted above, NBA athletes were also significantly over-represented from cities between 50,000 and 99,999 residents ($OR_{NBA} = 1.33$, $CI_{NBA} = 1.01–1.76$) and 2,500,000–4,999,999 residents ($OR_{NBA} = 2.41$, $CI_{NBA} = 1.65–3.52$).

As for population density, there was an over-representation for both the NBA and WNBA in relatively dense cities (Table 4). For the WNBA, extremely dense cities, (≥5,000 residents/km^2) were 8.3 times more likely to produce professional basketball players ($OR_{WNBA} = 8.30$, $CI_{WNBA} = 5.77–11.94$). For the NBA, the only population density category that was significantly over-represented was 2,500–4,999 residents/km^2 ($OR_{NBA} = 1.71$, $CI_{NBA} = 1.35–2.17$), which was also over-represented in the WNBA sample ($OR_{WNBA} = 1.85$, $CI_{WNBA} = 1.21–2.81$).

Discussion

The purpose of this study was to analyze the birthplace effects in both collegiate and professional United States basketball based on population size and density. By collecting data from two competitive levels and sexes, we were able to extend upon extant literature by providing a more nuanced understanding of birthplace effects in the sport of basketball in the United States. Notably, the largest over-representation in community size for NBA athletes were from cities between 250,000 and 499,999 residents, while WNBA athletes were most over-represented from cities between 500,000 and 999,999 residents. For both collegiate males and females, the highest

TABLE 2 Odds ratios (ORs) and confidence intervals (CIs) across population density categories for collegiate athletes.

Population density (inhabitants/km^2)	US (%)	MNCAA (%)	OR	CI	WNCAA (%)	OR	CI
≥5,000	14.96	11.82	0.76	0.69–0.84	8.51	0.53	0.47–0.59
2,500–4,999	13.70	14.65	1.08	0.99–1.18	14.52	1.07	0.98–1.17
1,000–2,499	40.19	48.17	1.38	1.30–1.47	47.74	1.36	1.23–1.40
500–999	17.11	18.6	1.11	1.02–1.12	20.46	1.25	1.16–1.34
250–499	6.54	4.92	0.74	0.64–0.85	4.78	0.72	0.62–0.83
100–249	3.74	1.24	0.32	0.26–0.43	1.78	0.47	0.37–0.59
50–99	1.75	0.25	0.14	0.08–0.26	0.40	0.23	0.14–0.37
<50	2.05	0.35	0.17	0.01–0.28	0.33	0.16	0.10–0.27

TABLE 3 Odds ratios (ORs) and confidence intervals (CIs) across city size categories for professional athletes.

Community size	US (%)	NBA (%)	OR	95% CI	WNBA (%)	OR	95% CI
≥5,000,000	2.78	0.52	0.18	0.05–0.73	3.33	1.21	0.45–3.27
2,500,000–4,999999	3.29	7.59	2.41	1.65–3.52	3.33	1.01	0.37–2.74
1,000,000–2,499,999	9.6	11.78	1.26	0.92–1.71	6.67	0.67	0.33–1.38
500,000–999,999	6.75	12.83	2.04	1.5–2.76	18.33	3.12	1.96–4.95
250,000–499,999	6.16	15.97	2.90	2.20–3.81	11.67	2.01	1.15–3.52
100,000–249,999	11.14	15.97	1.52	1.15–1.99	23.33	2.43	1.59–3.71
50,000–99,999	12.26	15.71	1.33	1.01–1.76	9.17	0.72	0.39–1.34
<50,000	48.06	23.04	0.32	0.26–0.41	24.2	0.34	0.23–0.52

TABLE 4 Odds ratios (ORs) and confidence intervals (CIs) across population density categories for professional athletes.

Population density (inhabitants/km^2)	US (%)	NBA (%)	OR	95% CI	WNBA (%)	OR	95% CI
≥5,000	14.87	16.23	1.11	0.85–1.46	59.17	8.30	5.77–11.94
2,500–4,999	14.71	22.77	1.71	1.35–2.17	24.17	1.85	1.21–2.81
1,000–2,499	39.53	43.72	1.12	0.97–1.45	14.17	0.25	0.15–0.42
500–999	16.76	12.83	0.73	0.54–0.99	0.83	0.04	0.01–0.30
250–499	6.38	0.52	0.08	0.02–0.31	0.83	0.12	0.02–0.83
100–249	3.6	0.52	0.14	0.04–0.57	0.83	0.23	0.03–1.61
50–99	1.88	0	0	–	0	0	–
<50	2.27	0	0	–	0	0	–

representation was from cities between 250,000 and 499,999 residents. For population density, NBA athletes were most likely to be from moderately dense areas (2,500–4,999 residents/km^2), while WNBA athletes were highly over-represented in extremely dense population centers (≥5,000 residents/km^2).

Referring to population size, both collegiate and professional datasets indicate that medium- to large-sized cities might be the most conducive to reaching elite-level performance, which aligns with previous findings in other professional and Olympic sports (6). However, these findings also suggest that since Côté et al.'s (1) initial study of the birthplace effect in the NBA, there appears to be a shift in optimal city size from small and medium cities (100,000–249,999 residents) to medium and large cities (250,000–999,999 residents). Given that researchers often credit smaller communities for fostering personal and talent development (4), it is possible that this shift to larger cities is due to other factors such as better competition and more opportunities. For example, the popularity of the Amateur Athletic Union (AAU) and other "elite" youth basketball clubs has drastically increased since 2010, with the majority of NBA athletes previously participating in the AAU, where tournaments are often nested in larger cities (22). Thus, this shift might be representative of increased opportunities to train and compete with highly skilled opponents, while importantly providing youth athletes with exposure to college scouts.

Additionally, the present study found that relatively dense populations were more conducive for both NBA and WNBA athletes (Table 4; 2,500–4,999 residents/km^2). Similar findings were observed for collegiate athletes, who additionally were found to be heavily over-represented from medium density communities (Table 2; 1,000–2,499 residents/km^2). Altogether, these findings were consistent with prior birthplace effect studies that have considered density in European populations (13). It is possible that these high-density centers, regardless of population size, are able to provide greater access to facilities, opportunities, and exposure to important sport cultural norms (12).

The present study has highlighted the shift from small to medium cities for professional basketball players with relatively high densities. It also provided additional analyses necessary in elite level basketball by including NCAA Division I athletes. However, this study has several limitations and considerations for future research. The included sample contained male and female basketball players from the collegiate and professional ranks, but it is not clear as to where the most elite players are coming from. For example, while the NCAA includes over 350 teams in Division I basketball, the majority of future professionals are recruited from a much smaller group of highly touted, well-resourced programs, while many smaller Division I institutions produce very few (if any) professionals (23).

One of the unique objectives of this study was to identify potential "talent hotspots" in both men's and women's basketball in the US. Through the analysis of the optimal community sizes and densities at both the collegiate (where most professional players are drafted from) and professional ranks, it was possible to identify community sizes and densities that are over-represented at both levels of competition. In men's basketball, there was a significant over-representation of collegiate and professional players from communities with populations of 100,000–999,999 residents. In terms of population density, there were no significant overlapping ORs across the men's collegiate and professional datasets. However, both data sets favor relatively dense communities (i.e., 500–4,999 residents/km^2). In women's basketball, there was a significant over-representation of both collegiate and professional players from communities with populations of 100,000–499,999, with the data skewing toward increasingly dense communities in the transition from the collegiate (i.e., 500–2,499 residents/km^2) to professional ranks (i.e., 2,499–$\geq$5,000 residents/km^2). Finally, in examination of collegiate and professional men's and women's basketball altogether, it is evident that communities of 100,000–249,999 residents can be considered "talent hotspots" as there are significant over-representations of athletes from communities of this size across all four data sets.

Through the identification of these potential "talent hotspots" in terms of both community size and density in elite basketball in the United States, we have presented a worthwhile avenue for future research. While these data were cross-sectional in nature, the identification of multiple consistent "talent hotspots" along the pathway to professional basketball helps to better understand the developmental nature of birthplace effects. Follow-up studies may wish to pinpoint specific communities that meet these population size and density criteria and investigate those which are most frequently observed in the sample of NBA and WNBA players. In doing so, it will be possible to go beyond just considering how infrastructure (related to community size) and social structure (related to density) impact athlete development, to begin exploring other indices of these communities that may be optimal for the development of elite basketball players [e.g., green space, organizations, and social norms (3)].

Key takeaway messages for the geography of talent development

It is evident that geography is a significant factor influencing talent development among athletes. Likely, this is because of favorable infrastructure and social structure that exist in certain communities. As indicated by the data presented herein, communities with optimal population sizes and densities might be considered talent hotspots. However, researchers ought to continue exploring other elements within such communities (e.g., crime rates and green spaces) to deepen our understanding of these potential hotspots. Such explorations might also identify environmental/geographic factors that consistently explain talent development advantages across sports and countries.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

DH led the writing of most sections of the paper. MV led the writing of the final section which includes the original research. AN contributed with article reviews, referencing, and reviewing. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Côté J, MacDonald DJ, Baker J, Abernethy B. When "where" is more important than "when": birthplace and birthdate effects on the achievement of sporting expertise. *J Sports Sci.* (2006) 24:1065–73. doi: 10.1080/02640410500432490

2. Baker J, Logan AJ. Developmental contexts and sporting success: birth date and birthplace effects in National Hockey League draftees 2000-2005. *Br J Sports Med.* (2007) 41:515–7. doi: 10.1136/bjsm.2006.033977

3. Hancock DJ, Coutinho P, Côté J, Mesquita I. Influences of population size and density on birthplace effects. *J Sports Sci.* (2018) 36:33–8. doi: 10.1080/02640414.2016.1276614

4. MacDonald DJ, King J, Côté J, Abernethy B. Birthplace effects on the development of female athletic talent. *J Sci Med Sport.* (2009) 12:234–7. doi: 10.1016/j.jsams.2007.05.015

5. Lidor R, Côté J, Arnon M, Zeev A, Cohen-Maoz S. Relative age effect and birthplace effects in Division 1 players: do they exist in a small country? *Talent Dev Exerc.* (2010) 2:181–92.

6. MacDonald DJ, Cheung M, Côté J, Abernethy B. Place but not date of birth influences the development and emergence of athletic talent in American football. *J Appl Sport Psychol.* (2009) 21:80–90. doi: 10.1080/10413200802541868

7. Low J, Ford PR, Williams AM. The effects of birth date and place on the development of expertise in professional cricket batters. *Int J Sport Psychol.* (2015) 46:676–88.

8. Lidor R, Arnon M, Maayan Z, Gershon T, Côté J. Relative age effect and birthplace effect in Division 1 female ballgame players: the relevance of sport-specific factors. *Int J Sport Exerc Psychol.* (2014) 12:19–33. doi: 10.1080/1612197X.2012.756232

9. Imtiaz F, Hancock DJ, Vierimaa M, Côté J. Place of development and dropout in youth ice hockey. *Int J Sport Exerc Psychol.* (2014) 12:234–44. doi: 10.1080/1612197X.2014.880262

10. Balish SM, Rainham D, Blanchard C. Community size and sport participation across 22 countries. *Scand J Med Sci Sports.* (2015) 25:e576–81. doi: 10.1111/sms.12375

11. Faria LO, Bredt SGT, Ribeiro AI, Galatti LR, Albuquerque MR. Inequality in Brazilian basketball: the birthplace effect. *Rev Bras Cineantropometria Desempenho Hum.* (2021) 23:e76932. doi: 10.1590/1980-0037.2021v23e76932

12. Rossing NN, Nielsen AB, Elbe AM, Karbing DS. The role of community in the development of elite handball and football players in Denmark. *Eur J Sport Sci.* (2016) 16:237–45. doi: 10.1080/17461391.2015.1009492

13. Rossing NN, Stentoft D, Flattum A, Côté J, Karbing DS. Influence of population size, density, and proximity to talent clubs on the likelihood of becoming elite youth athlete. *Scand J Med Sci Sports.* (2018) 28:1304–13. doi: 10.1111/sms.13009

14. van Nieuwstadt MHH, Das M, Elferink-Gemser MT. Mechanisms explaining the birthplace effect for male elite football players. *J Sports Sci.* (2021) 39:576–82. doi: 10.1080/02640414.2020.1835237

15. Farah L. *Community size effects in Canadian National Hockey League draftees: Exploring regional variations in community size effects and the influence of population density and proximity to Canadian Hockey League teams.* [Master's thesis] University of Ontario Institute of Technology. Oshawa, ON: DSpace Mirage (2017).

16. Hancock DJ. Navigating relative age and birthplace effects to ensure equal participation in youth sport. In: R Bailey, Agans JP, Côté J, Daly-Smith A, Tomporowski PD, editors. *Physical Activity and Sport During the First Ten Years of Life*. London: Routledge (2021), p. 113–23. doi: 10.4324/9780429352645-13

17. Hancock DJ, Côté J. Birth advantages, social agents, and talent development in youth sport. In: Gomes AR, Resende R, and Albuquerque A, editors. *Positive Human Functioning From a Multidimensional Perspective: Promoting High Performance*. New York, NY: Nova (2014), p. 15–32.

18. Wattie N, Schorer J, Baker J. Seeing the forest but not the trees: heterogeneity in community size effects in Canadian ice hockey players. *J Sports Sci.* (2018) 36:436–44. doi: 10.1080/02640414.2017.1313444

19. Farah L, Schorer J, Baker J, Wattie N. Heterogeneity in community size effects: exploring variations in the production of National Hockey League draftees between Canadian cities. *Front Psychol.* (2019) 9:2746. doi: 10.3389/fpsyg.2018.02746

20. US Census Bureau. *Population, housing units, area, and density: United States – States; and Puerto Rico Census 2000 summary file 1* [Data file]. (2000). Available online at: https://www.census.gov/data/datasets/2000/dec/summary-file-1.html (accessed January 8, 2018).

21. US Census Bureau. *Population, housing units, area, and density: United States – States; and Puerto Rico Census 2010 summary file 1* [Data file]. (2010). Available online at: https://www.census.gov/data/datasets/2010/dec/summary-file-1.htm (accessed January 8, 2018).

22. Dalton M. Shoe money, AAU basketball, and the effects on college basketball recruiting. *Miss Sports Law Rev.* (2016) 6:108–14.

23. Evans BA. From college to the NBA: what determines a player's success and what characteristics are NBA franchises overlooking? *Appl. Econ Lett.* (2018) 25:300–4. doi: 10.1080/13504851.2017.1319551

frontiers | Frontiers in Sports and Active Living

TYPE Mini Review
PUBLISHED 13 February 2023
DOI 10.3389/fspor.2023.1127151

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OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Elite Sports and Performance Enhancement, a section of the journal Frontiers in Sports and Active Living

RECEIVED 19 December 2022
ACCEPTED 19 January 2023
PUBLISHED 13 February 2023

CITATION
Henriksen K and Stambulova N (2023) The social environment of talent development in youth sport.
Front. Sports Act. Living 5:1127151.
doi: 10.3389/fspor.2023.1127151

The social environment of talent development in youth sport

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During the last decade, talent identification and development research that favours an individual perspective has been complemented by a focus on young athletes' social environments, termed "athletic talent development environments" (ATDEs). Two major lines of research have created a foundation for an ecological vision of talent development as the mutual accommodation between athletes and their ATDEs and of career development as an athlete's journey through various athletic and non-athletic environments. The Talent Development Environment Questionnaire allows the quantitative screening of athletes' environments, while the holistic ecological approach (HEA) promotes in-depth qualitative case studies of ATDEs. In this chapter, we focus mainly on the HEA, including: (a) two models that combine to illustrate an ATDE; (b) a summary of empirical case studies of successful environments in various sports and countries, culminating in a set of shared features of ATDEs that promote athletes' wellbeing and athletic and personal development; (c) an overview of recent trends within HEA (e.g. interorganisational collaboration in talent development) and (d) recommendations for coaches and sport psychology consultants, emphasising the importance of integrating efforts across the whole environment and building strong and coherent organisational cultures. In the discussion, we elaborate on developing the HEA discourse and point to future challenges for researchers and practitioners.

KEYWORDS
ecological psycholgy, youth sport, athletic talent, sport environment, holistic ecological approach, athletic talent development environment

Introduction

In August 2021, a Danish sailor won the Olympic gold medal in her event in Tokyo. While she was on the water, her Danish teammates watched the event together, their eyes filled with tears of joy and pride as she crossed the finish line. They felt they had a big share in that victory, and in the post-race interview the winner was quick to give them credit and highlight their important role in her success. That same year, she turned 30, neared the end of her university degree and was offered a way into the world of professional sailing. The media naturally took an interest in her plans and specifically her potential for a repeat Olympic performance. After half a year of silence, she announced that she had decided to aim for the Olympics again. Explaining her motivation, she did not say that another Olympic medal would change her life or that she wanted to taste the sweetness of success and nationwide recognition once again. Instead, she highlighted her training environment in which she could grow, learn, give back and feel at home, saying that with this team her journey towards the next Games would not only be fun but also realistic.

No one makes it on their own. Borrowing from an old African adage, it takes a village to raise an athlete, and when reflecting on their talent development pathways, elite athletes acknowledge people without whom they never would have made it. Elite athletes' tales often illustrate that successful talent development is a journey through good environments that have supported their striving as well as their thriving.

15–20 years ago, talent development research was dominated by individual perspectives (1), whereby researchers aimed to discover the unique characteristics (e.g., 2, 3) and pathways (e.g., 4, 5) of elite athletes to inform talent identification and development initiatives. Inspired by ecological perspectives in sport-related learning and decision making (see special issue 6);, two research groups in parallel initiated investigation of the role of the environment in talent development in sports. In Scotland, Martindale and colleagues (7) developed a survey that could assess the quality of an athletic talent development environment (ATDE), and in Denmark, Henriksen and colleagues completed a series of innovative in-depth case studies of successful ATDEs in Scandinavia (8, 9, 10). Today, the ecology of talent development discourse has matured, as visible in two recent reviews summarising key findings of more than a decade of ecological talent development research and related practice (11, 12).

The ecology of talent development in sport

In this chapter, we discuss research regarding ATDEs in youth sport and practical implications – both grounded in *the holistic ecological approach* (HEA). By *ecological*, we mean the focus on the athletes' environment that affects their development; *holistic* refers to a view of the environment as a complex and dynamic whole that consists of multiple interrelated settings, levels and domains (13, 14).

We begin with the model of Effective Talent Identification and Development Procedures by Martindale and colleagues (15) that was developed based on interviews with experienced coaches about successful ATDEs' contributions to the development of young athletes. The model formed the basis of the Talent Development Environment Questionnaire, TDEQ (7), that measures five features of an environment that fosters talent development: (a) long-term aims and methods; (b) wide-ranging and coherent messages and support; (c) emphasis on talent development rather than early selection; (d) individualised and ongoing development; and (e) an integrated and holistic system. The TDEQ and a subsequent revised version, TDEQ5 (16), have been used to gauge strengths and weaknesses of specific ATDEs to assist efforts to improve environments (e.g., 17). The instrument was further used to investigate associations between features of ATDEs and athletes' development. Although the various modifications of the structure warrant caution, research has demonstrated that athletes' favourable perception of their ATDE was linked positively to the satisfaction of their basic needs, mental toughness and wellbeing (18, 19) and negatively associated with burnout (20, 21).

We now move to *the holistic ecological approach* (HEA) that offers a case study (qualitative) approach to investigating the structure, culture and inner workings of ATDEs that have had varying degrees of success in helping athletes to make the junior-to-senior transition (14). To aid case studies, two working models (8) were created by taking inspiration from ecological psychology, systems theory and cultural psychology (22–24). **Figure 1** presents the ATDE working model as a framework for describing the roles and functions of the different components and relations within an environment. The prospective young elite athletes appear at the centre of the model, and other ATDE's components are structured into two levels (micro and macro) and two domains (athletic and non-athletic). The micro level refers to the environment in which the prospective elite athletes spend a good deal of their daily lives. The macro level refers to social settings, which affect but do not contain the athletes, as well as to the values and customs of the cultures to which the athletes belong. The athletic domain covers the part of the athletes' environment that is directly related to sport, whereas the non-athletic domain presents all the other spheres of the athletes' lives. The outer layer of the model represents the past, present and future of the ATDE, emphasising that the environment is dynamic.

The Environment Success Factors (ESF) working model (**Figure 2**) predicts that the ATDE's success is a result of the interplay between *preconditions, processes, individual* and *team development and achievements*, with *organisational culture* serving to integrate these elements.

The model's starting point is the environment's *preconditions* (e.g., human, material and financial), all of which are necessary but not sufficient for success. The model then illustrates how the daily *processes* (e.g., training, camps and competitions) lead to three outcomes: athletes' individual development and achievements (e.g., psychosocial and athletic skills), team achievements and organisational development and culture. *Organisational culture* (25) is central to the ESF model and consists of: cultural artefacts (e.g., stories, customs and physical manifestations such as clothing and organisation charts), espoused values (i.e., principles, goals and standards that the organisation shows to the world) and basic assumptions (i.e., taken for granted and serving as underlying reasons for actions). Key basic assumptions are integrated into a *cultural paradigm*, guiding the socialisation of new members and providing stability. Organisational culture is seen as an integrative factor of the ADTE's effectiveness in helping talented young athletes to develop into senior elite athletes (14). Broadly speaking, successful ATDEs are environments that promote athletes' wellbeing and long-term athletic and personal development (12).

The HEA models have been tested and empirically validated through in-depth and real-time case studies of successful ATDEs. Examples of these studies include (but are not limited to) the Danish national 49er sailing team (8), a Swedish track and field club (9), a Norwegian kayak team situated in an elite sport high school (10), soccer academies across Europe (26–29), two handball clubs in Denmark and Norway (30) and a world-class trampoline environment in Canada (31). In contrast, one study was focused on a less successful golf environment in Denmark (32). Further, cross-case comparisons (33) allowed us to conclude that even though all environments are unique (no two environments are ever the same), successful ATDEs employ many of the same principles in their work. These principles were implemented in different ways, and some environments compensated for a weakness in one feature by a strong presence of another. Thus, the uniqueness of each environment was expressed in how they implemented the common principles. In **Table 1**, we summarise the shared features of ATDEs, providing descriptions of their *positive* (research based) and *opposite* poles (inferred logically or grounded in the study of the less successful environment). The shared features fall within two overall categories related to the structure and the culture of the environment.

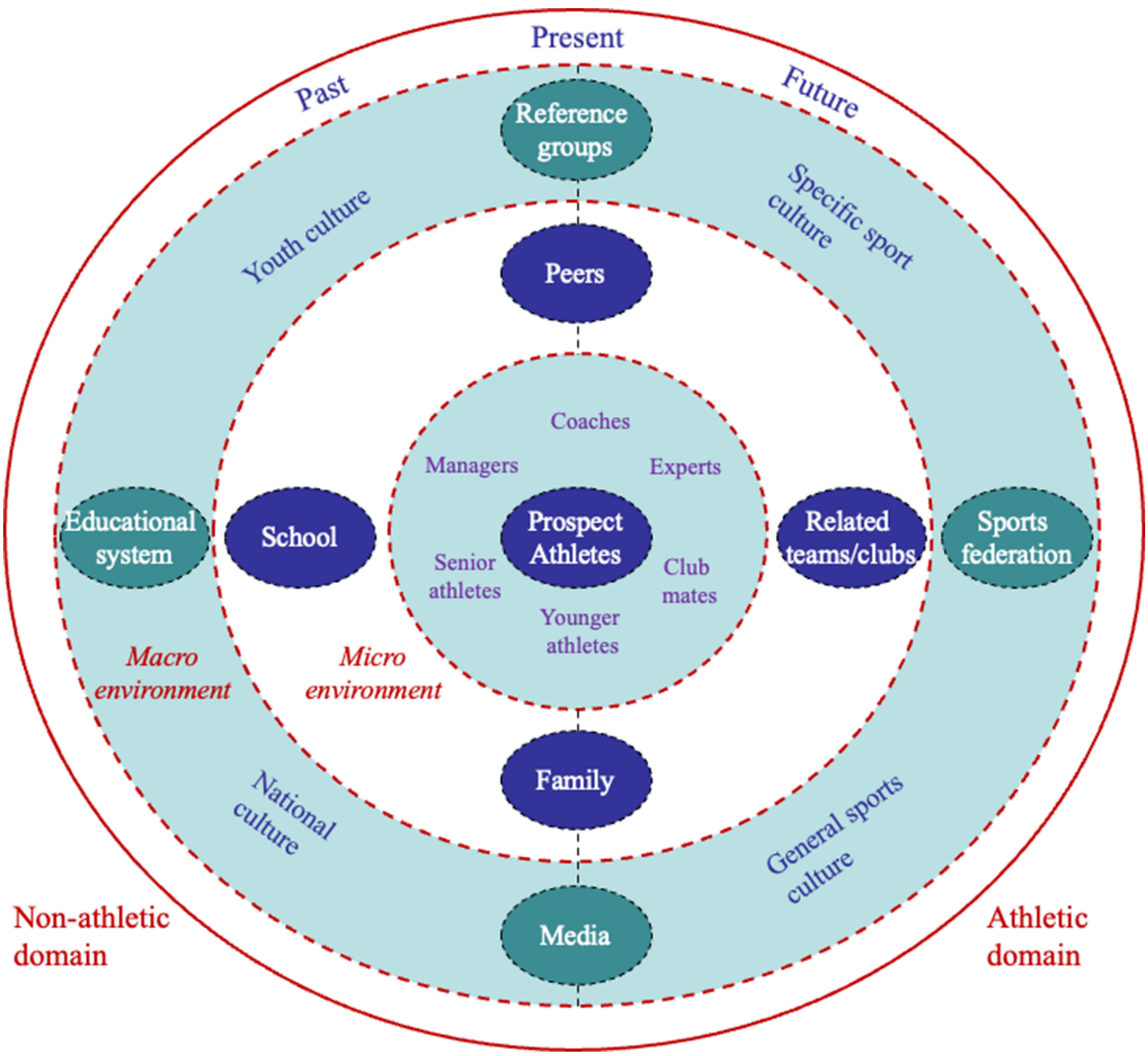

FIGURE 1
The athletic talent development environment (ATDE) working model. Reprinted with permission.

To continue with shared features, a recent scoping review of ATDEs (12) covered 44 studies published mainly during the last decade. In the analysis of the studies, the authors focused on *positive* (wellbeing, long-term athletic and personal development) and *less positive* (illbeing, limited athletic and personal development) *talent development outcomes* and related *functional* and *dysfunctional features of ATDEs*. Such an explicitly holistic definition of environment success is a welcome addition to the original literature that defined success as a track record of developing elite athletes but found that successful environment did in fact promote holistic development (11). The features were further sorted into four categories with clear connections to the ESF model (see **Figure 2** and **Table 1**): preconditions, organisational culture, integration of efforts and quality holistic preparation. To provide a glimpse into the authors' preliminary conceptual framework, on the functional side, *preconditions* include skilled staff, accessible role models and system-wide support; *organisational culture* is characterised by an empowering climate, psychological safety and coherent and lived values; *integration of efforts* includes social relationships outside of sport and collaboration among stakeholders; and *quality holistic preparation* focuses on holistic personal development and long-term athletic preparation. On the dysfunctional side, examples of corresponding features refer to limited and unskilled staff, lack of role models and facilities, promoting winning at all costs, isolation and lack of stakeholder collaboration, lack of interest in the athletes as persons and inhibited preparation. The authors conclude that ATDEs weighted in favour of the functional features (and compensating for or eliminating dysfunctional ones) will provide positive outcomes in regard to athletes' wellbeing and athletic and personal development.

A holistic and ecological outlook has clear implications for practitioners. Coaches and talent development managers are encouraged to look beyond their training sessions and take an interest in providing a whole environment that is conducive for the athletes' development. Related to the structure of the environment, coaches might coordinate training camps and intense training periods with school exam periods, deliberately recruit and support role models, ensure communication within athletes' micro-environments (e.g., club, academy and national team training) and

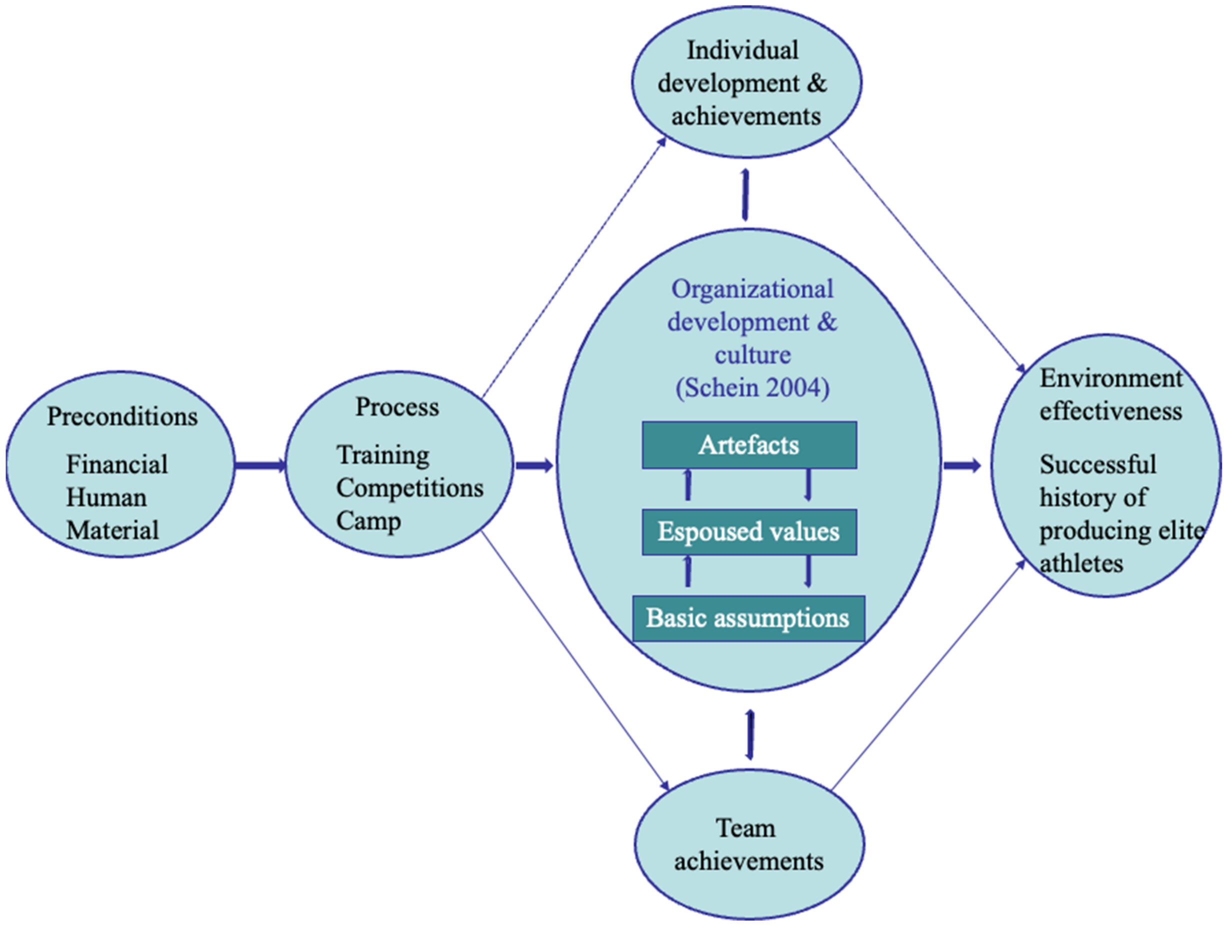

FIGURE 2
The environment success factors (ESF) working model. Reprinted with permission.

promote supportive training groups. In relation to organisational culture, coaches can acknowledge their role as cultural leaders (34), strive to develop a cohesive culture, stimulate athletes' free initiatives and maintain a long-term development focus. Sport psychology consultants are encouraged to conduct their interventions inside the athletes' natural settings and aim to optimise not only an athlete's individual psychological skills but the entire environment.

New trends in the holistic ecological research and practice

As HEA has gained popularity, the approach has found its way into new but related domains of research. Zooming in on the ATDE's macro level, a case study in Danish swimming (35) and subsequent case studies in multiple sports (36) examined the successful collaboration in talent development management between a federation, a municipality and a local club, termed "an organisational triangle". This research demonstrated that successful interorganisational collaboration in talent development required a shared philosophy and collaborative decisions, which allowed for coherent actions that would eventually lead to outcomes beneficial for the local athletes/clubs.

The next expansion of HEA has been its application in the study of Dual Career Development Environments (DCDEs) supporting athletes' efforts in combining their competitive careers with education or work. Seven case studies of successful DCDEs were conducted within the European Project "Ecology of Dual Careers" (37) based on adapted versions of the original ATDE and ESF models (38, 39). The further cross-case analysis led to the identification of ten essential features of DCDEs, such as a dedicated DC support team, integration of efforts, mentorship and access to expert support as characteristics of a holistic DCDE structure. Whole person and empowerment approaches, flexible solutions, care of mental health and a proactive approach to the development of the environment further described the shared dual career philosophy (40).

The most recent research project explored the nature of underserved athletic talent development environments (UATDE). An exploration of the career pathways of ten American professional athletes with low socioeconomic backgrounds highlighted the challenging circumstances they had to overcome to achieve athletic success and how their time in a UATDE had lasting ramifications in their lives (41). An interview study with stakeholders working in or with athletes from UATDEs unearthed specific challenges faced in UATDEs and demonstrated how developing within such environments impacted athletes even after

TABLE 1 Shared features of successful ATDEs.

Features of successful ATDEs	Descriptors	Opposite Poles
Structure		
Integration of efforts	Coordination and communication between sport, school, family and other components; athletes experience synergy	Lack of communication; conflicting interests; athletes experience contradicting demands
Training groups with supportive relationships	Opportunities for inclusion in a training community with supportive relationships and friendships	Individualized training programs at an early stage; training alone; rivalry and low cohesion
Proximal role models	Opportunities to train with the elite athletes who are willing to pass on their knowledge	Boundaries between athletes at different levels. Elite level athletes keep their secrets
Support of sporting goals by the wider environment	School, family and friends acknowledge the athletes' dedication to sport	Non-sport environment shows lack of understanding of elite sport
Organizational culture		
Coherent organizational culture	Coherence between espoused values and actions provides stability	Fragmented culture; espoused values do not correspond to actions; uncertainty
Support for the development of psychosocial skills	Opportunities to develop competences that are of benefit outside sport; considering athletes as "whole human beings"	Focus solely on sport; excessive control from coaches; focus on relative performance before personal improvement
Training that allows for diversification	Opportunities to sample different sports during early phases; focus on versatile basic sport skills in training	Promoting early specialization and sport specific skills only; considering other sports as rivals
A room for free initiative	Opportunities to organize training at own initiative across age- and training groups.	Inaccessible facilities and high training loads demotivate athletes to train outside formal training.
Knowledge sharing	Coaches share knowledge inside the ATDE and with coaches in other ATDEs	Coaches protect their "secrets" and consider other coaches only as rivals.
Focus on long-term development	Focus on long-term development of the athletes; age-appropriate training	Focus on early success; kids train like miniature elite athletes.

they reached the college and professional levels of sports (42). Finally, a case study applied the HEA as a lens to examine a specific UATDE in basketball (43) with adapted versions of the original HEA models used to guide data collection. This research demonstrated that operation of the UATDE was significantly influenced by the underserved community in which it was embedded and that the team's roster comprised athletically talented but psychosocially vulnerable players, requiring the support team to expend considerable resources in supporting the psychosocial development of their players. Nevertheless, the UATDE managed to support the athletes in making a successful transition to a professional career and a better life because of a small but dedicated support team and a cultural paradigm that set the person before the performer and catered to the athletes' needs beyond the basketball court, and which was carefully maintained by the head coach as a cultural leader.

Discussion: Major achievements and challenges for the future

The HEA research and practice were initially constructed in the overlap between talent development and career development discourses and have enriched both. Over a little more than a decade, we have observed how the HEA sport psychology discourse as a co-constructed and shared body of knowledge about athletes' environments (e.g., definitions, values and research-related and applied frameworks) has matured and created fruitful intersections with mental health, cultural and organisational sport psychology discourses. Combining the HEA with the holistic developmental approach (44) and a focus on athletes' mental health (45) led to a new understanding of career development as the pursuit of career excellence that sustains a healthy, successful and long-lasting career in sport and life (46). The HEA helps to understand that striving for career excellence is a dynamic process of mutual accommodation between athletes and their whole environments. Athletes use the environmental resources, just as they contribute to the success and development of their environments.

Being able to observe and contribute to development of the HEA discourse, we foresee the following lines of its further development:

- We envision successful athlete development as a journey through good environments that support the athletes' sport and personal development. This vison drives us to suggest that studies of successful and less successful environments at different career stages are needed, for example, youth sport and elite sport environments that come before and after the talent stage. For Bronfenbrenner (13), time was a key feature of the developmental processes, and research should pay more attention to the *journey*.
- Because of athletes' "travel" between different environments, career assistance programmes in the future should focus on helping athletes to prepare for, and cope with, environmental transitions as a supplement to the current focus on transitions between career stages.
- Environments can be resources and/or barriers for athletes' development and wellbeing. Recently, several elite athletes openly confessed their mental ill health, often pointing at abusive sport environments as key reasons. Keeping talented young athletes in sport requires the promotion of healthy and

safe climates in ATDEs by strengthening their functional features while eliminating or compensating for dysfunctional ones.
- The important role of health and wellbeing as a resource for performance and personal development is not limited to athletes. Therefore, researchers and practitioners are encouraged to investigate and promote healthy environments for coaches, managers, peers, parents and sport psychology consultants, who influence the athletes.
- The HEA is expanding into new horizons (e.g. DCDE, UATDE), and we expect researchers to gradually give more nuanced and contextualised recommendations to developing good social environments for young athletes across sporting contexts.

No one makes it on their own. We invite researchers and practitioners worldwide to collectively contribute to the HEA-informed research and practice to create environments facilitating athletes' successful career excellence pursuits.

Author contributions

The manuscript was developed on the initiative of KH. KH and NS both contributed to development of intellectual content, structure and key messages: KH wrote the majority of the text with NS concising and providing feedback. Both authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

1. Abbott A, Collins D, Martindale RJJ, Sowerby K. Talent identification and development: An academic review. Report for Sportscotland (2002).

2. Vaeyens R, Güllich A, Warr CR, Philippaerts R. Talent identification and promotion programmes of Olympic athletes. *J Sports Sci.* (2009) 27(13):1367–80. doi: 10.1080/02640410903110974

3. Williams AM, Reilly T. Talent identification and development in soccer. *J Sports Sci.* (2000) 18(9):657–67. doi: 10.1080/02640410050120041

4. Côte J, Lidor R, Hackfort D. ISSP Position stand: to sample or to specialize? Seven postulates about youth sport activities that lead to continued participation and elite performance. *Int J Sport Exerc Psychol.* (2009) 7(1):7–17. doi: 10.1080/1612197X.2009.9671889

5. Ericsson KA. The acquisition of expert performance in sport: how different types of deliberate practice cause improvements throughout the development of expert performance. *J Sport Exerc Psychol.* (2005) 27:S5–6.

6. Araújo D. Preface to "ecological approaches to cognition in sport and exercise". *Int J Sport Psychol.* (2009) 40(1):1–4. ISI:000263754500001.

7. Martindale RJJ, Collins D, Wang JCK, McNeill M, Lee KS, Sproule J, et al. Development of the talent development environment questionnaire for sport. *J Sports Sci.* (2010) 28(11):1209–21. doi: 10.1080/02640414.2010.495993

8. Henriksen K, Stambulova N, Roessler KK. A holistic approach to athletic talent development environments: a successful sailing milieu. *Psychol Sport Exerc.* (2010) 11:212–22. doi: 10.1016/j.psychsport.2009.10.005

9. Henriksen K, Stambulova N, Roessler KK. Succesful talent development in track and field: considering the role of environment. *Scand J Med Sci Sports.* (2010) 20:122–32. doi: 10.1111/j.1600-0838.2010.01187.x

10. Henriksen K, Stambulova N, Roessler KK. Riding the wave of an expert: a successful talent development environment in kayaking. *Sport Psychologist.* (2011) 25 (3):341–62. doi: 10.1123/tsp.25.3.341

11. Feddersen NB, Morris R, Ronkainen N, Saether SA, Littlewood M, Richardson D. A qualitative meta-study of a decade of the holistic ecological approach to talent development. *Scand J Sport Exerc Psychol.* (2021) 3:24–39. doi: doi.org/10.7146/sjsep.v3i.128317

12. Hauser L-L, Harwood CG, Höner O, O'Connor D, Wachsmuth S. Talent development environments within sports: a scoping review examining functional and dysfunctional environmental features. *Int Rev Sport Exerc Psychol.* (2022):1–27. doi: 10.1080/1750984X.2022.2129423

13. Bronfenbrenner U, Morris PA. The bioecological model of human development. In: RM Lerner, editors. *Handbook og child psychology: Vol 1. Theoretical models of human development (6 ed.)*. New York: Wiley (2006). p. 793–828.

14. Henriksen K. *The ecology of talent development in sport: a multiple case study of successful athletic talent development environments in Scandinavia* [*Doctoral thesis*]. Institute of Sport Science and Clinical Biomechanics, University of Southern Denmark (2010).

15. Martindale RJJ, Collins D, Abraham A. Effective talent development: the elite coach perspective in UK sport. *J Appl Sport Psychol.* (2007) 19(2):187–206. doi: 10.1080/10413200701188944

16. Li C, Wang CK, Pyun do Y, Martindale R. Further development of the talent development environment questionnaire for sport. *J Sports Sci.* (2015) 33(17):1831–43. doi: 10.1080/02640414.2015.1014828

17. Gledhill A, Harwood C. Toward an understanding of Players' perceptions of talent development environments in UK female football. *J Appl Sport Psychol.* (2019) 31 (1):105–15. doi: 10.1080/10413200.2017.1410254

18. Ivarsson A, Stenling A, Fallby J, Johnson U, Borg E, Johansson G. The predictive ability of the talent development environment on youth elite football players' well-being: a person-centered approach. *Psychol Sport Exerc.* (2015) 16:15–23. doi: 10.1016/j.psychsport.2014.09.006

19. Li C, Martindale R, Sun Y. Relationships between talent development environments and mental toughness: the role of basic psychological need satisfaction. *J Sports Sci.* (2019) 37(18):2057–65. doi: 10.1080/02640414.2019.1620979

20. Li C, Wang CKJ, Pyun DY. Impacts of talent development environments on athlete burnout: a self-determination perspective. *J Sports Sci.* (2017) 35(18):1838–45. doi: 10.1080/02640414.2016.1240370

21. Thomas CE, Gastin PB, Abbott G, Main LC. Impact of the talent development environment on the wellbeing and burnout of Caribbean youth track and field athletes. *Eur J Sport Sci.* (2021) 21(4):590–603. doi: 10.1080/17461391.2020.1775894

22. Bronfenbrenner U. Making human beings human: bioecological perspectives on human development. Thousand Oaks: Sage Publications (2005).

23. Hofstede G. *Cultures and organizations - software of the mind.* New York: McGraw-Hill (1997).

24. Lewin K. *Principles of topological psychology.* New York: McGraw-Hill (1936).

25. Schein E. Organizational culture [10.1037//0003-066X.45.2.109]. *Am Psychol.* (1990) 45:109–19. doi: 10.1037/0003-066X.45.2.109

26. Larsen CH, Alfermann D, Henriksen K, Christensen MK. Successful talent development in soccer: the characteristics of the environment. *Sport Exerc Perform Psychol.* (2013) 2(3):190–206. doi: 10.1037/a0031958

27. Larsen CH, Storm LK, Arve Sætter S, Pyrdol Christensen N, Henriksen K. A world class academy in professional football: the case of Ajax Amsterdam. *Scand J Sport Exerc Psychol.* (2020) 2:33–43. doi: 10.7146/sjsep.v2i0.119746

28. Ringereide R, Saether SA. The talent development environment in a Norwegian top-level football club. *Sport Sci Rev*. (2016) 25:159–82. doi: 10.1515/ssr-2016-0009

29. Ryom K, Ravn M, Düring R, Henriksen K. Talent development in football—a holistic perspective: the case of KRC Genk. *Int Sport Coaching J*. (2019) 7(3):360–9. doi: 10.1123/iscj.2019-0045

30. Storm LK, Ronglan LT, Henriksen K, Christensen MK. Organisational cultures of two successful scandinavian handball talent development environments: a comparative case study. *Sports Coaching Rev*. (2022) 11(2):147–69. doi: 10.1080/21640629.2021.1990652

31. Seanor M, Schinke RJ, Stambulova N, Henriksen K, Ross D, Griffin C. Catch the feeling of flying: guided walks through a trampoline Olympic development environment. *Case Stud Sport Exerc Psychol*. (2019) 3:11–9. doi: 10.1123/cssep.2019-0002

32. Henriksen K, Larsen CH, Christensen MK. Looking at success from its opposite pole: the case of a talent development golf environment in Denmark. *Int J Sport Exerc Psychol*. (2014) 12(2):134–49. doi: 10.1080/1612197X.2013.853473

33. Henriksen K, Stambulova N. Creating optimal environments for talent development: a holistic ecological approach. In: S Cobley, J Baker, J Schorer, N Wattie, editors. *Routledge handbook of talent identification and development in sport*. New York: Routledge (2017). p. 271–84.

34. Storm LK, Svendsen AM. Conceptualizing cultural leadership in physical education and youth sport: outlining a pedagogical concept. *Sport Educ Soc*. (2022):1–14. doi: 10.1080/13573322.2022.2065670

35. Mathorne O, Henriksen K, Stambulova N. An "organizational triangle" to coordinate talent development: a case study in danish swimming. *Case Stud Sport Exerc Psychol*. (2020) 4(1):11–20. doi: 10.1123/cssep.2019-0017

36. Mathorne O, Stambulova N, Book RT, Storm LK, Henriksen K. Shared features of successful interorganizational collaboration to promote local talent development environments in Denmark [journal article]. *Scand J Sport Exerc Psychol*. (2021) 3:2–12. doi: 10.7146/sjsep.v3i.121379

37. ECO-DC. Erasmus+ Sport Project: "Ecology of Dual Career: Exploring Dual Career Development Environments across Europe." Downloaded from https://dualcareers.eu/ (2018).

38. Henriksen K, Storm LK, Kuettel A, Linnér L, Stambulova N. A holistic ecological approach to sport and study: the case of an athlete friendly university in Denmark. *Psychol Sport Exerc*. (2020) 47:101637. doi: 10.1016/j.psychsport.2019.101637

39. Linnér L, Stambulova N, Henriksen K. Facilitating student-Athletes' dual career transition: a scandinavian university case study. *Sport Exerc Perform Psychol*. (2022) 11(2):107–23. doi: 10.1037/spy0000275

40. Storm LK, Henriksen K, Stambulova N, Cartigny E, Ryba T, De Brandt K, et al. Ten essential features of European dual career development environments: a multiple case study. *Sport Exerc Psychol*. (2021) 54. doi: 10.1016/j.psychsport.2021.101918

41. Book RT, Stambulova N, Henriksen K. Oatmeal is better than no meal: the career pathways of African American male professional athletes from underserved communities in the United States. *Int J Sport Exerc Psychol*. (2020) 19(4):504–23. doi: 10.1080/1612197X.2020.1735258

42. Book RT, Henriksen K, Stambulova N, Storm LK. All they have seen is a model for failure: stakeholder's Perspectives on athletic talent development in American underserved communities. *J Appl Sport Psychol*. (2021) 34(6):1037–57. doi: 10.1080/10413200.2021.1958953

43. Book RT, Henriksen K, Stambulova N, Mathorne OW. (2022, *under review*). "We are their last chance": A case study of a college basketball environment in an American underserved community.

44. Wylleman P. A developmental and holistic perspective on transitioning out of elite sport. In: MH Anshel, editors. *APA Handbook of sport and exercise psychology: vol. 1. Sport psychology*. New York: American Psychological Association (2019). p. 201–16.

45. Henriksen K, Schinke R, Moesch K, McCann S, Parham WD, Larsen CH, et al. Consensus statement on improving the mental health of high-performance athletes. *Int J Sport Exerc Psychol*. (2019) 18(5):553–60. doi: 10.1080/1612197X.2019.1570473

46. Stambulova N, Ryba TV, Henriksen K. Career development and transitions of athletes: iSSP position stand revisited. *Int J Sport Exerc Psychol*. (2021) 19(4):524–50. doi: 10.1080/1612197X.2020.1737836

Frontiers in Sports and Active Living

TYPE Opinion
PUBLISHED 28 July 2022
DOI 10.3389/fspor.2022.929981

OPEN ACCESS

EDITED BY
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SPECIALTY SECTION
This article was submitted to
Elite Sports and Performance
Enhancement,
a section of the journal
Frontiers in Sports and Active Living

RECEIVED 27 April 2022
ACCEPTED 04 July 2022
PUBLISHED 28 July 2022

CITATION
Quinaud RT, Capranica L, Doupona M and Guidotti F (2022) The holistic development of talented sportspersons through dual-career. *Front. Sports Act. Living* 4:929981. doi: 10.3389/fspor.2022.929981

The holistic development of talented sportspersons through dual-career

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KEYWORDS
student-athlete, education, athletes' career, sport, career support

The holistic development of talented athletes

In sport, talent development is a multidimensional, multiplicative, and dynamic interaction of performance, psycho-social, and educational processes (Simonton, 2001; Burgess and Naughton, 2010). In general, the development of talents spans a period of 15–20 years and encompasses different stages in the sport (e.g., initiation, talent development, talent retention, mastery, and perfection/elite performance), education (e.g., elementary school, high school, and university/vocational), and working levels (Stambulova and Wylleman, 2015, 2019; Wylleman, 2019; Moreno et al., 2021). Therefore, in pursuing an athletic career several decisions must be taken, which have a direct impact on the lives of the sportspersons and their academic/sport/family and peers supporting entourage (Ryba et al., 2015; Capranica and Guidotti, 2016; Condello et al., 2019; Gjaka et al., 2021; Leisterer et al., 2021; Stambulova et al., 2021; Tessitore et al., 2021; Varga et al., 2021). Also, the literature on sports talent identification emphasises the importance of significant actors for facilitating the holistic development of talented athletes, mainly through supportive initiatives/actions in pursuing wellbeing and in coping with stressful situations across life domains, such as training and competitive loads, injuries, lack of social life, and transitions to higher competition and academic levels (Morgan and Giacobbi, 2006; Johnston, 2018; Williams and MacNamara, 2022). In revisiting its position stance on athlete transitions and wellbeing, the International Society of Sport Psychology (ISSP) specifically highlighted career assistance as a crucial aspect (Stambulova et al., 2021). During talent development and career transitions, it is important to collect information on the athletes' lifestyles, relationships, and supportive entourage to plan and apply effective interventions.

During their developmental stages, youth athletes encounter increasing demands and challenges, also in relation to concurrent interactions between sport and education requirements (Salmela-Aro et al., 2008; MacNamara and Collins, 2010; Aquilina, 2013; Monteiro et al., 2017). In particular, to build a mastery elite performance level in their sport, student-athletes competing in different sports disciplines spend several hours in training, competition, and sport-related side activities (i.e., warm-up, cool down, recovery interventions), to be combined with academic commitments such as class attendance and individual study (Ericsson, 2006; Aquilina, 2013; Guidotti et al., 2015; Condello et al., 2019). The time spent in training, travelling to competitions, and competing poses athletes in a disadvantaged position compared to their non-athletic counterparts (European Commission, 2012; Xanthopoulos et al., 2020). In fact, athletes reported a lack of time to study, limited relations with teachers/professors, classmates, and peers, missed classes and exams, physical and mental fatigue, and identity conflicts (Gaston-Gayles and Baker, 2015; Stambulova et al., 2015; Gomez et al., 2018; Condello et al., 2019; Steele et al., 2020). Despite athletes having the main responsibility of their dual career paths (e.g., micro dimension) several individuals, institutions, or specific contexts have different and integrated responsibilities in accompanying and fostering talented athletes during their developmental years, mainly providing a critical balance of challenges and/or emotional and logistical support at the meso (e.g., parents, peers, teachers/employers, coaches, sport managers), macro (e.g., sports clubs/federations, educational institutions, and labour market), and policy (e.g., national and international governing bodies) dimensions of dual career (Larsen et al., 2012, 2013; Capranica and Guidotti, 2016).

Challenge for scholars on the dual career of athletes

In the last decade, several aspects have been studied to uncover the dual-career phenomenon (Guidotti et al., 2015; Stambulova and Wylleman, 2019; López-Flores et al., 2021). However, the actual interpretation of findings is limited by country-, sport-, and academic-specific socio-economic-cultural contexts, which determine tremendous differences in dual-career regulations, programmes, and services. In particular, the researchers tend to use the term student-athlete, which strictly refers to a sports context rooted in an educational system (e.g., United States) and could present some problems when applied to athletes as students competing in sports organisations not related to academic institutions (e.g., Europe). Another critical aspect pertains to relevant differences in the requirements and eligibility criteria for dual-career programmes and services adopted within and across countries, which determine unequal quantity and quality of dual career support (European Commission, 2016). Finally, the definition of a dual career as "a career with major foci on sport and studies" (Stambulova and Wylleman, 2015, p. 1) could allow different interpretations when the sport or the academic careers are not balanced or linear over time, and when strict academic and sport eligibility criteria are adopted, supporting a short-term approach to outcomes rather than long term holistic development of athletes (Martindale et al., 2005; Staurowsky and Sack, 2005; Capranica and Millard-Stafford, 2011). This lack of clarity has a direct influence on how scholars analyse and interpret findings, and suggests cautions when ways to support dual-career paths of talented athletes are envisaged.

Considering that the holistic development of youth athletes is a complex process involving different individuals, organisations, and socio-cultural-political systems, qualitative and quantitative multilevel mixed methods research designs are recommended to advance our understanding of the interactions occurring at its micro, meso, macro, and global levels (Headley and Plano Clark, 2019). In fact, the use of multilevel analysis lies in the fact that it considers the nature of data structure and the different sources of variation (Gelman and Hill, 2006). Furthermore, in light of the extensive globalisation of sport and the internationalisation of educational paths, the scientific community is urged to cooperate in establishing evidence for the implementation of dual-career guidelines for an effective sport- and academic-specific support of youth talented athletes. Besides the academic community, also the athletes and their supportive entourage, the managers, the policy-makers, and the stakeholders are required to contribute with innovative and cooperative approaches for the holistic development of the youth athletes. In this framework, the successful experience of the European Commission to allocate funds for cross-national cooperation through the ERASMUS+Sport Collaborative Partnerships focused on dual-career and youth development provides a valuable example for the establishment of a platform for fostering evidence- and eminence-base knowledge uncovering effective bidirectional relationships between policies and practises (Guidotti et al., 2015; Stambulova and Wylleman, 2019; Capranica et al., 2021; European Commission, 2021; López-Flores et al., 2021).

The responsibilities and challenges in the dual-career micro dimension

Talented athletes committed to achieving high performances in their sports might need effective proactive strategic planning to facilitate their transition to the elite level as well as to the labour market at the end of their sports career. Indeed, several individual aspects concur with a holistic developmental programme, including a deep understanding of the athletes' potential profiles in relation to the dynamic association of their endogenous (e.g., physical and mental traits, and personal values) and exogenous (e.g., cultural and physical environments) resources, as well as a sound understanding of potential barriers (Gagné, 2013; Simonton, 2017; Weissensteiner, 2017). Undoubtedly, intrapersonal characteristics could help define a strong student-athlete identity, motivation, willpower, and time management, which could improve the probability of successful dual-career paths (Li and Sum, 2017). Whilst athletes competing in championships managed by a sports federation or associations and being enrolled in a full-time high school or university degree could consider themselves student-athletes, different eligibility criteria are adopted to allow them to access institutionalised dual career services and provisions (Capranica and Guidotti, 2016: European Commission, 2016; Sanchez-Pato et al., 2017). Furthermore, individual self-identity and motivation to combine academic and sports careers differ based on the athletic level, sports career perspectives, self-awareness, and personal values of the athletes, as well as the dual-career support from cultural backgrounds and contexts (Gaston-Gayles, 2005; Harrison et al., 2014; de Subijana et al., 2015; Lupo et al., 2015; Quinaud et al., 2021; Lee et al., 2022). Therefore, the initial identification of future sports and academic performances would be based on a thorough understanding of the most relevant determinants supporting dual career paths and preventing risks of sports or academic burnout and dropouts. Finally, interventions might occur to implement the development of a dual career supporting entourage for the athletes.

The responsibilities and challenges at the dual-career meso dimension

The meso dimension of dual-career comprises actors having strong, direct, and personal relationships with the athlete in the family (e.g., parents, siblings, relatives, friends, and peers), the sport (e.g., coaches, managers, staff, dual-career tutor), and the academic (e.g., classmates, teachers, tutors, deans) environments. In particular, elite athletes competing at the 2017 summer Universiade (e.g., the world's largest and most prestigious multi-sport events organised for university athletes by the International University Sports Federation–FISU) declared that parents, coaches, and university staff are their best dual-career supporters (Condello et al., 2019). In fact, parents play a key role in the climate created for sports and education, whereas coaches and teachers increase their role as the athletes grow older and relocate to academies, or experience language barriers and cultural adjustment when migrating abroad (Baghurst et al., 2018; Fuchs et al., 2021; Palumbo et al., 2021). Parents, coaches, and teachers could have a concurrent and additive role in the athlete's outcomes and wellbeing when aligning objectives for the promotion of a holistic developmental process for the athletes. However, cooperation between coaches and parents of young athletes is not promoted (Capranica and Millard-Stafford, 2011; Knight et al., 2018; Mossman et al., 2021; Lemelin et al., 2022).

Recent research focusing on the parent's role in sustaining athletes' dual-career highlighted difficulties in establishing meaningful relationships with sports and academic staff for the construction of a coherent dual-career support environment (Gjaka et al., 2021; Tessitore et al., 2021; Varga et al., 2021). In considering that parents may lack the required knowledge to work individually and in teams with other key dual-career actors, a European framework informed the development of an online education programme for parents within the Erasmus+ Sport project EMPATIA to empower them in promoting a positive dual-career environment for their talented children (Capranica et al., 2018, 2022; Varga et al., 2021). To avoid the mutual interference between educational and athletic environments, academic and sport, staff might consider rethinking their role through appropriate formal (e.g., degree programs) non-formal (e.g., refreshment courses), and informal (e.g., reading, conversations with experts) training opportunities. Additionally, staff may consider a cultural-specific approach to integrating professional, interpersonal, and intrapersonal knowledge. The integration of such knowledge will contribute to establishing a climate of listening, questioning, and negotiation between dual-career actors to develop and/or support a team of facilitators of an effective development environment for talented athletes (European Commission, 2020; Neelis et al., 2020; Nikander et al., 2022).

The responsibilities and challenges in the dual-career macro dimension

The holistic development of individual and team sports athletes have a multi-centric organisational model encompassing sports bodies (e.g., clubs/national sports federations, athletes' organisations), educational institutions (e.g., schools/universities), and service provider of well-structured and coherent programmes at school and at sports levels that recognise athletes to be seen as whole persons (Capranica and Guidotti, 2016). Around the globe, the organisation of sports and education varies considerably in structure, typology, and administration, ranging from models embedding sport in the educational system to sports practised in clubs having no or limited relationship with the educational system (Camiré, 2014; European Commission, 2016).

At the sports level, national Olympic Committees and sports federations/associations could adopt a top-down approach by promoting dual-career programmes through educational courses for coaches and managers, and by fostering the inclusion of a dual career tutor at club levels to facilitate collaboration with educational institutions. Furthermore, athletes' organisations could adopt a bottom-up approach by requesting that clubs and sports bodies adopt measures in support of dual careers of youth talents for their holistic, integrated, and sustainable development. At the academic level, in the United States a well-structured dual career is in place, with the educational provision (e.g., scholarships, academic tutors, career counselling, etc.,) used as a strategic tool to recruit the most talented athletes for upholding high school and university sports teams considered symbols of academic institutions (www.nfhs.org; www.ncaa.org). In Europe, sports are mainly organised at the club level and there is a need for specific dual-career national guidelines and regulations to avoid a fragmented and incoherent culture to support youth athletes towards their achievements in the sport and academic domains (Aquilina and Henry, 2010;

De Bosscher et al., 2011, 2015; European Commission, 2012, 2016; Henriksen et al., 2014, 2020; Thomsen and Nørgaard, 2018; Kuettel et al., 2020; Morris et al., 2021; Nikander et al., 2022). Even when the athletes have been considered symbols of their schools, their academic performances have been an issue of concern. Despite there being no consensus regarding the negative influence of sport on graduation rates and academic success, the negative impact of stereotypes on the academic underperformance of athletes urge the creation and implementation of identity-safe environments (Jonker et al., 2009; Levine et al., 2014; Storm and Eske, 2021; Storm et al., 2021; Hsu et al., 2022).

To behave authentically, the sports and academic environments may need to pro-actively translate dual-career values into their own actual practises and to ameliorate strategically their processes and practises. In particular, we recommend to academic institutions: i) guarantee the recognition of the "student-athlete" status based on pre-defined criteria characterising elite sports-persons (e.g., enrolment in the National Team, sport professionalism, number of certified hours of training per week, certified competition level); and ii) provide the necessary services (e.g., flexibility in class attendance and examination schedule, tutoring/consulting, on-line learning opportunities) to meet athletes' needs to combine their sport and academic efforts. Similarly, sports organisations and coaching staffs may need to recognise the educational demands athletes' have to match with their training and competition schedule and to provide them concrete support in their dual career path (e.g., sports facilities and services, training schedule adaptation when possible, and proximity between sport and academic venues). Therefore, the alignment of sports and academic institutional efforts and strategies at both internal (e.g., education of the staff members, change in the processes of dual career management) and external (e.g., collaborative practises for the establishment of coordinated dual-career programmes through the involvement of all the relevant dual-career stakeholders) levels is crucial to develop and support athletes' dual career (Capranica and Guidotti, 2016). Despite a positive relationship between sports bodies and educational institutions being strongly envisaged to determine effective dual career paths, it is crucial to consider that no single programme or best practises implemented in specific settings could be generalised across national contexts, sports disciplines, and educational environments. Thus, tailored strategic inter-institutional agreements on dual-career support have to be designed, monitored, and evaluated over time (Emrich et al., 2009; Jonker et al., 2009; Henriksen et al., 2014; Thompson et al., 2022).

The responsibilities and challenges in the dual-career policy dimension

In addition to personal and organisational efforts in advancing dual-career values, understanding, and beliefs, also sports federations, governments, and societal expectations have a role in sustaining the advancement of the dual-career culture at both national and international levels through specific policies and financial resources (Capranica and Guidotti, 2016; Kuettel et al., 2018). At the international level, the European Parliament (2003, 2015, 2021), the European Commission (2012, 2021), Council of the European Union (2021), the Council of Europe (2021), the International School Sport Federation (ISF, 2022), the International University Sports Federation (FISU, 2021), and the International Olympic Committee (IOC, 2022), have a top-down influence and provide the framework for cross-national and cross-sectoral cooperation between decision-makers. Their recommendations could foster the identification and the promotion of the best practises in dual-careers at local, national, and international levels, as well as overcome the resilience of the educational and sports institutions that might not envisage the need for changes. In fact, to counteract the lack of education in favour of sports commercialisation during the athletes' developmental years, the recent Resolution of the Council of the European Union on a European Model of Sport (2021) and the Recommendations of the Council of Europe on the Revised European Sports Charter (2021) urge policymakers and sports stakeholders to stress the development of the youth and the rights of the child and to invest in education through sports (Council of Europe, 2021; Council of the European Union, 2021). Furthermore, the allocation of funds to cross-sectorial and cross-country partnerships and to studies focused on dual-career and youth development practises could accelerate the development of a culture supporting the holistic development of youth athletes (Guidotti et al., 2015; Stambulova and Wylleman, 2019; Capranica et al., 2021; European Commission, 2021; López-Flores et al., 2021).

Additionally, International and National guidelines on dual careers could further enhance major tenets and praxis for social support for the holistic development of talented athletes in different sports and educational settings (European Olympic Committee, 2011; European Commission, 2012). Moreover, the European Athlete as Student (EAS) network provides a platform for an effective dialogue between educational bodies (i.e., universities, high schools, sports schools), sports organisations (i.e., clubs, sports federations, National Olympic Committees), and cooperates with European institutions (e.g., European Parliament, European Commission, and Council of Europe) and several partners in the development of innovative international cross-national projects and research on a dual career in the diverse contexts, which represent a laboratory for reconciling youth sport and education also beyond Europe (Aquilina and Henry, 2010; Capranica et al., 2015, 2021; Capranica and Guidotti, 2016; Condello et al., 2019; Stambulova and Wylleman, 2019; López-Flores et al., 2021).

Conclusion

Despite the primacy and independence of sports and education policies and legislation, in the past decade, there is a growing concern to sustain the athlete's right of combining sport and academic careers and to identify the relevant factors that impact the nature of support provision and the level of disruption leading to a sport or academic drop-out (Henry, 2013). At present, the evidence indicates that no single individual, variable, or model effectively ensures the sound development of talented athletes (Guidotti et al., 2015; Stambulova and Wylleman, 2019; López-Flores et al., 2021). Consequently, extensive cooperation between public authorities, sports bodies, academic institutions, and other stakeholders is strongly recommended to promote opportunities for the implementation of dual-career guidelines (European Commission, 2012; Mittag et al., 2021). Furthermore, sports scholars are urged to increase the clarity of definitions of terms and to apply innovative, multidisciplinary, and cross-national research approaches for envisaging proper strategies that enhance the holistic development of talented athletes.

Scientific evidence could help overcome some resistance due to stereotypes privileging education over sports to prepare for a future life, or privileging sports over education to obtain outstanding athletic outcomes. Several issues not fully operationalized in the literature might need further investigations to verify: The impacts of financial resources on the athletes' development; the actual sports and academic outcomes of athletes receiving qualified dual-career measures; the implementation of dual-career programmes resulting from educational programmes for sports and academic staff; and the monitoring and evaluation measures to implement the efficacy of dual-career development environments. In fact, in considering the increased socio-cultural expectations of supporting talented athletes, the combination of education and sport is not sufficiently implemented to facilitate favourable dual-career environments (European Commission, 2016).

Author contributions

All authors contributed intellectually to the conceptualisation and the actual writing-up of this opinion paper.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Aquilina, D. (2013). A study of the relationship between elite athletes' educational development and sporting performance. *Int. J. History. Sport.* 30, 374–392. doi: 10.1080/09523367.2013.765723

Aquilina, D., and Henry, I. (2010). Elite athletes and university education in Europe: a review of policy and practice in higher education in the European Union Member States. *Int. J. Sport. Policy.* 2, 25–47. doi: 10.1080/19406941003634024

Baghurst, T., Fiaud, V., Tapps, T., Bounds, E., and LaGasse, A. (2018). Considerations when coaching the international athlete. *Int. J. Kines. Higher. Edu.* 2, 76–86. doi: 10.1080/24711616.2018.1425936

Burgess, D., and Naughton, G. (2010). Talent development in adolescent team sports: a review. *Int. J. Sports Physiol. Perform.* 5, 103–116. doi: 10.1123/ijspp.5.1.103

Camiré, M. (2014). Youth development in North American high school sport: review and recommendations. *Quest.* 66, 495–511. doi: 10.1080/00336297.2014.952448

Capranica, L., Figueiredo, A., Ābelkalns, I., Blondel, L.,Foerster, J., Keldorf, O., et al. (2021). The contribution of the european athlete as student network (EAS) to European dual career ERASMUS+ sport collaborative partnerships: an update (La Contribución de la Red European Athlete as Student (EAS) a las European Dual career ERASMUS+ Sport: Una actualización). *Cult. Cienc. y Deporte.* 16, 7–17. doi: 10.12800/ccd.v16i47.1693

Capranica, L., Foerster, J., Keldorf, O., Leseur, V., Vandewalle, P., Ābelkalns, I., et al. (2015). The European Athlete as Student Network (" EAS"): prioritising dual career of European student-athletes. *Kinesiol. Slov.* 21, 5–10.

Capranica, L., and Guidotti, F. (2016). *Research for Cult Committee Qualifications/Dual Careers in Sports. European Parliament: Directorate-General For Internal Policies. Policy Department. Structural and Cohesion Policies: Cultural And Education.* Available online at: https://www.europarl.europa.eu/thinktank/en/document/IPOL_STU(2016)573416%20 (accessed July 15, 2022).

Capranica, L., Guidotti, F., Gonçalves, C. E., Blondel, L., Bovis, M., Costa, R., et al. (2022). Development of an online multi-lingual educational programme for parents of dual career athletes: A participatory design. *Front. Psychol.* 13, 855531. doi: 10.3389/fpsyg.2022.855531

Capranica, L., MacDonncha, C., Blondel, L., Bozzano, E., Burlot, F., Costa, R., et al. (2018). Towards the construction of an educational model for dual career parenting: the EMPATIA project. *Kinesiol. Slov.* 24, 19–30.

Capranica, L., and Millard-Stafford, M. L. (2011). Youth sport specialization: how to manage competition and training? *Int. J. Sports Physiol. Perform.* 6, 572–579. doi: 10.1123/ijspp.6.4.572

Condello, G., Capranica, L., Doupona, M., Varga, K., and Burk, V. (2019). Dual-career through the elite university student-athletes' lenses: the international FISU-EAS survey. *PLoS ONE,* 14, e0223278. doi: 10.1371/journal.pone.0223278

Council of Europe (2021). *Recommendation CM/Rec(2021)5 of the Committee of Ministers to member States on the Revised European Sports Charter*. Available online at: https://rm.coe.int/recommendation-cm-rec-2021-5-on-the-revision-of-the-european-sport-cha/1680a43914 (accessed July 15, 2022).

Council of the European Union (2021). *Resolution of the Council and of the Representatives of the Governments of the Member States Meeting Within the Council on the Key Features of a European Sport Model*. Available online at: https://data.consilium.europa.eu/doc/document/ST-14430-2021-INIT/en/pdf(accessed July 15, 2022).

De Bosscher, V., Shibli, S., Westerbeek, H., and Van Bottenburg, M. (2015). Successful elite sport policies: an international comparison of the sports policy factors leading to international sporting success (SPLISS 2.0) in 15 nations: Meyer & Meyer. *Sport*. doi: 10.4324/9781315753461-9

De Bosscher, V., Shilbury, D., Theeboom, M., Van Hoecke, J., and De Knop, P. (2011). Effectiveness of national elite sport policies: a multidimensional approach applied to the case of flanders. *Eur Sport Manag Q*, 11, 115–141. doi: 10.1080/16184742.2011.559133

de Subijana, C. L., Barriopedro, M. I., and Sanz, I. (2015). Dual career motivation and athletic identity on elite athletes. *Rev. de Psicol. del Deporte*. 24, 55–57. doi: 10.1016/j.psychsport.2015.04.012

Emrich, E., Fröhlich, M., Klein, M., and Pitsch, W. (2009). Evaluation of the elite schools of sport: Empirical findings from an individual and collective point of view. *Int. Rev. Sport Sociol*. 44, 151–171. doi: 10.1177/1012690209104797

Ericsson, K. A. (2006). "The influence of experience and deliberate practice on the development of superior expert performance," in *The Cambridge Handbook of Expertise and Expert Performance*, eds K. A. Ericsson, R. R. Hoffman, A. Kozbelt, and A. M. Williams (Cambridge: Cambridge University Press), 685–705.

European Commission (2016). *Directorate General for Education and Culture., Amsterdam University of Applied Sciences., Birch Consultants., Talented Athlete Scholarship Scheme., Vrije Universiteit Brussel. Study on the Minimum Quality Requirements for Dual Career Services: Final Report*. LU: Publications Office. Available online at: https://op.europa.eu/en/publication-detail/-/publication/e06e5845-0527-11e6-b713-01aa75ed71a1 (accessed July 15, 2022).

European Commission (2021). *Erasmus+2021-2027: Enriching Lives, Opening Minds*. Available online at: https://www.euneighbours.eu/en/east/stay-informed/publications/erasmus-2021-2027-enriching-lives-opening-minds (accessed July 15, 2022).

European Commission. (2012). *EU Guidelines on Dual Careers of Athletes: Recommended Policy Actions in Support of Dual Careers in High-Performance Sport*. Available online at: http://ec.europa.eu/sport/library/documents/dual-career-guidelines-final_en.pdf (accessed July 15, 2022).

European Commission. (2020). *Guidelines Regarding the Minimum Requirements in Skills and Competences for Coaches. Publications Office of the European Union*. Available online at: https://op.europa.eu/en/publication-detail/-/publication/8f28e3a0-6f11-11ea-b735-01aa75ed71a1/language-en (accessed July 15, 2022).

European Olympic Committee (2011). *Guidelines: Promoting Dual Career in the EU*. Available online at: https://sportperformancecentres.org/sites/default/files/A2B_guidelines_final.pdf (accessed July 15, 2022).

European Parliament (2003). *Combining Sport and Education: Support for Athletes in the EU Member States*. Available online at: https://www.europarl.europa.eu/thinktank/en/document.html?reference=DG-4-CULT_ET(2004)341532 (accessed July 15, 2022).

European Parliament (2015). *EU Sport Policy. An overview. Brussels: European Parliamentary Research Service*. Available online at: http://www.europarl.europa.eu/RegData/etudes/IDAN/2015/565908/EPRS_IDA(2015)565908_EN.pdf. (accessed July 15, 2022).

European Parliament (2021). *European Parliament Resolution of 23 November 2021 on EU Sports Policy: Assessment and Possible Ways Forward*. Available online at: https://www.europarl.europa.eu/doceo/document/TA-9-2021-0463_EN.html (accessed July 15, 2022).

FISU (2021). *Dual Career at FISU*. Available online at: https://www.fisu.net/education/projects-cooperation/dual-career. (accessed July 15, 2022).

Fuchs, P. X., Doupona, M., Varga, K., Bon, M., Cortis, C., Fusco, A., et al. (2021). Multi-national perceptions on challenges, opportunities, and support structures for dual career migrations in European student-athletes. *PLoS ONE*. 16, e0253333. doi: 10.1371/journal.pone.0253333

Gagné, F. (2013). "*Yes, Giftedness (aka "innate" talent) Does Exist", in The complexity of Greatness: Beyond Talent or Practice*, eds S. B.Kaufman, (New York, Oxford University Press), 191–221.

Gaston-Gayles, J., and Baker, A. (2015). Opportunities and challenges for first-year student-athletes transitioning from high school to college. *New. Dir. Stud. Leadersh*. 147, 43–51. doi: 10.1002/yd.20142

Gaston-Gayles, J. L. (2005). The factor structure and reliability of the student athletes' motivation toward sports and academics questionnaire (SAMSAQ). *J. Coll. Stud. Dev*. 46, 317–327. doi: 10.1353/csd.2005.0025

Gelman, A., and Hill, J. (2006). *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Cambridge: Cambridge University Press.

Gjaka, M., Tessitore, A., Blondel, L., Bozzano, E., Burlot, F., Debois, N., et al. (2021). Understanding the educational needs of parenting athletes involved in sport and education: the parents' view. *PLoS ONE*. 16, e0243354. doi: 10.1371/journal.pone.0243354

Gomez, J., Bradley, J., and Conway, P. (2018). The challenges of a high-performance student athlete. *Ir Educ Stud*. 37, 329–349. doi: 10.1080/03323315.2018.1484299

Guidotti, F., Cortis, C., and Capranica, L. (2015). Dual career of European student-athletes: a systematic litaruture review. *Kinesiol. Slov*. 21, 5–20.

Harrison, C. K., Tranyowicz, L., Bukstein, S., McPherson-Botts, G., and Lawrence, S. M. (2014). I am what I am? The baller identity measurement scale (BIMS) with a division i football team in American higher education. *Sport Sci. Health*. 10, 53–58. doi: 10.1007/s11332-014-0171-3

Headley, M. G., and Plano Clark, V. L. (2019). Multilevel mixed methods research designs: advancing a refined definition. *J. Mix. Methods Res*. 14, 145–163. doi: 10.1177/1558689819844417

Henriksen, K., Larsen, C. H., and Christensen, M. K. (2014). Looking at success from its opposite pole: the case of a talent development golf environment in Denmark. *Int. J. Sport Exerc. Psychol*. 12, 134–149. doi: 10.1080/1612197X.2013.853473

Henriksen, K., Storm, L. K., Kuettel, A., Linnér, L., and Stambulova, N. (2020). A holistic ecological approach to sport and study: the case of an athlete friendly university in Denmark. *Psychol. Sport Exerc*. 47, 101637. doi: 10.1016/j.psychsport.2019.101637

Henry, I. (2013). Athlete development, athlete rights and athlete welfare: a European Union perspective. *Int. J. Hist. Sport*. 30, 356–373. doi: 10.1080/09523367.2013.765721

Hsu, Y., Lin, T. Y., and Lu, F. J. (2022). Combating stereotype threat toward athletes' academic performance: experiments on identity safety and self-complexity. *Curr. Psychol*. 1–22. doi: 10.1007/s12144-021-02519-4

IOC (2022). *Dual Career*. Available online at: https://olympics.com/athlete365/what-we-do/career/dual-career/ (accessed July 15, 2022).

ISF (2022). *Quality Education*. Available online at: https://www.isfsports.org/isf-education-values (accessed July 15, 2022).

Johnston, C. S. (2018). A systematic review of the career adaptability literature and future outlook. *J. Career Assess*. 26, 3–30. doi: 10.1177/1069072716679921

Jonker, L., Elferink-Gemser, M. T., and Visscher, C. (2009). Talented athletes and academic achievements: a comparison over 14 years. *High Abil. Stud*. 20, 55–64. doi: 10.1080/13598130902863691

Knight, C. J., Harwood, C. G., and Sellars, P. A. (2018). Supporting adolescent athletes' dual careers: the role of an athlete's social support network. *Psychol. Sport. Exerc*. 38, 137–147. doi: 10.1016/j.psychsport.2018.06.007

Kuettel, A., Boyle, E., Christensen, M. K., and Schmid, J. (2018). A cross-national comparison of the transition out of elite sport of Swiss, Danish and Polish athletes. *Sport Excer. Psychol. Rev*. 14, 3–22.

Kuettel, A., Christensen, M. K., Zysko, J., and Hansen, J. (2020). A cross-cultural comparison of dual career environments for elite athletes in Switzerland, Denmark, and Poland. *Int. J. Sport Exerc. Psychol*. 18, 454–471. doi: 10.1080/1612197X.2018.1553889

Larsen, C., Alfermann, D., and Christensen, M. K. (2012). Psychosocial skills in a youth soccer academy: a holistic ecological perspective. *Sport. Sci. Rev*. 21, 51–74. doi: 10.2478/v10237-012-0010-x

Larsen, C., Alfermann, D., Henriksen, K., and Christensen, M. K. (2013). Successful talent development in soccer: the characteristics of the environment. *Sport Exerc. Performance Psychol*. 2, 190–206. doi: 10.1037/a0031958

Lee, Y., Immekus, J., Lim, D., Hums, M., Greenwell, C., Cocco, A., et al. (2022). Validation of the student athletes' motivation toward sports and academics questionnaire (SAMSAQ) for Korean college student-athletes: an application of exploratory structural equation modeling. *Front. Psychol*. 1–10. doi: 10.3389/fpsyg.2022.853236

Leisterer, S., Lautenbach, F., Walter, N., Kronenberg, L., and Elbe, A. M. (2021). Development of a salutogenesis workshop for SPPs to help them, their athletes, and the athlete's entourage better cope with uncertainty during the COVID-19 pandemic. *Front. Psychol.* 12, 1574. doi: 10.3389/fpsyg.2021.612264

Lemelin, E., Verner-Filion, J., Carpentier, J., Carbonneau, N., and Mageau, G. A. (2022). Autonomy support in sport contexts: the role of parents and coaches in the promotion of athlete well-being and performance. *Sport Exerc. Perform. Psychol.* 1–15. doi: 10.1037/spy0000287

Levine, J., Etchison, S., and Oppenheimer, D. (2014). Pluralistic ignorance among student–athlete populations: a factor in academic underperformance. *High Educ.* 68, 525–540. doi: 10.1007/s10734-014-9726-0

Li, M., and Sum, R. K. W. (2017). A meta-synthesis of elite athletes' experiences in dual career development. *Asia Pac. J. Sport Soc. Sci.* 6, 99–117. doi: 10.1080/21640599.2017.1317481

López-Flores, M., Hong, H. J., and Botwina, G. (2021). Dual career of junior athletes: Identifying challenges, available resources, and roles of social support providers. *Cult. Cienc. Deporte.* 16, 117–129.

Lupo, C., Guidotti, F., Goncalves, C. E., Moreira, L., Doupona Topic, M., Bellardini, H., et al. (2015). Motivation towards dual career of European student-athletes. *Eur. J. Sport Sci.* 15, 151–160. doi: 10.1080/17461391.2014.940557

MacNamara, Á., and Collins, D. (2010). The role of psychological characteristics in managing the transition to university. *Psychol. Sport Exerc.* 11, 353–362. doi: 10.1016/j.psychsport.2010.04.003

Martindale, R. J., Collins, D., and Daubney, J. (2005). Talent development: a guide for practice and research within sport. *Quest.* 57, 353–375. doi: 10.1080/00336297.2005.10491862

Mittag, J., Bock, V., and Tisson, C. (2021). *Research for CULT Committee - EU Sports Policy: Assessment and Possible Ways Forward. EU Sports Policy: Assessment and Possible Ways Forward.* Available online at: https://www.europarl.europa.eu/thinktank/en/document/IPOL_STU(2021)652251 (accessed July 15, 2022).

Monteiro, D., Cid, L., Marinho, D. A., Moutão, J., Vitorino, A., and Bento, T. (2017). Determinants and reasons for dropout in swimming - systematic review. *Sports.* 5, 50. doi: 10.3390/sports5030050

Moreno, R., Chamorro, J. L., and Lopez de Subijana, C. (2021). Employee-athletes: exploring the elite Spanish athletes' perceptions of combining sport and work. *Front. Psychol.* 12, 250. doi: 10.3389/fpsyg.2021.633133

Morgan, T. K., and Giacobbi, P. R. (2006). Toward two grounded theories of the talent development and social support process of highly successful collegiate athletes. *Sport Psychol.* 20, 295–313. doi: 10.1123/tsp.20.3.295

Morris, R., Cartigny, E., Ryba, T. V., Wylleman, P., Henriksen, K., Torregrossa, M., et al. (2021). A taxonomy of dual career development environments in European countries. *Eur. Sport Manag. Q.* 21, 134–151. doi: 10.1080/16184742.2020.1725778

Mossman, G. J., Robertson, C., Williamson, B., and Cronin, L. (2021). Coaches, parents, or peers: who has the greatest influence on sports participants' life skills development? *J. Sports Sci.* 39, 2475–2484. doi: 10.1080/02640414.2021.1939980

Neelis, L., Faucett, A., and Thompson, M. (2020). Quality sport coaching: the role of the national standards for sport coaches. *Strategies.* 33, 7–13. doi: 10.1080/08924562.2020.1812328

Nikander, J. A. O., Ronkainen, N. J., Korhonen, N., Saarinen, M., and Ryba, T. V. (2022). From athletic talent development to dual career development? A case study in a Finnish high performance sports environment. *Int. J. Sport Exerc. Psychol.* 20, 245–262. doi: 10.1080/1612197X.2020.1854822

Palumbo, F., Fusco, A., Cortis, C., and Capranica, L. (2021). Student-athlete migration: a systematic literature review. *Hum. Mov.* 22, 80–91. doi: 10.5114/hm.2021.99988

Quinaud, R. T., Gonçalves, C. E., Possamai, K., Morais, C. Z., Capranica, L., and Carvalho, H. M. (2021). Validity and usefulness of the student-athletes' motivation toward sport and academics questionnaire: a Bayesian multilevel approach. *PeerJ.* 9, e11863. doi: 10.7717/peerj.11863

Ryba, T. V., Ronkainen, N. J., and Selänne, H. (2015). Elite athletic career as a context for life design. *J. Vocat. Behav.* 88, 47–55. doi: 10.1016/j.jvb.2015.02.002

Salmela-Aro, K., Kiuru, N., and Nurmi, J. E. (2008). The role of educational track in adolescents' school burnout: a longitudinal study. *Br. J. Educ. Psychol.* 78, 663–689. doi: 10.1348/000709908X281628

Sanchez-Pato, A., Isidori, E., Calderon, A., and Brunton, J. (2017). *An Innovative European Sports Tutorship Model of the Dual Career of Student-Athletes.* Murcia: UCAM Catholic University of Murcia.

Simonton, D. K. (2001). Talent development as a multidimensional, multiplicative, and dynamic process. *Curr. Dir. Psychol. Sci.* 10, 39–43. doi: 10.1111/1467-8721.00110

Simonton, D. K. (2017). "Does Talent Exist?: Yes!" in *Routledge Handbook of Talent Identification and Development in Sport*, eds J. Baker, S. Cobley, J. Schorer, N. Wattie. (London, New York, NY: Routledge), 10–18.

Stambulova, N. B., Engström, C., Franck, A., Linnér, L., and Lindahl, K. (2015). Searching for an optimal balance: dual career experiences of Swedish adolescent athletes. *Psychol. Sport Exerc.* 21, 4–14. doi: 10.1016/j.psychsport.2014.08.009

Stambulova, N. B., and Wylleman, P. (2015). Dual career development and transitions. *Psychol. Sport Exerc.* 21, 1–3. doi: 10.1016/j.psychsport.2015.05.003

Stambulova, N., and Wylleman, P. (2019). Psychology of athletes' dual careers: a state-of-the-art critical review of the European discourse. *Psychol. Sport Exerc.* 42, 74–88. doi: 10.1016/j.psychsport.2018.11.013

Stambulova, N. B., Ryba, T. V., and Henriksen, K. (2021). Career development and transitions of athletes: The international society of sport psychology position stand revisited. *Int. J. Sport Exerc. Psychol.* 19, 524–550. doi: 10.1080/1612197X.2020.1737836

Staurowsky, E. J., and Sack, A. L. (2005). Reconsidering the use of the term student-athlete in academic research. *J. Sport Manag.* 19, 103–116. doi: 10.1123/jsm.19.2.103

Steele, A. R., van Rens, F. E., and Ashley, R. (2020). A systematic literature review on the academic and athletic identities of student-athletes. *J. Intercolleg. Sport.* 13, 69–92. doi: 10.17161/jis.v13i1.13502

Storm, L. K., Henriksen, K., Stambulova, N. B., Cartigny, E., Ryba, T. V., De Brandt, K., et al. (2021). Ten essential features of European dual career development environments: a multiple case study. *Psychol. Sport Exerc.* 54, 101918. doi: 10.1016/j.psychsport.2021.101918

Storm, R. K., and Eske, M. (2021). Dual careers and academic achievements: does elite sport make a difference? *Sport Educ. Soc.* 27, 747–760. doi: 10.1080/13573322.2021.1919070

Tessitore, A., Capranica, L., Pesce, C., De Bois, N., Gjaka, M., Warrington, G., et al. (2021). Parents about parenting dual career athletes: a systematic literature review. *Psychol. Sport Exerc.* 53, 101833. doi: 10.1016/j.psychsport.2020.101833

Thompson, F., Rongen, F., Cowburn, I., and Till, K. (2022). The impacts of sports schools on holistic athlete development: a mixed methods systematic review. *Sports Med.* 1–39. doi: 10.1007/s40279-022-01664-5

Thomsen, K. R., and Nørgaard, J. (2018). Grades for goals? Challenging associations between educational engagement and improved football performance among Danish male elite players. *Soccer Soc.* 21, 152–165. doi: 10.1080/14660970.2018.1541798

Varga, K., MacDonncha, C., Blondel, L., Bozzano, E., Burlot, F., Costa, R., et al. (2021). Collective conceptualization of parental support of dual career athletes: the EMPATIA framework. *PLoS ONE.* 16, e0257719. doi: 10.1371/journal.pone.0257719

Weissensteiner, J. R. (2017). "How contemporary international perspectives have consolidated a best-practice approach for identifying and developing sporting talent," *in Routledge Handbook of Talent Identification and Development in Sport*, eds J. Baker, S. Cobley, J. Schorer, and N. Wattie. (London, New York, NY: Routledge), 51–68.

Williams, G. G., and MacNamara, Á. (2022). Challenge is in the eye of the beholder: exploring young athlete's experience of challenges on the talent pathway. *J. Sports Sci.* 40, 1078–1087. doi: 10.1080/02640414.2022.2047503

Wylleman, P. (2019). "A Developmental and Holistic Perspective on Transiting out of Elite Sport," in *APA Handbook of Sport and Exercise Psychology.* eds M. H. Anshel, and T. A. Petrie (Steinfeldt: American Psychological Association), 201–216.

Xanthopoulos, M. S., Benton, T., Lewis, J., Case, J. A., and Master, C. L. (2020). Mental health in the young athlete. *Curr. Psychiatry Rep.* 22, 63. doi: 10.1007/s11920-020-01185-w

MINI REVIEW
published: 17 June 2022
doi: 10.3389/fspor.2022.926974

Talent Identification and Development in Paralympic Contexts: Current Challenges

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This short review explores the state of talent identification and development of athletes in Paralympic contexts. While talent identification typically occurs during adolescence, this practice is more complex and variable in Paralympic contexts compared to non-Paralympic contexts. For example, Paralympic athletes can have impairments that are congenital or acquired at any time across their lives. Therefore, they can enter performance pathways at unpredictable times. Furthermore, differences and nuances associated with athlete impairments (type and severity), compounded by other systematic complexities (e.g., systems of classification) highlight the need to consider alternative and creative approaches to talent identification and development. We provide an overview of some of these complexities, highlight areas for future research, and provide recommendations for practitioners.

Keywords: para sport, athletes with impairment, pathway, selection, expertise

OPEN ACCESS

Edited by:
Carlos Eduardo Gonçalves, University of Coimbra, Portugal

Reviewed by:
Ruud J. R. Den Hartigh, University of Groningen, Netherlands
Ricardo Quinaud, Universidade do Extremo Sul Catarinense, Brazil
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Specialty section:
This article was submitted to Elite Sports and Performance Enhancement, a section of the journal Frontiers in Sports and Active Living

Received: *23 April 2022*
Accepted: *27 May 2022*
Published: *17 June 2022*

Citation:
Dehghansai N, Pinder RA and Baker J (2022) Talent Identification and Development in Paralympic Contexts: Current Challenges. Front. Sports Act. Living 4:926974. doi: 10.3389/fspor.2022.926974

INTRODUCTION

Talent identification and development has been forefront of discussions in the practical and scientific realm for quite some time. At the core of these discussions remains a lack of clarity around a universal definition of "talent" (Dohme et al., 2017; Baker et al., 2019). Many scientists argue that without a clear understanding of what talent *is*, it becomes difficult to identify and develop *it*, but more importantly, to track it and evaluate our efficiency and effectiveness of the factors identified as *talent* (Issurin, 2017; Baker et al., 2018). It appears that we are not particularly good at identifying "talent" (Till and Baker, 2020), or predicting future potential based on current indicators (Güllich, 2014; Baker et al., 2019). In Paralympic contexts, our scientific base and understanding is further challenged, with much of the existing knowledge being in informed by work that is completed outside these contexts. While it may be argued that organizations in Paralympic contexts face some of the same challenges as those in other contexts (e.g., lack of clarity on operational definition of talent, challenges in forecasting future performance on current indicators), there are specific constraints that introduce additional challenges. Primarily, the underpinning challenges reside in relation with impairment-related factors which can have a marked impact across micro- (i.e., athlete-specific or directly related to, including classification, program and facility availability and accessibility) and macro-levels (broader societal landscape pertaining to policy, infrastructure, funding, and resource allocation, Radtke and Doll-Tepper, 2014; Patatas et al., 2018; Dehghansai et al., 2020). The aim of this short review is to introduce two primary factors that are pertinent to talent identification and development, that is, impairment onset and classification (and by extension type of impairment). In the process we will also highlight two systemic constraints: limited pools of athletes and funding, which influence the dynamics of the athlete development environment. Finally, we provide recommendations for researchers and practitioners, including resources for coaches and talent identifiers.

IMPAIRMENT-RELATED FACTORS

Impairment Onset

Research has identified that athletes with congenital impairments have marked differences in developmental trajectories compared with athletes with acquired impairments (Dehghansai et al., 2017; Patatas et al., 2018). Athletes in Paralympic contexts enter sport systems at various stages in their careers due to the varied onset of impairment (Radtke and Doll-Tepper, 2014) andimpairment onset represents a key marker to reference across athletes' careers. This is an important frame of reference to understanding how trajectories are shaped. For example, an athlete with an impairment acquired in adulthood may have extensive experience in non-Paralympic sports, prior to pursuing a high-performance career in Paralympic contexts. This may differ from a younger athlete with a congenital impairment interested in recreational sport, and/or an athlete with congenital impairment looking to embark on a journey to becoming an elite athlete with little to no previous sporting experience.

In extension of this work, Dehghansai et al. (2021b) examined the variation in athletes' careers based on when they acquired their impairment. The authors categorized athletes into groups representing different biological maturation phases to better understand the interaction between athletes' impairment and the phase during development that they acquire their impairment. Findings highlighted high degrees of variation in athletes' sporting careers based on the onset of their impairment. More specifically, athletes with congenital or early acquired impairments reached milestones at a younger age; however, athletes with later acquired impairments (i.e., early adulthood or adulthood) progressed through these milestones at a faster pace. Groups also had different training profiles, with changes to how much time was invested in different training types (sport-specific, physical preparation, mental preparation, etc.) and settings (with a coach and other teammates or alone, etc.). Furthermore, athletes with experience in other sports (both non-Paralympic and Paralympic) reported participating in sports that were similar to their current sport.

Previous research findings, including the impact of impairment-onset, are crucial to understanding and improving the quality of the developmental environment across the pathway. First, it highlights the array of issues that need to be considered for athlete recruitment, identification and/or transfer (Dehghansai and Baker, 2020; Patatas et al., 2020). More specifically, where athletes are in their sporting career (i.e., their sport/training age) will differ from their chronological age, and, therefore, the experiences they bring to the sport will vary. Relatedly, the type of sport they had experience in could affect their abilities and their "baseline" in their new sport (Dehghansai et al., 2021b). Second, once an athlete enters a performance pathway, the type of resources necessary to support optimal development can vary based on their readiness (Dehghansai et al., 2020, 2021b). This includes impairment-specific considerations (e.g., equipment, accessibility of venues, etc.) as well as the type/style of coaching they require (Bentzen et al., 2020; Dehghansai et al., 2021c), their preference for a type of training profile (Dehghansai et al., 2021b), and so forth. These elements should be taken into consideration when developing policies and guidelines for resource allocation and athlete support. A challenge many stakeholders in the Paralympic context face, given the limited funding and accessibility to resources (Dehghansai et al., 2021d; Patatas et al., 2021, 2022).

Classification

With the aim of "keeping a level playing field" (e.g., similar to how many sports may use age, weight, and sex categorizations), Paralympic sport utilizes classification systems to better organize athletes with similar levels of activity limitation as a result of their physical, vision, or intellectual impairments. While this is exclusionary (there are only a set number of eligible impairments and classifications within a sport), at the competitive level, it is necessary to provide (or at least attempt) a competition environment that is fair and evidence based. Like impairment onset, data have suggested variations in athlete impairment type influences performance trajectories and training histories (Dehghansai et al., 2021a). Similarly, coaches and high-performance personnel have highlighted how athletes' impairment type and severity, and, therefore, their *potential* classification is used as a key indicator for initial identification and successful development (Dehghansai et al., 2021c; Patatas et al., 2022). Indeed, it has been highlighted that one of the key skills (and challenges) for Paralympic coaches and other support personnel is the ability to be able to anticipate which class an athlete will potentially be classified in Radtke and Doll-Tepper (2014), Mann et al. (2017), and Dehghansai et al. (2021c). While provisional classification (i.e., a quick prediction of an athlete's classification) can and does occur in many domestic contexts, athletes are required to be classified officially, at an international event. There are clearly risks associated with this; for example, an athlete may spend extensive time (e.g., training hours) developing in a sport, with that sport investing significant resources, only for the athlete to eventually be found to be ineligible for a given Paralympic sport class either due to inaccurate initial provisional classification, changes in the athlete's impairment, or a change in the criteria used to determine classification.

Scenarios may also arise where an athlete is classified in what is perceived as an "unfavorable" class (i.e., they are at the "lower" end of their class when considering the severity of their impairment in comparison to other athletes in that class). Athletes classified in the higher end of a class may be given more resources (more coaching, access to camps, etc.) which further supports their development in a cyclical relationship where effects are magnified over time (similar to evidence found with relative age effect highlighting the consequential benefits for athletes with earlier maturation onset, for a review, see Wattie et al., 2015). In addition, certain sports may aim to be strategic and identify classes that are less competitive internationally, or target athletes closer to class "cut offs" which introduces an additional layer of complexity regarding the most appropriate athlete for a given sport, at a given time. Thus, classification system and by extension, athletes' impairment add to the complexity of forecasting athletes' future performance in sport.

OTHER FACTORS

Resources

Paralympic sports have historically had less funding compared to their non-Paralympic counterparts which extends to limited resources supporting Paralympic sport athletes' development (Martin-Ginis et al., 2016; Patatas et al., 2020). While sports are already an expensive participation activity (e.g., travel and competition expenses, expenses associated with private coaching and access to training facilities, team registration fees, etc.), the additional costs associated with impairment-related factors exacerbates athletes' circumstances (e.g., equipment cost including prosthetics or wheelchairs, travel for classification). Furthermore, some athletes have higher support needs and are dependent on caregivers or parents' assistance for access to training facilities and travel domestically and abroad for camps or competitions. The challenges related to athlete wellbeing and care introduce an additional layer of obstacles for athletes' participation in sports (Goodridge et al., 2015). Because of the typically smaller pool of athletes in Paralympic sports compared with non-disabled sports, and the limited competitive opportunities domestically, exposure to international competition can be seen paramount to athletes' development. Impairment-related factors compound these costs (i.e., equipment cost, accessible infrastructure, accommodation and flight costs, classification, support needs, etc.), and the number of athletes a sport can support is inevitably reduced.

In addition, while the Paralympic Games have become a globally recognized event, this increased appreciation and recognition has not generally resulted in meaningful differences in incentives for Paralympic sports domestically. Therefore, sports must be strategic with how they use their funding in creating environments to maximize the potential for their athletes. At times, the limited resources result in less athletes being supported through sports, and the athletes that are unable to fund their own sporting journeys are left with little chance for exposure to high-performance training facilities, camps and/or competitions that are invaluable to their development. Limited funding also constrains sports from being able to best support coaches and their development. With resources scarce, sports are not able to monitor and expand on key sport-related components including data tracking and analysis, program development, or educational resources that could help athletes, coaches, and practitioners. Relatedly, there are challenges to maintaining an optimal group of support staff to surround the athlete and coach (e.g., physiotherapists, psychologists, etc.). Therefore, sports tend to find strategic ways to either support the coaches and other practitioners in their organizations or most often, are under-staffed and overworked with limited resources to support their developments (Patatas et al., 2018; Dehghansai et al., 2019).

Athlete Pool

Given classification is an exclusionary process, selecting athletes who are (a) eligible for classification, and (b) good "bets" for future success has merits. The consequences of this approach are felt when considering the number of *potential* athletes for a specific sport since not all persons with a given impairment are interested in participating in sports generally, let alone at the high-performance level. The challenge of identifying potential athletes is exacerbated by the limited resources a sport has and the type of athlete they choose to support. While more mature sports with a history of established programs and a wider classification system (e.g., Para athletics or Para swimming) may have less difficulty recruiting athletes into the system, they too, will have to be strategic in which athletes they select based on issues related to athletes' potential given their classification, the pool of depth in that class, and so forth. Even within these sports, there are certain classifications that have limited numbers of athletes involved. The two athlete cohorts that are visibly less involved in Paralympic sports are athletes with high support needs and female athletes (Dehghansai and Baker, 2020; Lowry et al., 2022). While the reasons underpinning athletes with high support needs' lack of participation in sport is beyond the scope of this review (e.g., cost of participation, specialized equipment, travel cost, lack of inclusive and accessible environments, qualified coaches/staff, tailored programs; Goodridge et al., 2015), these barriers lead to having less coaches and athletes involved in these classes. Similarly, the inclusivity of the environment along with intersection of other social, personal, and cultural factors have been identified as reasons for lack of female athlete participants in the Paralympic contexts (Shakib, 2003; Dehghansai and Baker, 2020; Dehghansai et al., 2021c).

APPLICATION FOR PRACTITIONERS

Given the complexity of talent identification and development, the ideal approach would be to delay the exclusionary process (i.e., sport classification) and instead allow athletes with different abilities to participate in sports as long as possible. However, given funding limitations (and consequently impacting staffing and resources), this approach is not feasible for many Paralympic sport organizations. In this section, we provide emerging ideas to extend the discussion of how practitioners currently approach talent identification and development in Paralympic settings. We recognize the importance of individual contexts, and that each environment will call for unique approaches and, thus, the purpose of this section is to stimulate "outside of the box thinking" rather than providing a concrete solution to the key challenges discussed above.

1. **Resource pooling:** There are many ways sports could pool resources, whether it is through collaboration with other sports, other stakeholders (e.g., including impairment-specific organization such as the International Blind Sport Federation), national organizations (e.g., National Paralympic Committees), or local and state networks (e.g., local clubs, state sport or impairment governing bodies) to identify strategies on how to utilize limited resources more effectively to address pervasive problems across the pathway. For example, strategies developed at the national level to support coaches working with high-performance athletes could be modified to meet the needs of coaches at earlier stages of the development pathway. Similarly, general framework recommendations developed by a Blind Sport Federation on

how to work with athletes with visual impairment could be shared with all sports that have athletes with visual impairments. A shared resource model could also provide multi-sport access opportunities for athletes at earlier stages of their careers (e.g., multisport hubs). This would allow athletes opportunity to sample sports, while giving each sport a larger pool of athletes at the participation level. Furthermore, this could provide opportunities for cross-cultural development for coaches, and allow sports to delay or extend the selection process while providing development environments for athletes. Creating hubs of this nature could also incorporate provisional classification where guidance can be provided to sports with athletes pending official classification. While resources are scarce, pooling support staff across multiple sports may also enable flexibility and at the same time, ensure athletes receive a higher level of support for their continued participation and development.

2. **Formalized entry points and a flexible pathway:** Formalizing entry points at various points across the pathway could allow sports more flexibility in how resources are allocated to support athletes. This structure allows for better organization of resources, task distribution among staff, and increases effective communication and accountability within the network. The formalization could include better understanding of the system, where resources are located across the country, including protocols on how to integrate an athlete into the system while considering their expertise and where they would "sit" within the pathway. For example, if a high-performance athlete with experience in a non-Paralympic sport acquired an impairment and was joining Para cycling from BMX, ensuring there are formalized processes embedded into the pathway to support the athlete's transition from entry to integration and subsequent development is paramount. Steps to formalize the process could include (a) dedicated personnel to oversee the proceeding, (b) a streamlined athlete testing process, (c) identification of local clubs with structured mechanisms to support the athlete, (d) established communication line between the governing body and clubs to organize and facilitate the transition, (e) clear benchmarks for coaches and the athlete to understand the evaluation process and potential growth opportunities, and (f) transparent guidelines on resource allocation and facilitation. This formalized entry point could also facilitate a more effective transfer system, where athletes interested in switching sports at the high-performance level are given a platform to request and broadly explore other sports without fear of repercussion from, or impact on, their current sport (Dehghansai et al., 2022). Collaboration and open communication become paramount to the success of any of the initiatives whether it is recruitment or transfer, given the number of moving parts and organizations involved in the process.
3. **Network collaborations:** Sports could also look to universities and research centers for collaborations to gather data and expand key components pertaining to their sport. As alluded to in the previous recommendation, the importance of benchmarking, understanding athlete profiles, and being able to track and monitor progress are vital to the system improvement. Utilizing an array of scientists and trainees to gather, collate, disseminate findings can bypass resource capacity challenges, while at the same time, providing valuable opportunity for professional development of junior scholars. Moreover, embedding research teams into the sport allows for evidence informed decision making, which in turn, can help in improving the allocation of resources and support to the athletes and coaches (Dehghansai et al., 2019).

CONCLUSION

While Paralympic sport contexts carry similar challenges to that of their non-Paralympic counterparts, there are additional complexities that Paralympic sport organizations must navigate. Specifically, these organizations have to be creative in how they design their programs considering the limited resources. Sharing of resources between sports on strategies can reduce costs associated with certain operational components (e.g., sharing of camp spaces, resource development, and coaching frameworks). Formalization of the entry points and network collaborations could further increase the efficiency and maximize the resources available to sports. Continuing to innovate and challenge to think "outside the box" could not only lead to solutions to immediate constraints but spark new ways of operating and managing systems.

AUTHOR CONTRIBUTIONS

All authors contributed to the development of the ideas, content, and editing of the manuscript, with the lead author taking the responsibility to collate, formulate, and finalize the paper.

REFERENCES

Baker, J., Schorer, J., and Wattie, N. (2018). Compromising talent: issues in identifying and selecting talent in sport. *Quest* 70, 48–63. doi: 10.1080/00336297.2017.1333438

Baker, J., Wattie, N., and Schorer, J. (2019). A proposed conceptualization of talent in sport: the first step in a long and winding road. *Psychol. Sport Exerc.* 43, 27–33. doi: 10.1016/j.psychsport.2018.12.016

Bentzen, M., Alexander, D., Bloom, G. A., and Kentta, G. (2020). What do we know about research on Parasport coaches? A scoping review. *Adapt. Phys. Activ. Q.* 38, 109–137. doi: 10.1123/apaq.2019-0147

Dehghansai, N., Allan, V., Pinder, R., and Baker, J. (2021c). The impact of athletes' impairment type on their developmental trajectories. *Adapt. Phys. Activ. Q.* 39, 129–138. doi: 10.1123/apaq.2021-0107

Dehghansai, N., and Baker, J. (2020). Searching for paralympians: characteristics of participants attending 'search' events. *Adapt. Phys. Activ. Q.* 37, 129–138. doi: 10.1123/apaq.2019-0071

Dehghansai, N., Headrick, J., Renshaw, I., Pinder, R. A., and Barris, S. (2019). Olympic and Paralympic coach perspectives on effective skill acquisition support and coach development. *Sports Educ. Sci.* 25, 667–680. doi: 10.1080/13573322.2019.1631784

Dehghansai, N., Lemez, S., Wattie, N., and Baker, J. (2017). Training and development of Canadian wheelchair basketball players. *Eur. J. Sport Sci.* 17, 511–518. doi: 10.1080/17461391.2016.1276636

Dehghansai, N., Lemez, S., Wattie, N., Pinder, R. A., and Baker, J. (2020). Understanding the development of elite parasport athletes: current understanding and future direction. *Front. Psychol.* 11, 502981. doi: 10.3389/fpsyg.2020.502981

Dehghansai, N., Mazhar, A., and Baker, J. (2022). Coach and athlete perspectives on talent transfer in Paralympic sport. *Adapt. Phys. Activ. Q.* 1–31.

Dehghansai, N., Pinder, R. A., and Baker, J. (2021a). Pathways in paralympic sport: an in-depth analysis of athletes' developmental trajectories and training histories. *Adapt. Phys. Activ. Q.* 39, 37–85. doi: 10.1123/apaq.2021-0095

Dehghansai, N., Pinder, R. A., and Baker, J. (2021b). "Looking for a golden needle in the haystack": perspectives on talent identification and development in Paralympic sport. *Front. Sports Act. Living* 3, 635977. doi: 10.3389/fspor.2021.635977

Dehghansai, N., Pinder, R. A., Baker, J., and Renshaw, I. (2021d). Challenges and stresses experienced by athletes and coaches leading up to the paralympic games. *PLoS One* 16, e0251171. doi: 10.1371/journal.pone.0251171

Dohme, L. C., Backhouse, S., Piggot, D., and Morgan, G. (2017). Categorising and defining popular psychological terms used within the youth athlete talent development literature: a systematic review. *Int. Rev. Sport Exerc. Psychol.* 10, 134–163. doi: 10.1080/1750984X.2016.1185451

Goodridge, D., Klassen, R. M., Jeffery, B., Knox, K., Rohatinsky, N., and Linassi, G. (2015). Access to health and support services: perspectives of people living with a long-term traumatic spinal cord injury in rural and urban areas. *Disabil. Rehabil.* 37, 1401–1410. doi: 10.3109/09638288.2014.972593

Güllich, A. (2014). Selection, de-selection and progression in German football talent promotion. *Eur. J. Sport Sci.*14, 530–537. doi: 10.1080/17461391.2013.858371

Issurin, V. B. (2017). Evidence-based prerequisites and precursors of athletic talent: a review. *Sports Med.* 47, 1993–2010. doi: 10.1007/s40279-017-0740-0

Lowry, A., Townsend, R. C., Petrie, K., and Johnston, L. (2022). 'Cripping' care in disability sport: an autoethnographic study of a highly impaired high-performance athlete. *Qual. Res. Sport Exerc. Health.* doi: 10.1080/2159676X.2022.2037695. [Epub ahead of print].

Mann, D. L., Dehghansai, N., and Baker, J. (2017). Searching for the elusive gift: advances in talent identification in sport. *Curr. Opin. Psychol.* 16, 128–133. doi: 10.1016/j.copsyc.2017.04.016

Martin-Ginis, K. A., Ma, J. K., Latimer-Cheung, A. E., and Rimmer, J. H. (2016). A systematic review of review articles addressing factors related to physical activity participation among children and adults with physical disabilities. *Health Psychol. Rev.* 10, 478–494. doi: 10.1080/17437199.2016.1198240

Patatas, J. M., De Bosscher, V., Derom, I., and De Rycke, J. (2020). Managing parasport: an investigation of sport policy factors and stakeholders influencing para-athletes' career pathways. *Sport Manag. Rev.* 23, 937–951. doi: 10.1016/j.smr.2019.12.004

Patatas, J. M., De Bosscher, V., Derom, I., and Winckler, C. (2022). Stakeholders' perceptions of athletic career pathways in Paralympic sport: From participation to excellence. *Sport Soc.* 25, 299–320. doi: 10.1080/17430437.2020.1789104

Patatas, J. M., De Bosscher, V., and Legg, D. (2018). Understanding parasport: an analysis of the differences between able-bodied and parasport from a sport policy perspective. *Int. J. Sport Policy Polit.* 10, 235–254. doi: 10.1080/19406940.2017.1359649

Patatas, J. M., De Rycke, J., De Bosscher, V., and Kons, R. L. (2021). It's a long way to the top: determinants of developmental pathways in Paralympic sport. *Adapt. Phys. Activ. Q.* 38, 605–625. doi: 10.1123/apaq.2020-0147

Radtke, S., and Doll-Tepper, G. (2014). *A Cross-Cultural Comparison of Talent Identification and Development in Paralympic Sports*. Cologne: Sportverlag.

Shakib, S. (2003). Female basketball participation: negotiating the conflation of peer status and gender status from childhood through puberty. *Am. Behav. Sci.* 46, 1405–1422. doi: 10.1177/0002764203046010008

Till, K., and Baker, J. (2020). Challenges and [possible] solutions to optimizing talent identification and development in sport. *Front. Psychol.* 11, 664. doi: 10.3389/fpsyg.2020.00664

Wattie, N., Schorer, J., and Baker, J. (2015). The relative age effect in sport: a developmental systems model. *Sports Med.* 45, 83–94. doi: 10.1007/s40279-014-0248-9

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers | Frontiers in Sports and Active Living

TYPE Mini Review
PUBLISHED 31 March 2023
DOI 10.3389/fspor.2023.1179767

Check for updates

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Elite Sports and Performance Enhancement, a section of the journal Frontiers in Sports and Active Living

RECEIVED 04 March 2023
ACCEPTED 15 March 2023
PUBLISHED 31 March 2023

CITATION
Baker J, Gayman A and Johnston K (2023) Lifespan models of athlete development: What have we learned from previous attempts? Front. Sports Act. Living 5:1179767. doi: 10.3389/fspor.2023.1179767

Lifespan models of athlete development: What have we learned from previous attempts?

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Sport has a unique place in many cultures, emphasizing the links between physical elements of movement with psychological and social outcomes. Sport participation continues to attract the interest of researchers from a range of perspectives, yet there remains a strong need to understand the "who", "what", "where", "when" and "why" aspects of sport involvement over the life course. While the research literature includes multiple athlete development models that consider these components, they are incomplete frameworks for understanding lifespan sport engagement. In this article, we discuss the value in building multidimensional developmental models of sport participation that encapsulate experiences across all ages and stages of competitive and recreational sport, and pay special attention to the high degree of complexity of the movement between and within sport both competitively and recreationally. In addition, we highlight several challenges to creating such a lifespan development model, and consider areas of future direction to overcome some of these hurdles.

KEYWORDS

sport, aging, skill acquisition, models, frameworks, recreational sport, competitive sport

Introduction

Sport has a unique place in many cultures, emphasizing the links between physical elements of movement with psychological and social outcomes. Many nations have seen a shift towards increased participation in organized, high-performance sport at the youth, adolescent, early and late adulthood levels. Accompanying this shift has been an increase in funding from national sporting bodies to cultivate athletic "talent" (1) as well as increased research attention (2), showcasing the importance of understanding the costs and benefits of this shift. For example, several recent reviews have been completed on issues related to athlete development, ranging from early specialization [see (3)] and youth athletic development models [see (4)] to sport for older adults (5). In many sports, in many countries, participation can occur across the lifespan.

The concept of "lifespan development" has been used in domains such as education (6), employment (7), and medicine (8) to explore the mechanisms that generate commonalities, variability, and change in behaviour across the spectrum of human experience, from fetal development to old age (9, 10). Often, such research leads to the creation of conceptual models that help shape the way we interpret and predict behaviour. For example, modeling psychological development (i.e., psychological and neuronal changes and adaptations throughout the lifespan), allows exploration of complex person-environment interactions (11, 12). A more complete understanding subsequently informs interventions designed to support different types of learners (13, 14). While these models provide opportunities to tailor conceptually-supported interventions that promote optimal development, as well as evidence-informed support and instruction, caution has been raised in crafting models that are too reductionist and "nonrepresentative" of human experience, which may disproportionately affect some individuals or groups [c.f., (15, 16)].

In sport, lifespan models offer the same potential benefits. For example, they can provide insight into individual development in, and through, sport over the lifespan, spanning various ages, stages, abilities, and backgrounds, among other factors. This knowledge can also inform research (i.e., drive the creation and use of various methodologies and methods) and practice (i.e., including aspects of programming, techniques, strategies) for coaching and coach education [e.g., (17, 18)] as well as training and interventions (19, 20). In turn, lifespan models have the potential to enhance our understanding of how to foster more holistic (i.e., considering an athlete's psychological, physical, social, and spiritual needs), inclusive (i.e., reducing barriers for participation and success), and developmentally-appropriate sport programs that cater to athlete needs and promote sustained sport involvement, improved performance, and health across the lifespan.

Current discussions of athlete development are dominated by the Developmental Model of Sport Participation [DSMP: (21)] and the Long-Term Athlete Development (LTAD) framework (22) as well as emerging models like Australia's Foundations, Talent, Expertise and Mastery (FTEM) framework (23), and Lloyd and Oliver's (24) Youth Physical Development Model [see (25) for a review]. A common thread connecting these areas of exploration is their focus on athletes in the early stages of development (pre-elite). This has left little work examining elite athlete development [i.e., at the highest level; (26)] or post-elite development (i.e., the period after the high-performance career has ended). One example of a model that has worked to incorporate both the elite and post-elite developmental stages is Canada's Sport for Life framework, which highlights the potential value of capturing sport participation over the lifespan (both recreationally and competitively from youth to older adulthood; (27)). Models such as this, which span broader developmental periods into older adulthood, are becoming increasingly more relevant, as recent evidence on Masters sport (i.e., international-level competition for individuals over the age of 35[1]) indicates the number of international competitors (including the number of nations participating; currently over 50) is at an all time high (see https://imga.ch/ for more). This presents a critical opportunity for researchers and practitioners to investigate adult and older-adult populations' experiences in sport from a biopsychosocial perspective—with the hope of building more inclusive, accessible, and developmentally-appropriate programs for sport involvement across the lifespan. Ultimately, a comprehensive model of lifespan athlete development would go beyond simply stating broad goals such as being "active" or "competitive for life". Instead, it would be capable of providing knowledge of, and support and guidance for, phases of athlete development at all levels of involvement across this extended period, as well as transitions out of, or between stages. Moreover, given the obvious inter-connections between participatory and high-performance sport, a thorough model would denote the various pathways through the sports system and acknowledge the complex interactions between competitive and recreational sport participation, and how these different forms of sport engagement interact to shape lifespan sport involvement (**Figure 1**).

Challenges and concerns in creating a lifespan model of athlete development

By no means do we wish to imply the creation of this type of model would be easy. Like other lifespan development models, sport development models come with some obvious and less-obvious challenges. In the following section, we briefly highlight several key challenges for future work.

Language clarity

One of the most fundamental concerns raised by researchers and practitioners pertains to the clarity and consistency of language. Several recent papers have emphasized the inconsistent and "blurry" nature of terminology in athlete development research. For instance, the DSMP regularly refers to the notions of "sampling" and "early specialization". These terms have received recent attention by the research community [see (3, 28), respectively], highlighting their conceptual confusion and lack of clarity. The absence of an agreed upon definition of what these terms [and other terms; see for example, (29)] mean, will continue to make measurement, assessment, and implementation strategies imprecise and difficult.

Perhaps the most glaring discrepancy relates to a broad, yet foundational component of these models—the conceptualization of "sport". Despite the widespread use of sport as a general term, it is difficult to pin down a clear definition (30). Furthermore, research and popular discourse tell us that sport is not just one "thing"; rather, there are noteworthy variabilities across countries and cultures. With emerging technologies and interests, coupled with the growth of new sport disciplines (e.g., e-sports, pickleball, and disc golf), these definitional lines may become even less clear. This ambiguity further complicates the creation and validation of lifespan models, which need to accommodate such definitions. As growth and expansion in the types of sports available continues, a comprehensive model will need to consider and evolve to capture inter-sport differences (e.g., age of entry, specialization, and peak performance) and variability across demographic groups (e.g., male vs. female sports, youth sport compared to Masters sport, Olympic vs. Paralympic sports, amateur compared to professional).

[1]The youngest participants are 22 for sports like gymnastics that have an earlier peak-age.

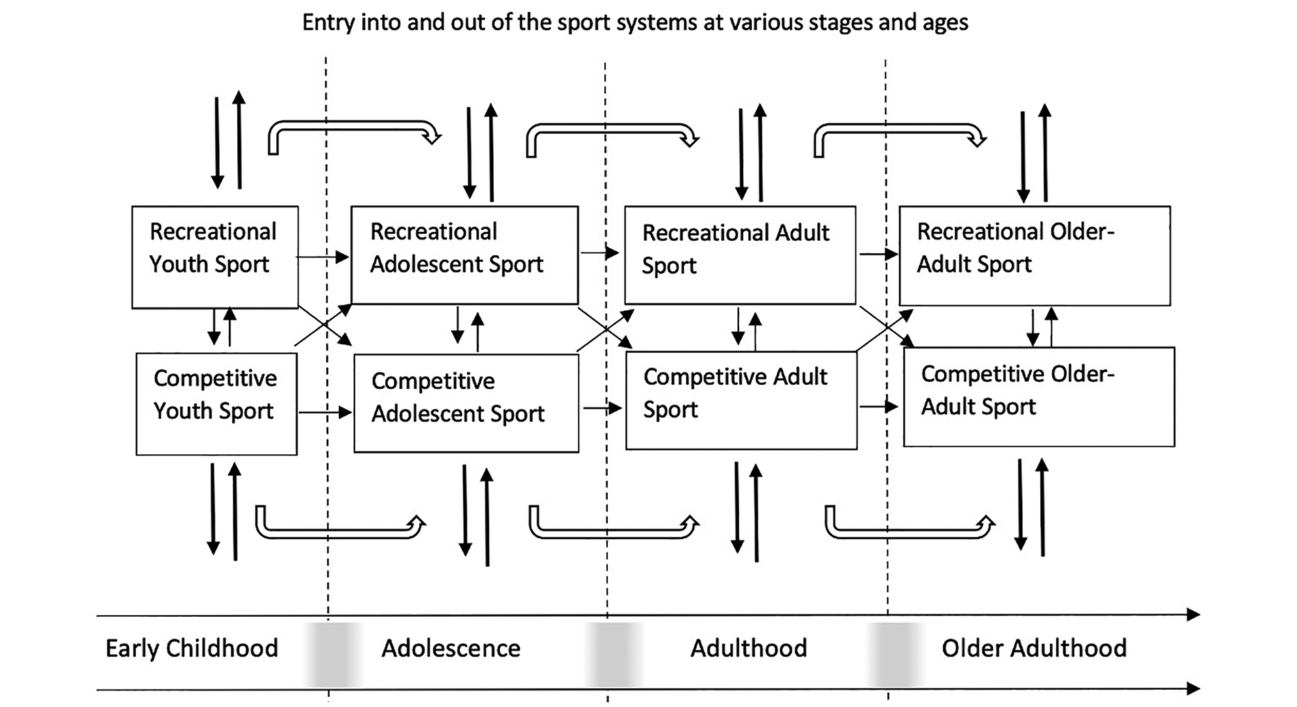

FIGURE 1
A proposed model of the complex and intertwined pathways of sport experience across the lifespan. The thick arrows at each stage from youth, adolescents, adulthood and older adulthood indicate that a person can enter (and exit) at various ages and stages into either competitive sport or recreational sport. The white arrow with the black outline indicates the opportunity for re-entry into the sport system once someone has left a sport. This could be re-entry into that same sport or re-entry into different sports. The small, short arrows indicate the movement between and within the recreational and competitive sport systems. What is further depicted is the lifespan stages of development sub-divided into the 4 broad stages examined in prior sport models, early childhood, adolescence, adulthood, and older adulthood, which will allow for age-and development-stage specifications/recommendations/interventions for sport participation, while also appreciating there is no discrete timeline when someone ends one stage and starts another, as indicated by the transition "grey areas" between each stage that represent individual variation of developmental age and stage.

Development as a lifespan process

A comprehensive model also needs to reflect development as a lifelong process, integrating elements of learning, expertise development, and competitive performance/success across the life course. A key learning from prior work is the need to create "optimized training environments" that match the learning environment to the needs of the athlete's stage of development (e.g., based on maturity, experience, etc.). Moreover, learning, skill acquisition and performance needs will undoubtedly change across development, although precisely *when* and *how* remain largely unknown (see below for more detail on this point).

A greater understanding of the processes and predictors of athlete development across the lifespan, with appreciation of the complexities involved at different life stages, has the potential to inform and strengthen public health policies and priorities. In this sense, a clearer understanding of how individuals experience various stages of development over time could support the creation of more effective, inclusive, and developmentally appropriate programs and interventions.

Integrating related aspects of athlete development

Currently, the conceptualization of athlete development is convoluted by the broad range of related topics under study (e.g., athletic development, career transitions, participant development, positive youth development, talent development), which vary in terms of their emphasis on personal growth, lifelong sport involvement, sport-specific expertise, and performance excellence. The often disconnected and narrow focus of different approaches to understanding the development of sport participants has prompted calls for greater interdisciplinary collaboration and knowledge sharing (31–34).

Ultimately, future efforts will need to adopt a multidisciplinary lens that accounts for the holistic, integrated nature of athlete development. Researchers have recognized that development is ongoing and dynamic. It is a complex phenomenon influenced by a host of factors inherent to person-environment interactions within and beyond the sport setting (35, 36). Moreover, athlete development rarely unfolds in a linear manner. It is a highly individualized process with many different participation pathways and career transitions to consider (33, 34, 37, 38).

Furthermore, performance success at the highest level of competitive or professional sport is not the final developmental stage or end goal for the majority of sport participants who pursue recreational, community-based forms of engagement. An inclusive framework is needed to gain insight into the factors that support and constrain enhanced biopsychosocial development as individuals of all ages, involved in all levels and contexts of sport, move in and out of the sport system over time (38).

Into the unknown: Key questions for future work

Do we understand the purpose(s) of sport across the lifespan?

Adding further complexity to the issues discussed above, is the reality that sport holds different, often conflicting, meanings and purposes across the lifespan. In childhood and youth, the goals of youth sport have been framed as relating to participation, performance, and personal development (39), although presumably the first is the mechanism driving effects in the latter two. From this perspective, the value of sport is in its potential to promote positive youth development (40) and the acquisition of fundamental movement skills and physical literacy (41). However, the purpose(s) of sport later in life is less clear. Some researchers have suggested it is valuable for challenging negative age-related stereotypes (42), decreasing chronic disease burden (43), and promoting positive developmental outcomes (44), as well as more obvious outcomes such as enjoyment and social connection.

Importantly, it will be critical to distinguish the value(s) and benefits of sport in later life compared to neighboring domains like "exercise" and "physical activity", which are commonly promoted at this stage of life. Without a clear understanding of the role and value of sport across the lifespan, and if/when/how the objectives of sport change during different life stages, it is difficult to understand how to enhance an athlete's development, regardless of what the objective of that engagement might be.

What do "pathways" for older athletes look like?

Evidence-based perspectives of developmental trajectories in middle-to late-adulthood are another important consideration for future research on the role of sport for older people. Although some models of sport involvement (e.g., LTAD and FTEM) recognize participation occurs across the lifespan, engagement is usually presented in generic ways such as in Canada's Sport for Life Model which defines the entire phase after sporting excellence as simply active, fit or competitive for life, based on the type of engagement. Longitudinal research examining all levels and patterns of participation, including athletes who dropout or withdraw from sport, is sorely needed (45).

Importantly, the literature pertaining to sport for older people has focused predominantly on competitive athletes involved in Masters and Senior Games with much less attention devoted to individuals who participate in community-based recreational sport (42). We know relatively little about the different combinations of pathways later in life that adults may pursue, what factors influence participation patterns and developmental opportunities from childhood to older adulthood, and best/better practices to support the developmental goals of middle-aged and older sport participants. To gain insight into patterns of stability and instability in developmental trajectories over time, researchers need longitudinal data pertaining to sport involvement of diverse samples as they age, to assess continued, resumed, and first-time involvement in sport (46).

One model or several?

A relatively indisputable finding from previous work is that sport is highly nuanced (i.e., varying across types, age groups, competition levels, cultures, and time). From this perspective, it may be too much to expect a single model to adequately capture the variability in what sport is and means for all individuals across all these contexts. Potentially, a general model could dilute attention to the critical issues for athlete development in a single sport. One example can be seen in how the issue of "early specialization" has been framed in general models—as something to be avoided, unless you happen to be in a sport that specializes early (e.g., gymnastics).

Instead, it might be useful to reframe the overall purpose of athlete development models/frameworks to providing insight and recommendations for different categories of sports. Returning to our example of early specialization noted above, an athlete development model for "early specialization sports" (or, perhaps a more precise category name would be "sports with an earlier age of peak performance" or "aesthetic sports") such as gymnastics, diving, and figure skating would allow a more thoughtful discussion of the risks and consequences of an athlete specializing early so that these can be managed by coaches and practitioners. Other categories may also be helpful, allowing policy makers, administrators, and coaches to focus on the unique needs of athletes in similar contexts, such as categories of Paralympic sports (47), low participation sports [e.g., see (48) for a discussion of this in Dutch table tennis], women's sport (49), and/or Masters sport (17).

While these concerns are warranted, we believe there is still value in a general lifespan model of athlete development—provided it focused on elements best captured in a generic model. For example, this model may be most useful as a guiding framework, reflecting knowledge about human development broadly (e.g., what is appropriate for a given age group?). As we learn more about the types of training and experiences best suited for different participation outcomes (e.g., lifespan participation, recreational competition, or elite athlete development), this general foundation may provide guidance for advocating one form of training over another. For instance, satisfying basic psychological needs of social connection and autonomy may be more conducive to recreational or life-long participation, while a focus on developing feelings of competence and performance-focused orientations may be more strongly related to elite skill development. This general model could inform context specific models that focus on elements related to different categories of sport. Potentially, these category models could be followed up with sport specific ones. For instance, a sport may consider issues relative to their specific sport context (e.g., differences in performance requirements, training resources, etc.), how these relate to other sports within the same category (e.g., are there ways to share resources to improve system efficiency?), and whether athlete development decisions correspond to broad learning and developmental needs to individuals at that stage of human development. This *Sport-Category-General* approach may alleviate some of the criticisms that have been made of general models in the past.

Concluding thoughts

A comprehensive approach is needed to understand *how* and *why* to promote better supported athlete development from childhood to older adulthood. A lifespan model(s) of athlete development could guide empirical investigations of personal and environment factors that shape biopsychosocial development over time as sport participants age, and account for varying motives, goals, and participation patterns. We recognize, however, that such efforts may be affected by wider environmental, cultural, and political issues that shape program development, applied practice, policy implementation, and sport governance. Pragmatically, the adoption and implementation of a lifespan model in the applied setting may hinge on the value key stakeholders and society, in general, ascribe to sport as a context to facilitate athlete development beyond youth, high performance competitive sport. Perhaps most notably, successful creation and implementation of a comprehensive, evidence-informed, general model of lifespan athlete development will be driven by an integrated, collegial, and collaborative approach among researchers, applied scientists, coaches, and policy makers. Although this may be a difficult hill to climb, there are undoubtedly riches on the other side.

Author contributions

All authors were equally involved in the creation and production of this manuscript. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

1. Weissensteiner J. The global evolution of talent promotion within Olympic sports: a focus on the national systems and contribution of the former German Democratic Republic, Australia and the United Kingdom. *Front Sports Act Living*. (2023) 4:1124234. doi: 10.3389/fspor.2022.1124234

2. Baker J, Wilson S, Johnston K, Dehghansai N, Koenigsberg A, De Vegt S, et al. Talent research in sport 1990–2018: a scoping review. *Front Psychol*. (2020) 11:607710. doi: 10.3389/fpsyg.2020.607710

3. Mosher A, Fraser-Thomas J, Baker J. What defines early specialization: a systematic review of literature. *Front Sports Act Living*. (2020) 27(2):596229. doi: 10.3389/fspor.2020.596229

4. Varghese M, Ruparell S, LaBella C. Youth athlete development models: a narrative review. *Sports Health*. (2022) 14(1):20–9. doi: 10.1177/19417381211055396

5. Patelia S, Mazhar A, Baker J. What do we know about the value of sport for older adults: a scoping review. *J Aging Phys Act*. (2023) 1:1–16. doi: 10.1123/japa.2022-0146

6. Alexander PA. The path to competence: a lifespan developmental perspective on reading. *J Lit Res*. (2005) 37(4):413–36. doi: 10.1207/s15548430jlr3704_1

7. Rudolph CW, Zacher H. Considering generations from a lifespan developmental perspective. *Work Aging Retirement*. (2017) 3(2):113–29. doi: .org/10.1093/workar/waw019

8. Walco GA, Krane EJ, Schmader KE, Weiner DK. Applying a lifespan developmental perspective to chronic pain: pediatrics to geriatrics. *J Pain*. (2016) 17 (9):T108–17. doi: 10.1016/j.jpain.2015.11.003

9. Lindenberger U, Lövdén M. Brain plasticity in human lifespan development: the exploration–selection–refinement model. *Ann Rev Dev Psychol*. (2019) 1:197–222. doi: 10.1146/annurev-devpsych-121318-085229

10. Lindenberger U, Li SC, Bäckman L. Delineating brain-behavior mappings across the lifespan: substantive and methodological advances in developmental neuroscience. Editorial. *Neurosci Biobehav Rev*. (2006) 30(6):713–7. doi: 10.1016/j.neubiorev.2006.06.011

11. Krakauer JW, Ghazanfar AA, Gomez-Marin A, MacIver MA, Poeppel D. Neuroscience needs behavior: correcting a reductionist bias. *Neuron*. (2017) 93 (3):480–90. doi: 10.1016/j.neuron.2016.12.041

12. Schaie KW. A field-theory approach to age changes in cognitive behavior. *Vita Humana*. (1962) 5(3):129–41. http://www.jstor.org/stable/26761552

13. Lövdén M, Fratiglioni L, Glymour MM, Lindenberger U, Tucker-Drob EM. Education and cognitive functioning across the life span. *Psychol Sci Public Interest*. (2020) 21(1):6–41. doi: 10.1177/1529100620920576

14. Wenger E, Kühn S, Verrel J, Mårtensson J, Bodammer NC, Lindenberger U, et al. Repeated structural imaging reveals nonlinear progression of experience-dependent volume changes in human motor cortex. *Cereb Cortex*. (2017) 27 (5):2911–25. doi: 10.1093/cercor/bhw141

15. Gould SJ. A critique of Heckhausen and Schulz's (1995) life-span theory of control from a cross-cultural perspective. *Psychol Rev*. (1999) 106(3):597–604. doi: 10.1037/0033-295X.106.3.597

16. Heckhausen J, Schulz R. A life-span theory of control. *Psychol Rev*. (1995) 102 (2):284–304. doi: 10.1037/0033-295X.102.2.284

17. Callary B, Young B, Rathwell S. *Coaching masters athletes: Advancing research and practice in adult sport*. New York: Routledge (2021).

18. Lemyre F, Trudel P, Durand-Bush N. How youth-sport coaches learn to coach. *Sport Psychol*. (2007) 21(2):191–209. doi: 10.1123/tsp.21.2.191

19. Oh J, Chopik WJ, Konrath S, Grimm KJ. Longitudinal changes in empathy across the life span in six samples of human development. *Soc Psychol Personal Sci*. (2020) 11(2):244–53. doi: 10.1177/19485506198494

20. Smart J. *Disability across the developmental life span: For the rehabilitation counselor*. New York: Springer (2011).

21. Côté J, Vierimaa M. The developmental model of sport participation: 15 years after its first conceptualization. *Sci Sports*. (2014) 29:S63–9. doi: 10.1016/j.scispo.2014.08.133

22. Balyi I, Way R, Higgs C. *Long-term athlete development*. Champaign: Human Kinetics (2013).

23. Gulbin JP, Croser MJ, Morley EJ, Weissensteiner JR. An integrated framework for the optimisation of sport and athlete development: a practitioner approach. *J Sports Sci*. (2013) 31(12):1319–31. doi: 10.1080/02640414.2013.781661

24. Lloyd RS, Oliver JL. The youth physical development model: a new approach to long-term athletic development. *Strength Cond J*. (2012) 34(3):61–72. doi: 10.1519/SSC.0b013e31825760ea

25. Baker J, Wattie N. Athlete development models. In: D Gould, C Mallett, editors. *Sport coaches' handbook*. Champaign: Human Kinetics (2020). p. 119–32.

26. Baker J, Koz D, Kungl AM, Fraser-Thomas J, Schorer J. Staying at the top: playing position and performance affect career length in professional sport. *High Ability Stud*. (2013) 24(1):63–76. doi: 10.1080/13598139.2012.738325

27. Higgs C, Way R, Harber V, Jurbala P, Balyi I. *Long-term development in sport and physical activity 3.0*. Sport for Life. (2019).

28. Murata A, Goldman DE, Martin LJ, Turnnidge J, Bruner MW, Côté J. Sampling between sports and athlete development: a scoping review. *Int J Sport Exerc Psychol*. (2021) 30:1752–6. doi: 10.1080/1612197X.2021.1995021

29. McAuley AB, Baker J, Kelly AL. Defining "elite" status in sport: from chaos to clarity. *German J Exerc Sport Res*. (2022) 52(1):193. doi: 10.1007/s12662-021-00737-3

30. Carlson C, Frías FJL, Schieman K, Reid HL, McClelland J, Strudler K, et al. *Defining sport: Conceptions and borderlines.* Lanham: Lexington Books (2016).

31. Bruner MW, Erickson K, Wilson B, Côté J. An appraisal of athlete development models through citation network analysis. *Psychol Sport Exerc*. (2010) 11(2):133–9. doi: 10.1016/j.psychsport.2009.05.008

32. Collins D, Toms M, MacNamara A, Ford PA. Rethinking participant development in sport and physical activity. In: NL Holt, M Talbot, editors. *Lifelong engagement in sport and physical activity: Participation and performance across the lifespan*. Abingdon: Taylor & Francis (2011). p. 45–62.

33. Coutinho P, Mesquita I, Fonseca AM. Talent development in sport: a critical review of pathways to expert performance. *Sports Sci Coaching*. (2016) 1(2):279–93. doi: 10.1177/1747954116637499

34. Stambulova NB, Ryba TV, Henriksen K. Career development and transitions of athletes: The international society of sport psychology position stand revisited. *International Journal of Sport and Exercise Psychology*. (2021) 19(4):524–550. doi: 10.1080/1612197X.2020.1737836

35. Abbott A, Collins D. Eliminating the dichotomy between theory and practice in talent identification and development: considering the role of psychology. *J Sports Sci*. (2004) 22(5):395–408. doi: 10.1080/02640410410001675324

36. Baker J, Wattie N, Schorer J. A proposed conceptualization of talent in sport: the first step in a long and winding road. *Psychol Sport Exerc*. (2019) 43:27–33. doi: 10.1016/j.psychsport.2018.12.016

37. Baker J, Johnston K, Wojtowicz M, Wattie N. What do we really know about elite athlete development? Limitations and gaps in current understanding. *Br J Sports Med*. (2022) 56(23):1331–2. doi: 10.1136/bjsports-2022-105494

38. Bergeron MF, Mountjoy M, Armstrong N, Chia M, Côté J, Emery CA, et al. International Olympic committee consensus statement on youth athletic development. *Br J Sports Med*. (2015) 49:843–51. doi: 10.1136/bjsports-2015-094962

39. Côté J, Strachan L, Fraser-Thomas J. Participation, personal development and performance through youth sport. In: N Holt, editor. *Positive youth development through sport*. Abingdon: Routledge (2008). p. 34–45.

40. Holt NL, Deal CJ, Pankow K. Positive youth development through sport. In: G Tanenbaum, RC Eklund, editors. *Handbook of sport psychology*. 4th ed. Hoboken: Wiley (2020). p. 429–46.

41. Corbin CB. Implications of physical literacy for research and practice: a commentary. *Res Q Exerc Sport*. (2016) 87(1):14–27. doi: 10.1080/02701367.2016.1124722

42. Jenkin CR, Eime RM, Westerbeek H, O'Sullivan G, van Uffelen JGZ. Sport and ageing: a systematic review of the determinants and trends of participation in sport for older adults. *BMC Public Health*. (2017) 17:976. doi: 10.1186/s12889-017-4970-8

43. Patelia S, Stone RC, El-Bakri R, Adli M, Baker J. Masters or pawns? Examining injury and chronic disease in male Masters Athletes and chess players compared to population norms from the Canadian community health survey. *Eur Rev Aging Phys Act*. (2018) 15:1–9. doi: 10.1186/s11556-018-0204-z

44. Baker J, Fraser-Thomas J, Dionigi R, Horton S. Sport participation and positive development in older persons. *Eur Rev Aging Phys Act*. (2010) 7(1):3–12. doi: 10.1007/s11556-009-0054-9

45. Gallant F, Bélanger M. Empirical support for the tenets of sport participation and physical activity-based models: a scoping review. *Front Sports Act Living*. (2021) 3:1–15. doi: 10.3389/fspor.2021.741495

46. Gayman AM, Fraser-Thomas J, Baker J. Relational developmental systems metatheory: a conceptual framework to understand and promote older adults' involvement in sport. *Eur Rev Aging Phys Act*. (2017) 14:12. doi: 10.1186/s11556-017-0182-6

47. Dehghansai N, Pinder RA, Baker J. *Talent development in paralympic sport*. Abingdon: Routledge (2022).

48. Faber I, Damsma T, Pion J. Finding talent and establishing the road to excellence in table tennis: the Dutch case. In: J Baker, S Cobley, J Schorer, editors. *Talent identification and development in sport*. 2nd ed. Abingdon: Routledge (2020). p. 115–29.

49. MacMahon C, Clarke A, Leabeater A, Roberts A. Female sport expertise through a skill acquisition lens. In: D Farrow, J Baker, C MacMahon, editors. *Developing sports expertise: Researchers and coaches put theory into practice*. 3rd ed. Abingdon: Routledge (in press).

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