IOC consensus statement on elite youth athletes competing at the Olympic Games: essentials to a healthy, safe and sustainable paradigm

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ABSTRACT

With the pronounced ongoing growth of global youth sports, opportunities for and participation of youth athletes on the world sports stage, including the Olympic Games, are expected to escalate. Yet, adolescence is a vulnerable period of development and inherently dynamic, with non-linear and asynchronous progression of physical, physiological, psychological and social attributes. These non-concurrent changes within and between individuals are accompanied by irregular and unpredictable threats and impediments. Likewise, the evident age-based criteria and conventional path for those youth athletes deemed eligible candidates for the Olympic Games are not well or consistently defined. Furthermore, the unstructured and largely varying policies and practices across the sporting International Federations specific to youth participation underscore the need to establish a contemporary universal paradigm that would enable elite youth athletes to navigate an individualised healthy pathway to personal, athletic and sport success. First, we reviewed and summarised key challenges facing elite youth athletes and the relevant evidence fundamental to facilitating and supporting central aspects of health and well-being, while empowering safe, sustainable and positive engagement during athletic and personal advancement and competition. Second, we developed and present a modern elite youth athlete model that emphasises a child-centred, practical framework with corresponding guidelines and recommendations to protect health and well-being while safely and favourably managing international sport competition. Our proposed evidence-informed paradigm will enable and support individualised pathways for healthy, well-rounded and sustainable positive engagement while achieving sport success for youth contending or aiming to compete at world-class international sporting events.

INTRODUCTION

Sports participation can be highly rewarding to youth at all levels. Documented benefits include diverse psychological and social advantages as well as enhanced academic achievement, improvements in overall health and fitness and career success later in life,[1–6] but there are often barriers to participation and recognised threats to the physical and mental health and well-being of youth athletes; and involvement at the elite world-class level is no exception.[7–11] With a youth-centred holistic focus and priority, highlighting the especially vulnerable and impressionable adolescent development period, the International Olympic Committee (IOC) 2015 consensus statement on youth athletic development stands as the leading evidence-informed reference and guidelines for sustainably *developing* healthy, resilient and capable youth athletes.[12] This current complementary IOC statement, however, specifically focuses on *highly trained, national level and above*, elite youth athletes training for and participating in international sport events, most notably the Olympic Games. Nonetheless, this consensus with accompanying guidelines and recommendations is *not* a prescription for Olympic selection and achieving medals. Rather, we propose a contemporary paradigm that is integral for enabling and supporting individualised pathways for healthy and sustainable engagement and well-rounded advancement as an athlete *and* person while achieving sport success (broadly defined) for those youth contending or aiming to compete at the world-class level.

The fundamental challenge

With the global youth sports market projected to continue its pronounced growth from USD 37.5 billion in 2022 to USD 69.4 billion by 2030,[13] opportunities for and participation of youth athletes on the world sport stage, including at the Olympic Games, are expected to escalate. A parallel concern for clarity and guidance on age eligibility has likewise grown. Figure 1 indicates the proportional breakdown of those youth athletes (under 18 years) who participated in the Olympic Games from 2012 through 2022, whereas figure 2 shows how these participants were distributed across the distinct disciplines of the respective sports (IOC internal data). Minimum age eligibility requirements (AERs) across the International Federations (IFs) for youth participation in the Olympic Games

Executive summary

The fundamental challenge

⇒ Whereas sports participation can be highly rewarding to youth at all levels, there are often barriers to participation and recognised threats to the physical and mental health and well-being of youth athletes.
⇒ With the global youth sports landscape projected to continue its pronounced growth, opportunities for and participation of youth athletes on the world sports stage, including at the Olympic Games, are expected to escalate.
⇒ Minimum age eligibility requirements across the International Federations (IFs) for youth participation in the Olympic Games or other elite-level international competitions are largely variable with age limits that are not fully scientifically informed.
⇒ The fundamental challenge is that adolescence is inherently dynamic and non-linear with asynchronous development of physical, physiological, psychological and social attributes within and between individuals continuing from late childhood into early adulthood.

Road to the Olympic Games—a contemporary paradigm

⇒ The International Olympic Committee is committed to encouraging and promoting fair and safe sport with the highest standards of ethics and good governance to protect athletes from all forms of harassment and abuse in sport.
⇒ The evident age-based selection criteria and conventional path for those choice youth athletes deemed eligible candidates for the Olympic Games are not well or consistently defined.
⇒ The unstructured and largely varying policies and practices across the IFs specific to youth participation underscore the need to establish a contemporary universal paradigm that would enable elite youth athletes to navigate an individualised healthy pathway to personal, athletic and sport success.

Inherent changes, threats and challenges

⇒ Athletic development during adolescence is reciprocally augmented and challenged by concurrent changes in age-related growth and maturation, the individual timing of which is not possible to forecast precisely.
⇒ Adolescent athletes are more susceptible to specific musculoskeletal injuries, notably those associated with growth, maturation and/or overuse.
⇒ The ongoing intersections of evolving bio-psychosocial challenges and related health risks inherent to adolescence and consequent to the intense physical and mental demands of their respective sport present an increasingly complex test with great psychosocial strain and mental health challenges to elite youth athletes.

Modifiable threats—opportunities for mitigating risk

⇒ Seemingly countless scenarios, exposures and influences can impose additional risk to elite youth athlete health, well-being and sport performance.
⇒ However, there are pronounced opportunities to modify risk and adverse impacts notably related to frequency, duration and intensity of training, competition and travel loads, dietary intake and behaviours, unrealistic expectations and undue pressure, family and personal support network separation and influences from commercialisation and social media.

Conditions for healthy engagement and optimal performance in elite youth sport

⇒ Key tenets that are central to facilitating healthy engagement and optimal and sustainable performance in elite youth sport include safe, supportive and appropriate competitive settings and environments, caring and positive social ecosystems reinforced by quality personal relationships and personal engagement that promotes positive individual assets and skills. This must be complemented by ongoing individualised appraisal of autonomy readiness and providing corresponding suitable support to progressively equip and encourage each elite youth athlete to act more independently.
⇒ Such an encompassing contemporary model and ecological approach must be aptly variable and responsive to changing needs across adolescence and sport participation.

Mental health and safeguarding across the development continuum

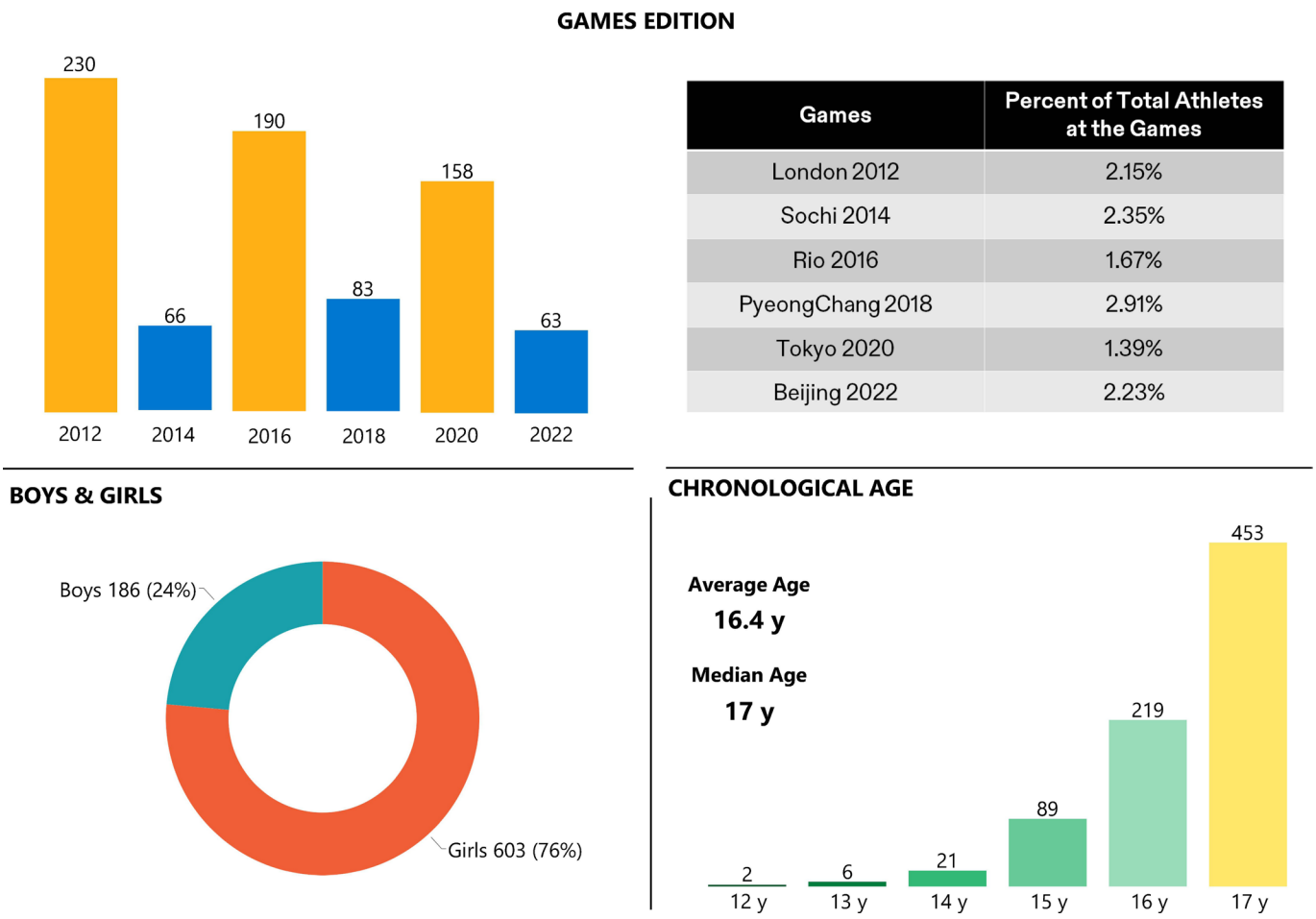
⇒ Prevention and early involvement should be prioritised in elite youth sport to respectively reduce general and sport-specific risk factors for mental ill-health and to provide timely interventions as warranted.
⇒ All those closely working with and overseeing elite youth athletes should also be sensitive and responsive to the everchanging and diverse safeguarding needs and opportunities in addressing risks across the dynamic continuums of adolescent athletic and maturational development.

Is age eligibility the solution—*or part of the problem*?

⇒ Age determination and eligibility standards for youth athletes remain a concern and challenge for professional sports academies and international sport governing bodies that organise high-profile sporting events.
⇒ However, the practical scientific and clinical evidence that would warrant and support standardised AERs and corresponding sport-specific guidelines and exceptions is not presently available.

Implementing a contemporary elite youth athlete paradigm

⇒ The collective guidelines and recommendations presented in this consensus statement constitute a rational, evidence-informed contemporary paradigm with practical steps to support elite youth athletes in safely and favourably managing training and international sport competition.
⇒ Going forward, to extend and strengthen the evidence base applicable to healthy, sustainable and successful participation and advancement pathways across adolescence in elite youth athletes and bolster implementation of the proposed paradigm, ongoing evaluation and improvement of best practices, reinforced by corresponding modern predictive modelling research and translation, must be pursued.



Games	Percent of Total Athletes at the Games
London 2012	2.15%
Sochi 2014	2.35%
Rio 2016	1.67%
PyeongChang 2018	2.91%
Tokyo 2020	1.39%
Beijing 2022	2.23%

Figure 1 Proportional breakdown of those youth athletes (under 18 years) who participated in the Olympic Games from 2012 through 2022 (IOC internal data; data on youth participation prior to this period are unavailable). One athlete participated in two editions of the Games as under 18 (London and Rio); thus, in the by Games and Chronological Age graphs, the total indicates 790 athletes, whereas the overall number of unique U18 athletes (boys and girls) and Season is 789. IOC, International Olympic Committee.

or other elite-level international competitions are largely variable with age limits that are not fully scientifically informed. Nevertheless, the proportion and distribution of age eligibility thresholds in the Summer and Winter disciplines as reported by the Olympic IFs in 2022 are shown in figure 3 (IOC internal data). The IOC data further indicate just over 30% of those U18 youth participating in the Olympics returned to participate as an adult. Though valid explicit interpretation driving this trend would be premature, concerns regarding undue mental pressures, psychological and sexual abuse, doping, ethics violations, training/competition overload and immature development-related injuries and their long-term impact on affected elite youth athletes are ongoing.[7 10 14–19]

The fundamental challenge is that adolescence is inherently dynamic and non-linear with asynchronous development of physical, physiological, psychological and social attributes within and between individuals continuing from late childhood into early adulthood. The trajectories, timing and tempo across the biological, cognitive and psychosocial domains of development also vary by sex, race and ethnicity.[20] Moreover, adolescence is a highly vulnerable and impressionable period characterised by heightened social awareness and sensitivity[21] where there are irregular, ever-changing and unpredictable threats and impediments. Accordingly, considerations and accompanying measures to mitigate risk, maintain health and support well-being for elite youth athletes go far beyond age eligibility to include ongoing apt and timely responsiveness to each athlete's own multifaceted requirements, challenges and changing environment.

Priorities for the elite youth athlete

The IOC has initiated a comprehensive focus on four key areas to support and protect elite youth athletes. These comprise (a) a review of the current minimum performance and eligibility criteria, including age requirements set by each IF, for all respective athletes and teams aiming to compete at the Olympic Summer and Winter Games, with the compelling recommendation to the IFs to confirm alignment with evidence-informed best practices for safeguarding these youth athletes, (b) a comprehensive review and historical risk assessment (including prevalence of injuries and illnesses) of the Olympic Games and Youth Olympic Games (YOG) and corresponding policies and structures to assure the safety and protection of youth athletes, (c) an operational framework to ensure that the human rights of youth athletes are considered alongside the elite athlete pathway, as aligned with the IOC human rights and safe sport priorities for the broader Olympic Movement and (d) this current consensus statement which will inform all related planned outcomes and

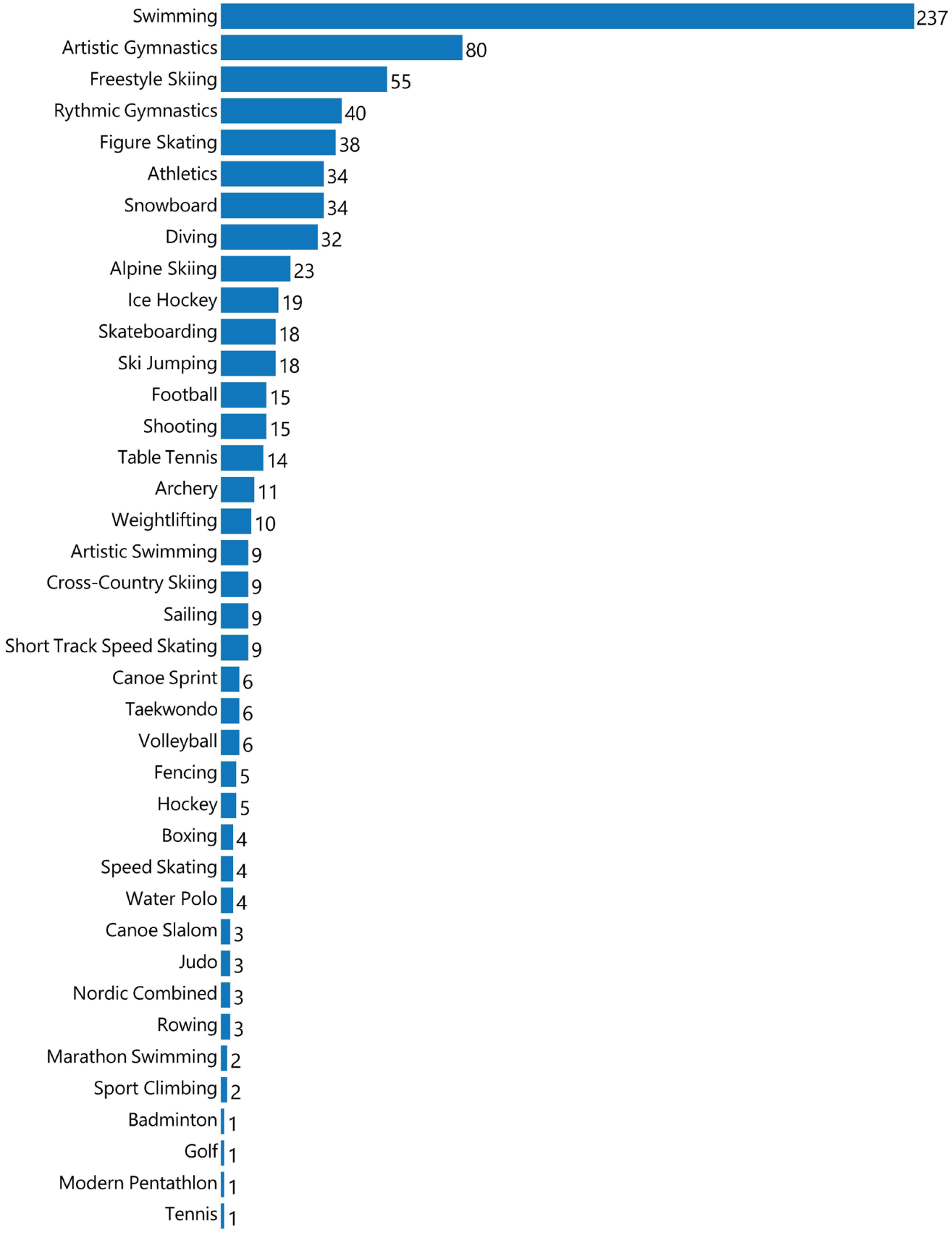


Figure 2 Distribution of youth athletes (under 18 years) who participated in the Olympic Games from 2012 through 2022 across the distinct disciplines of the respective sports (IOC internal data; data on youth participation prior to this period are unavailable). IOC, International Olympic Committee.

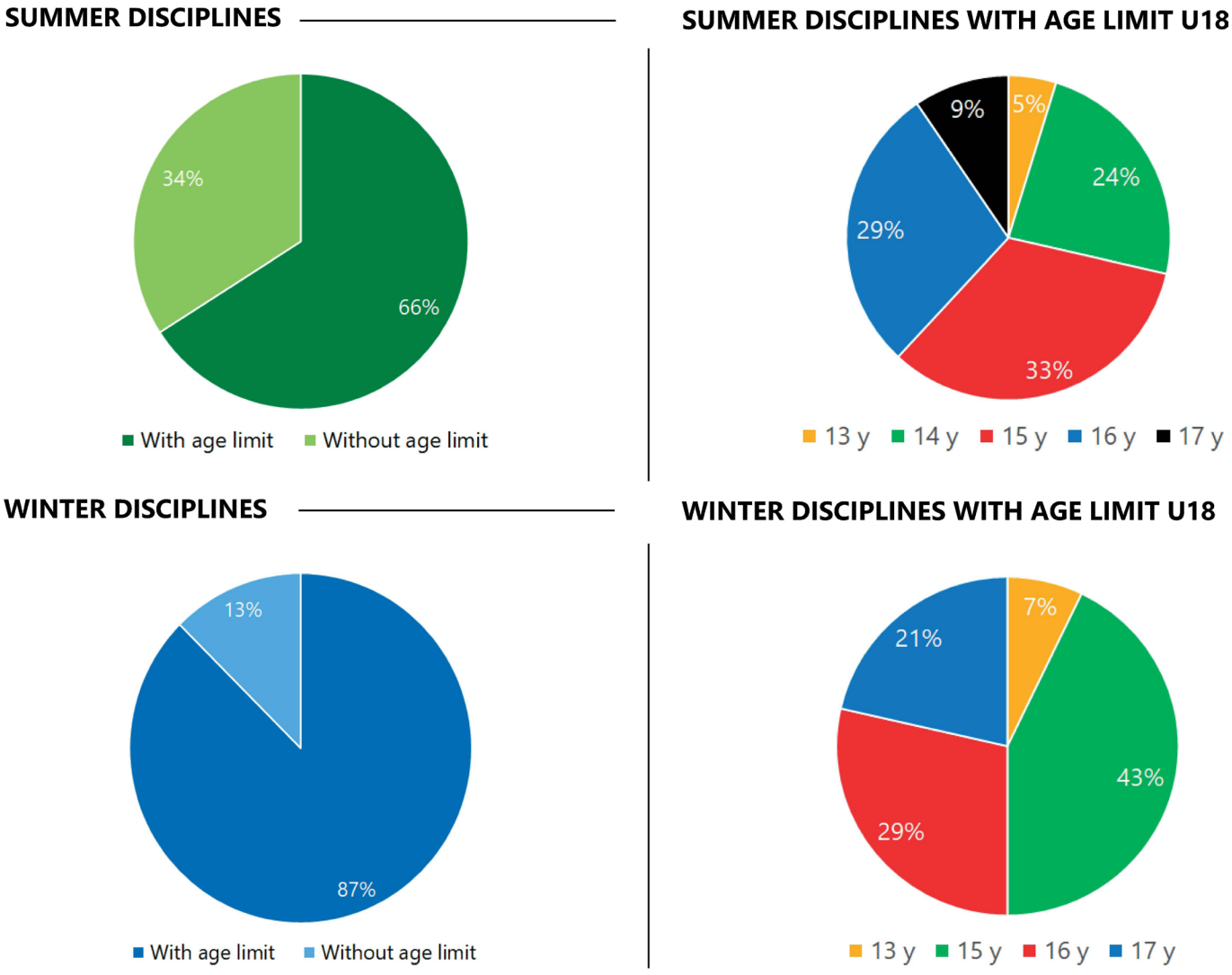


Figure 3 The proportion and distribution of age eligibility thresholds in the Summer and Winter disciplines as reported by the Olympic International Federations in 2022 (IOC internal data). IOC, International Olympic Committee.

succeeding measures (ie, evidence-informed guidelines for best practices and corresponding practical toolkits, education and other resources). A new Olympic benchmark for elite youth athletes will emerge from these IOC priorities that will promote healthy, holistic, sustainable and child-centred rights-respecting athletic development and sport success.

Prioritising and incorporating children's rights

Fundamental to the above priorities and complementary to the guidelines and recommendations provided in this consensus is the IOC's commitment to clarify children's right-derived duty of care obligations for sports and embed them as part of the 'comprehensive operational framework' addressed to sport governing bodies. The new IOC *Comprehensive Framework Towards the Realization of Children's Rights* will be designed to elucidate which rights of children need to be respected and how, with a specific focus on youth athletes who are aiming to participate in the YOG and Olympic Games. These rights include privacy, safety and balancing training/competition with ample opportunities for learning, recreation and social interaction that will encourage overall health, well-being and development. Accordingly, the target audience includes the sport governing bodies, youth athletes, parents, coaches and influencing others such as sponsors, media and event organisers. Underpinning this IOC initiative is a distinguishing commitment to collaboratively engage the child athletes and each of these groups in genuinely overcoming barriers and embracing opportunities to establish a child rights-respecting sports environment.

Road to the Olympic Games—a contemporary paradigm

The IOC is committed to encouraging and promoting fair and safe sport and, with the highest standards of ethics and good governance, protect athletes from all forms of harassment and abuse in sport.[22 23] From this fundamental context, however, the evident age-based selection criteria and conventional path for those choice youth athletes deemed eligible candidates for the Olympic Games are not well or consistently defined. Furthermore, the unstructured and largely varying policies and practices across the IFs specific to youth participation underscore the need to establish a contemporary universal paradigm that would enable elite youth athletes to navigate an individualised healthy pathway to personal, athletic and sport success. Whereas the youth athletes will ultimately be influenced by the outcomes of this consensus, the intended primary targets are the National Olympic Committees and IFs who affect change at the national and global sport levels.

Consensus aims

Building on the pillars of 2015 IOC Consensus on Youth Athletic Development,[12] this IOC Consensus Statement distinctively highlights the key issues specific to youth involvement in elite-level international sport competition, including at the Olympic Games. Moreover, we provide practical guidelines and recommendations to inform and suitably inspire parents, coaches and the governing bodies who oversee and regulate each sport and those participating. As applied here, 'youth' largely refers to adolescents (11-year to 17-year olds, including preadolescents and adolescents within this chronological age range). These highly trained and dedicated youth athletes are committed to a single sport (note that we are recognising this distinctive track and not necessarily endorsing it broadly) and routinely participate at national level (tier 3) to world-class (tier 5) athletic competitions.[24] In this regard, it is essential to clarify 'elite' as a characterisation of the *pathway and participation level*—not the athletes per se. Nevertheless, elite youth athletes are children warranting a child-centred approach and are entitled to protections as defined in the 1990 UN Convention on the Rights of the Child.[25]

Aims:

1. **Challenges and nurturing elements**. Review and summarise key challenges facing elite youth athletes and relevant evidence that is fundamental to facilitating and practically supporting central aspects of health and well-being, while enabling safe, sustainable and positive engagement, athletic and personal advancement and competition for these aspiring participants on the world sport stage.
2. **A contemporary paradigm**. Develop and present an ensuing modern elite youth athlete model that emphasises a child-centred, practical framework with corresponding guidelines and recommendations to mitigate risk, maintain health and support well-being, while safely and favourably managing training and international sport competition.

METHODOLOGY

Equity, diversity and inclusion statement

The IOC convened a consensus meeting in Lausanne, Switzerland on 24–26 May 2023. The consensus faculty deliberately included a broad range of scientific/clinical knowledge and experience in youth athletic health and development that especially encompassed inherent changes and challenges across adolescence and requisite complementary determinants of physical and psychological fitness, readiness and resilience to aptly manage high-level training and international competition. Collectively, these chosen professionals have demonstrated expertise in growth and maturation, developmental exercise science, paediatric orthopaedics and sports medicine, injury and illness risk and prevention, physical medicine and rehabilitation, biopsychosocial development, mental health, ethics, safeguarding, youth sport coaching principles and key influential relationships and related dynamics affecting youth athletes that can facilitate or undermine sport achievement and success. Faculty members were also selected to provide a strong diverse global representation of administrative and sport leadership, experience and expertise from within the IOC (including the Medical and Scientific, Corporate and Sustainable Development and Sports Departments and an Olympian from the IOC Athletes' Commission) and IFs. The IF representatives offered perspective and insights to enhance practical application, employment and effectiveness of the proposed paradigm.

Evidence reviews

With current procedures guiding international sport participation by youth athletes across the IFs and corresponding disciplines being ambiguous and variable, systematically examining specific questions to confirm or refute the effectiveness of these directives and/or practices was premature. Thus, the consensus panel initially relied predominantly on expert narrative reviews. However, three relevant domains fundamental to our objectives and central to elite youth athletes were defined and selected for scoping reviews. The scope of pertinent emerging research in these distinctive general areas were determined, the findings were interpreted and then the below sections and key messaging presented here were complemented, as warranted.[26 27] The designated scoping reviews comprised separate searches for (a) growth and maturation changes across adolescence that exacerbate injury risk and could serve as barriers to elite youth athlete performance, (b) risk and vulnerability to mental disorders, psychological distress and/or impaired mental well-being in adolescent elite youth athletes and (c) conditions and settings that facilitate elite youth athlete positive engagement, individual assets and development during adolescence. Searches were conducted *in general* adhering to Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews.[28] All searches were conducted with each respective institutional library and were refined to identify peer-reviewed articles written in English and to target 'all text' (ie, keywords, titles, abstracts and full text).

Search strategy and screening—growth, maturation and injury risk

Considering the existing literature, a series of unique search terms were used to capture articles investigating the impact of growth and/or maturation on injury in elite youth athletes. The Boolean Operators 'OR' and 'AND' were used to broaden the search results, define the population of interest (ie, elite youth athletes), restrict the intended outcomes of our search (ie, injury) and link the various search terms. An asterisk (*) was applied to some keywords to search the database for all endings of the word or phrase (eg, matur*). The final search strategy being: (1) 'elite' AND 'youth' AND 'athlete', (2) AND 'growth' OR 'matur*' OR 'pubert*' and (3) AND 'Injur*' OR 'medial epicondyle apophysitis' OR 'Proximal Humeral Epiphysitis' OR 'stress fracture' OR 'growth plate fracture' OR 'Pars' OR 'Femoroacetabular impingement' OR 'apophysitis' OR 'Sever's' OR 'Osgood' OR 'osteochondrosis' OR 'osteochondritis dissecans' OR 'spondylolysis'.

The databases SPORTDiscus, Embase, PubMed, MEDLINE and Web of Science were searched for published articles from 2000 onward. Completed in May 2023, the searches retrieved a total of 871 citations of which 519 remained after removing duplicates. After screening at the title and abstract level, 37 full-text articles were retained for consideration. Of the 30 articles that met the final inclusion criteria (specific to growth and/or maturation on injury), 28 employed quantitative methods and prospective cohort designs ranging from 8 weeks to 20 years, whereas two studies employed qualitative research designs. Most of these investigations were conducted in soccer (n=19), with the others focusing on gymnastics (n=3), dance, skiing, track and field (for each, n=2), squash and handball (for each, n=1). Twenty-three studies were exclusive to male athletes, whereas seven considered both male and female athletes. None of the studies was exclusive to female athletes.

Search strategy and screening—mental health and well-being

Vulnerability to mental health symptoms and disorders and/or impaired well-being (including stress and burnout) in elite youth athletes travelling and competing internationally for their sport was examined. Searches were conducted in MEDLINE, Embase, PsycInfo (Ovid) and SPORTDiscus (EbscoHost) using search terms to identify mental well-being, psychological distress and a range of specific mental health symptoms and disorders in athletes with a mean age <18 years. Databases were searched from inception to 16 March 2023, with extracted articles confined to those peer-reviewed publications from 2000. The search strategy retrieved a total of 2769 publications (including 322 auto-detected duplicates), leaving 2447 records. Title and abstract screening identified a further 282 duplicates and 1913 records were excluded (where one article could not be retrieved), yielding 252 records for full-text review. Of these, 33 records met the inclusion criteria.

The selected articles encapsulated data from 5826 youth athletes (2538 boys, 3288 girls). The most frequently studied topic was disordered eating (k=16),[29–43] followed by anxiety (k=7)[31 44–49] and depression (k=5),[41 45–48] with two studies measuring combined anxiety/depression.[32 34] Additionally, burnout,[50–53] substance misuse[54 55] and various markers of mental well-being were measured, including stress, coping and affect/emotions.[56–61] Caseness estimates (referring to mental health symptoms at a level that would usually warrant treatment by a health professional) for disordered eating ranged from 0% to 14.4% for boys[31 34] and 11% to 34% for girls.[32 43] Only two studies provided caseness estimates for depression (6% in a mixed gender sample; 14% for boys and 40% for girls) and one for anxiety (8% for boys, 28% for girls).[41 48] Risk factors for mental health outcomes included sex, elite athlete status, coach/parent relationship factors and mental health comorbidity. However, given the nascent nature of the existing literature, these factors varied between studies (eg, higher competition level was associated with higher *and* lower rates of disordered eating).[32 42]

Search strategy and screening—positive athlete engagement and development

Nine unique search terms were employed to capture articles that discussed conditions, settings and/or frameworks to facilitate elite youth athlete engagement and positive outcomes. The Boolean Operator 'OR' was used to broaden the search results while denoting the population of interest and these areas of focus. Further, the Boolean Operator 'AND' was employed to link part one of the search to the second word or set of words. An asterisk (*) was applied to some keywords to instruct the database to search for all endings of the word or phrase (eg, athlete*). The final search strategy being: 'elite youth athlete*' OR 'elite youth' OR 'elite youth sport*' OR 'elite adolescent athlete*' OR youth elite athlete*' AND 'positive development' OR 'positive youth development' OR 'positive outcome*' OR 'facilitate*'. The selected databases were SPORTDiscus (33 articles), APA PsycINFO (via PsycNet) (18 articles), Web of Science (68 articles) and Sports Medicine & Education Index (430 articles). Searches were completed in March 2023, and resulted in the identification of 549 articles. All articles were exported to Covidence to remove duplicates (75), leaving 474 articles for review.

Other inclusion criteria required that all articles (a) discussed findings related to facilitating engagement and positive outcomes for elite youth athletes and (b) included participants under the age of 18, with no constraints regarding year of publication. Two members of the research team examined all 549 articles at the title and abstract level while a third member was the deciding vote for inclusion, resolving decisional conflicts (54 conflicts). Through this first stage, 400 articles were deemed irrelevant with the majority eliminated because 'elite' designated athletes competing at a lower level (eg, an 'elite' level city team) versus national or Olympic level. In stage 2, the same research team members conducted a full-text review of the remaining 74 articles for eligibility, and a third member resolved any conflicting eligibility decisions (23 conflicts). A total of 28 articles were excluded in this stage for reasons such as incorrect population, not including facilitators of athlete engagement or full text not in English. A total of 46 articles were ultimately identified to meet the inclusion criteria and were further examined to determine the accuracy and relevance of the searches. Three articles were removed as they did not specifically focus on positive youth development or positive outcomes, resulting in a final sample of 43 articles. From these selected publications, 16 studies used a qualitative approach,[62–77] 14 collected quantitative data,[70 78–90] 2 adopted mixed methods[91 92] and 11 were reviews.[12 14 93–101]

Consensus

All aspects of the consensus statement and proposed contemporary paradigm were subjected to ongoing open discussion online in advance as the initial draft was being developed and more thoroughly during our in-person meeting where we considered dissent and new perspectives and made refinements accordingly. During the in-person meeting, we also arrived at a preliminary consensus for the nine paradigm implementation recommendations. This was promptly followed after the meeting by a Delphi-like method[102] of online anonymous Likert scoring (1–9) to determine consensus (≥80% of the participants providing a score ≥7 for a recommendation to be finally included, following edits and repeated rounds of voting as needed). Finally, we provided multiple opportunities for all panel members to review the manuscript and provide feedback online throughout further development and final approval.

THE ELITE YOUTH ATHLETE—CHALLENGES AND SOLUTION OPPORTUNITIES

'Growth and maturation' refers to the natural increase in the size of one's body or specific part(s), as well as the combination of accompanying underlying physiological processes, including timing and tempo of secondary sex characteristics appearance and development and other related biological phases and milestones, across puberty.[103] The evolving interdependent changes to an athlete's inherent adaptive psychobiological system that occur coincident with and consequent to growth and maturation appreciably and uniquely affect athletic and psychosocial development, resilience and corresponding aspects of vulnerability in sports.[104] This is especially evident during early adolescence, which has been identified as an inflection point for many health-related conditions and risk behaviours.[105] Individuals who enter puberty at a younger age may be more susceptible, as they are characteristically less likely to have the requisite cognitive and social capacities to adapt and successfully and fittingly manage adult-oriented international competition. Likewise, these risks and adverse outcomes may

be amplified in those emerging from less advantaged and supportive environments.[21]

Inherent changes, threats and challenges

Physical and physiological changes

Athletic development during adolescence is reciprocally augmented and challenged by concurrent changes in age-related growth and maturation, the individual timing of which is not possible to forecast precisely. Thus, there is an asymmetric enhancement of strength, speed, power and aerobic and anaerobic metabolism. In turn, youth sport performance is variably supported by a range of integrated physical and physiological characteristics (eg, size, physique, exercise metabolism, cardiorespiratory fitness (CRF), muscular strength and power and sprint speed). The asynchronous development of these features is thus inherent to the successes and challenges experienced by elite youth athletes as they move from childhood, through adolescence and into young adulthood. For example, the dynamic reliance on and interplay between aerobic and anaerobic metabolism affecting training, performance and recovery vary not only with the mode, intensity, frequency and duration of exercise but also with the youth athletes' developmental exercise physiology driven by their personal biological clocks.[106]

Children are characterised by more enhanced aerobic than anaerobic metabolism during exercise, with a progressive increase in glycolytic flux as youth athletes age, grow and mature.[107 108] In relation to chronological age, there are wide individual differences in CRF with male CRF typically increasing in a near-linear manner with age, from 10 to 18 years, and female CRF tending to level off from about age 14. In both sexes, the development of active skeletal muscle mass driven by the timing and tempo of maturation is the most powerful influence on increases in CRF and its components (ie, pulmonary ventilation, stroke volume, cardiac output and arteriovenous oxygen content difference).[109 110] Similarly, increases in active skeletal muscle mass, accompanied by a progressive enhancement of muscles' potential for anaerobic metabolism, are the principal drivers of increased muscle power output as youth athletes progress through adolescence.[110 111] In both sexes, skeletal muscle mass increases progressively through childhood and early adolescence, with boys, but not girls, experiencing a marked growth spurt in skeletal muscle mass in late adolescence, followed by a pronounced increase in muscle strength and sport-related benefits.[112 113] The natural gains in strength and power that accompany puberty may be augmented nonetheless for all youth through participation in developmentally appropriate strength and conditioning programmes promoting both neuromuscular and structural (ie, hypertrophic) adaptation, but especially in male athletes due to significant increases in testosterone post peak height velocity (PHV).[114] Female athletes, in comparison, experience smaller pubertal gains in absolute strength and power which may, when expressed relative to body size, plateau or decline with advancing maturity. Sprint speed increases linearly with age in childhood, normally followed by a significant spurt in boys' speed and a gradual levelling-off in girls' sprint speed in late adolescence. However, the complex interplay in the timing and tempo of the developing components makes the expected changes in sprint speed very difficult to predict confidently.[115 116] Accordingly, with the numerous integrated physiological changes driven by personal biological clocks, counting on and thus planning around a consistent gradual progression of performance and sustained sport success is notably problematic across the adolescent continuum.

Maturity status and injury

Adolescent athletes are more susceptible to specific musculoskeletal injuries, notably those associated with growth, maturation and/or overuse.[117 118] When a broad definition of injury is adopted (ie, to include all complaints), incidence and/or burden generally increase with advancing maturity, with values increasing from before to around peak height velocity (circa-PHV),[119–122] increasing[120 123] or stabilising[119 122] from circa- to post-PHV, and, in the case of burden, peaking in skeletally mature athletes.[120] Contrastingly, a non-linear association between maturation status and injury incidence is observed in non-contact sports, such as gymnastics,[124] or when the injury mechanism is classified as non-contact, with peak incidences/burden approximating age at PHV.[119 124–128] Similarly, a non-linear association between maturity status and injury incidence/burden is observable for apophyseal, growth-related or overuse injuries, with risk/burden lowest in fully mature athletes[127] and peak values approximating the age and/or stage of PHV.[119 120 124 127 129–131] Moreover, these injuries follow a distal-to-proximal growth gradient,[127 129] reflecting the sequential and asynchronous nature of the adolescent growth spurt where peak linear growth across age-specific body segments coincides with a dissociation between bone expansion and bone mineralisation.[129 132 133] More rapid changes in growth and maturity (tempo) are also associated with greater risk for injury[121 134–136] and burden[130] in soccer and greater injury incidence in track and field[133] and dance.[137] Potential elevated risks following overuse injuries in youth include early closure of the physeal plate, growth arrest, postural and joint instability, maladaptive morphological changes, acute and chronic muscle and joint pain and reduced performance and motor skill control. Chronic consequences can also contribute to athlete burnout and poorer mental health and quality of life as well as greater susceptibility for reinjury and future injuries as an adolescent or adult.[16 138–141]

The reported prevalence of overuse injuries in youth athletes across sports varies from 17% (across endurance, technical and team sports) to 37% (skiing & handball) and 68% (running),[11] yet it may be higher due to inconsistencies in the definition of injury across studies. Previous studies have also demonstrated that young players with high levels of athletic skills are at greater risk of sustaining acute and overuse injuries than less skilled teammates; and, moreover, that higher training volumes, performance level and an elevated competition load among the highly skilled or more mature team sport athletes may exacerbate injury risk further.[142 143] Adjusting for age and hours spent in sport participation, the prevalence of overuse injuries is also reportedly higher in athletes that specialise in (ie, focus solely on) a single sport.[144] However, single-sport development and specialisation programmes that are neither appropriately designed nor applied in a way that is responsive to individual readiness, needs, tolerance and physical and physiological development are likely highly prominent contributing factors. This is especially expected when there is excessive sport exposure, a regular high volume of vigorous sports activity and an emphasis on early (premature) achievement of high performance that is contradictory to the pace of normal growth and development.[145 146] Alternatively, specialising in a more individualised, holistic and progressively balanced way while sampling different experiences and being regularly exposed to a wide range of complementary athletic movements and development activities within a specific sport domain may be a healthy and viable strategy for achieving sport success at the highest levels.[12 147 148]

The onset of puberty also initiates sex-specific increases in the risk of acute injury. Anterior cruciate ligament (ACL) injuries, for example, occur approximately 3.5 times more often in female athletes, a discrepancy that does not emerge until the onset of puberty.[149] Sex differences in ACL injury risk attributed to hormonal and structural differences (eg, Q and knee valgus angles, knee-ligament laxity) may likewise reflect sex-associated differences in relative strength and convenient access to and application of high-quality coaching and training/conditioning and medical resources.[117 150 151] However, regardless of sex, injury risk reduction strategies to address modifiable contributing factors should be implemented early.[152] Adolescent athletes may also be particularly at increased risk for stress fractures related to Relative Energy Deficiency in Sport, with or without disordered eating, irregular menses, low bone mineral density or some of the other characteristic features associated with this novel physiological model.[153 154] A similar risk is evident with late-maturing female athletes where the pubertal growth spurt is accompanied by a greater training and/or competition load characteristic of older adolescents.[155] Moreover, for boys and girls, significant psychological consequences (eg, related to self-identity, self-esteem, self-efficacy, health locus of control, fear/avoidance, kinesiophobia and depression) can emerge following ACL or other serious sports-related injuries. This can potentially jeopardise return to play, increase subsequent reinjury risk and, with repeated and/or prolonged absence from sport, lead to the development of mental health disorders.[156 157]

Sociocognitive development

Sociocognitive development in youth is largely sculpted by experiences in one's sociocultural environment, highlighting the importance of the family, school and coaching environments.[158] This includes a diverse range of sociocognitive skills involving attention, memory, planning, self-regulation, reasoning and motivation. Across adolescence, individuals rapidly refine and integrate these processes and progressively become more uniquely capable of thinking and behaving in more complex and abstract ways such as problem-solving, rationalising successes and failures and considering alternate points of view, setting the stage for a positive transition to adulthood.[159] Participation in quality physical education and sport is generally associated with enhanced cognitive development and academic performance at the recreational level.[160–162] These benefits are not necessarily a direct result of physical education and sport participation alone; but they are likely to be mediated and moderated by the nature of the youth's experiences including their interactions with teachers and coaches, the quality of instruction and the nature and purpose of the physical education and sport environments. Sporting environments that are child centred, developmentally appropriate and supervised by competent coaches, promote the enjoyment, learning and holistic development of the child and are more likely to foster and support sociocognitive development in youth athletes.[161] However, with some elite youth athletes, sports participation at the highest competitive level may not provide the same benefit to academic performance.[163] This highlights the challenges in balancing concomitant sport and academic demands and underscores the importance of implementing valid strategies and support programmes to facilitate dual careers among elite youth athletes.[91 164] Furthermore, as cognitive development is not fully complete until approximately 25 years of age,[165] the extent to which youth athletes possess the necessary faculties to effectively and safely adapt to the stress and challenges associated with participation in sport at the adult level should be accordingly considered.

Psychosocial strain

Numerous basic physical, cognitive and psychosocial developmental needs that foster well-being must be broadly met for youth athletes to mature into healthy adults. Adolescents must also cultivate autonomy and independence, constructive relationships with peers and adults, affirmative self-esteem and self-identity and an optimistic sense of purpose and meaning in life.[166 167] However, the ongoing intersections of evolving bio-psychosocial challenges and related health risks inherent to adolescence and consequent to the intense physical and mental demands of their respective sport present an increasingly complex test and great psychosocial strain to elite youth athletes.[168] For instance, the potential adverse effects on overall health from physical injuries or burnout[16 52 141] can be exacerbated by a resulting escalation in anguish and strain on mental health and social functioning, resulting in depression, anxiety and possibly eating disorders.[34 169] Even a temporary separation from positive sport engagement following an injury often reveals the inherent risks associated with characteristic athletic identity foreclosure.[170 171] Likewise, a parallel undue pressure to perform and fear of failure can encourage additional stress and emotional distress.[172 173]

To be able to train and ultimately perform at a national and then top international level, elite youth athletes often leave their families and move to special academies with boarding schools where the familiar support system to assist in coping with school and elite sport demands is no longer present. Moreover, high training volume, controlled meal routines and very densely packed daily schedules with restricted free time limit opportunities to engage in normal social activities, potentially prompting difficulties in maintaining healthy relationships and thus consequent feelings of social isolation and loneliness.[174 175] To date, relatively little high-quality prospective research has specifically addressed psychosocial risks and strain faced by this select population; though some limited research on academy involvement with elite youth athletes assuages certain concerns around a negative impact on psychosocial development and well-being.[176]

Mental health

The onset of most common mental health disorders—including anxiety, substance misuse and mood, eating and neurodevelopmental disorders—commonly occurs during adolescence, with an estimated 50% of such disorders emerging before the age of 18 years.[177 178] Major risk factors for mental health disorders during this vulnerable developmental phase include puberty, social disadvantage and poverty, abuse, neglect, bullying and other forms of victimisation and trauma[179] as well as general transitional challenges associated with adolescence, such as identity formation and deindividuation from parents.[180] Girls have characteristically been aligned with exhibiting and reporting a greater prevalence in internalising mental health conditions (eg, anxiety, mood disorders), whereas exhibiting and reporting externalising conditions (eg, ADHD, substance misuse) has been linked more commonly to boys.[181–183] Nonetheless, these general risk factors for mental ill-health apply to all elite youth athletes, with additional heightened sport-specific challenges entwined with managing academic and escalating vocational demands[184 185] while adjusting to higher and more senior levels of international competition.[186]

Despite the peak onset of mental health disorders occurring during adolescence, few studies (with notably none from the YOG) have examined mental health development among elite youth athletes, with the extant literature consisting of cross-sectional designs involving cohorts of elite-*striving* athletes aged 12–18 years. Self-reported rates of mental health symptoms range from nearly 7%[187] to just over 20%,[188] with girls/women significantly more likely to report symptoms than boys/men in both studies, which is consistent with epidemiology in the general community.[189 190] *Type* of sport may also be influential, with athletes in individual sports reporting greater symptom severity than those from team sports,[191] which may reflect a greater tendency for internal attributions for success and failure in individual sport athletes. Age may be another relevant risk factor, as evidenced by routine clinical assessments conducted by psychologists and physicians with a large sample of French athletes (classed as junior through to 'high' elite levels across national sporting federations) where current psychopathology was most prevalent in those aged 12–18 years (15.1%) and 18–21 years (13.1%) compared with those aged 22 years and over (10.4%).[192]

To date, there have been no published prospective studies of mental health in elite youth athletes and a paucity of research considering the mental health needs and challenges of youth athletes travelling and competing at world-class-level events. There is also a dearth of developmentally and contextually appropriate *measures* of mental health and related conditions in elite youth athletes, which are required to further advance understanding and guide interventions for this population (see, eg, Rice *et al*[193]). Whereas empirical research is increasing, as reinforced by our corresponding scoping review,[194] there is a clear need for further robust and representative examinations into the prevalence, nature and correlates of mental health symptoms and disorders in elite youth athletes.

To optimally navigate these changing characteristic features of adolescents and mitigate the inherent ongoing threats and challenges, it is essential for elite youth athletes and their entourage to have access to accurate relevant information and resources. Likewise, consistent appropriate support from parents, coaches and all the medical personnel involved with providing care and guidance (including mental health services) is vital.[195] However, coaches and other adults are not always sufficiently qualified to recognise early indications and promptly address the broad changing needs of maturing adolescent athletes.[167] Moreover, coaching and medical care in elite sports are often overly oriented to the narrow emphasis on performing at the next event, which can lead to, for example, a return to competition too soon after an injury, illness or chronic undue fatigue and reinforce a willingness to compete hurt.[196–198] Whereas sport performance and overall well-being entail multiple integrated domains across adolescence, mismanagement of one or more fundamental dimensions (ie, physical, physiological, maturation, sociocognitive, psychosocial and mental) of elite youth athlete development can permanently jeopardise these select athletes' health and athletic careers.[7 199]

Modifiable threats—opportunities for mitigating risk

Seemingly countless scenarios, exposures and influences can impose additional risk to elite youth athletes' health, well-being and sport performance. The below *briefly* highlights threats particularly relevant to this group and pronounced opportunities to modify risk and related adverse impacts.

Frequency, duration and intensity of training, competition and travel loads

The competitive careers of elite youth athletes are often temporarily halted or sometimes permanently derailed by repeated undue physiological strain and overuse/overload injuries, resulting from excessive training and competition loads and insufficient regular rest and recovery, commonly with disregard to the personal timing and tempo of concurrent changes in growth and maturation.[7 16 200–202] Mismanaging the varying interplay between physiological demands and individual resilience with youth athletes also plays out in other notable ways. For example, amply hydrated and heat-acclimatised healthy youth athletes are not at a distinguishing cardiovascular or thermoregulatory disadvantage compared with correspondingly fit, well-hydrated and acclimatised adults during exercise in the heat.[203] However, across adolescence, elite youth athletes and those directing their training and competition loads, scheduling and recovery need to be cognizant of and appropriately accommodate progressively greater sweat losses, potential increases in thermal strain and exertional heat illness risk that are correspondingly associated with physical growth, biological maturation and, in certain scenarios, higher levels of fitness and athletic/sport skill.[204] Sleep is also integral to optimal athletic development, sport performance, recovery, mental well-being and injury prevention.[205] And while sleep needs are uniquely individualised, attaining enough sleep can be recurrently challenged by irregular scheduling and disproportionate levels and frequency of training, competition and travel.[206 207] This is especially evident in adolescent athletes experiencing reductions in both sleep time and quality due to disruptive circadian sleep patterns.[208]

Nutrition, supplements and body size/composition

Nutritional strategies to enhance sport performance and recovery have been well described.[209–211] For elite youth athletes, however, a perceived performance advantage solution often focuses unduly on supplements over well-timed and appropriately selected and portioned foods and fluids. Whereas 'prohibited substances' are clearly defined,[212] legal but potentially harmful 'nutritional supplements' are commonly encouraged without a valid risk–benefit analysis or sufficient evidence to warrant or guide utility.[213–217] The emphasis to youth in sport needs to stress the health and performance advantage of a nourishing balanced diet with ample energy and other macro and micronutrient availability in relation to sex-specific growth and maturation and sport demands. Moreover, healthy nutrition needs to be managed and reinforced without misguided pressure and persuasion in achieving premature muscle development or maintaining a purported 'optimum' strict sport-specific body size/composition for aesthetics or performance in an unrealistic or unhealthy way, especially because of the potential lasting physical and psychological negative impact on youth athletes.[153 209 218–222] Correspondingly, body composition assessment and interpretation should be limited to medical and ethical scientific purposes for those less than 18 years old and only with careful consideration, appropriate consensus and proper consent.[12 154 223]

Expectations of sport success

Unrealistic expectations of sport success, especially with premature selection favouring early maturers, can be among the foremost contributing factors in prompting mental and psychosocial stress in elite youth athletes, leading to withdrawal, burnout and eventually dropout from sport.[16 146] Often these expectations

emerge subtly and intricately over time from the athlete's entourage, parents, sponsors, peers and even the National Olympic Committee an athlete represents, though the mounting impact can be considerably damaging nonetheless. Beyond social withdrawal, notable outward signs and symptoms include loss of sleep and appetite, decreased fun and satisfaction and unexplained lower performance and injury.[224] Undue pressure (notably often from coaches) to achieve better results, along with ignorance on the related risks, also sometimes influences a youth athlete to engage in doping.[225]

Athlete migration

The globalisation and professionalisation of youth sport has led to increased athlete migration between and within nations.[226] Adolescent athletes identified as supposedly 'talented' may be urged to relocate to cities, training facilities or professional academies that purportedly provide the best opportunities for future success. In some instances, relocation may include offers of financial incentives for the youth (eg, scholarships, professional contracts) and occasionally as well for the parents or guardians (eg, via employment opportunities). Whether intra or international, the practice of migration generally presents a considerable challenge and degree of risk for the children. In addition to leaving their home, family and social community, each youth athlete must adapt to a new environment and educational system and may be required to develop new language skills. Also, acculturalisation can prompt extensive stress, homesickness and social and cultural isolation.[227] To mitigate such risks and prevent the unlawful coercion or trafficking of young athletes, some sport governing bodies, such as FIFA, have established strict rules pertaining to the protection of minors and transfer of players under 18 years old, including limitations on proximity of residence and requirements for financial and circumstantial transparency. There are also provisions for adequate sport, academic and vocational education and training, optimal living standards and social support (ie, a host family, mentor).[228]

Commercialisation

Commercialisation in elite sports has become increasingly influential, where the reliance on sponsors and media continues to escalate. The golden triangle comprising widespread media coverage, huge sponsorship deals and sport—affecting high-profile athletes to fan engagement—drives today's lucrative business of global elite sports,[229] and it continues to be increasingly prevalent at the youth level.[230 231] While the resultant effects and influences can be positive and negative, the overall impact on sports and athletes, including their right to privacy and protection of image, will be lasting. Elite youth athletes may also be notably jeopardised by economic exploitation imposed by sponsors and media who unintentionally rationalise and reinforce this practice (via direct or indirect financial incentives and showcasing negative values and behaviour) through their own narratives and publicised exposure.[232]

Social media

World Athletics reported on online abuse via social media platforms directed to athletes competing at the World Athletics Championships in 2022.[233] These disturbing findings are consistent with their previous statement from the 2020 Tokyo Olympic Games.[234] Both reports indicated greater levels of online abuse targeting female athletes; though the impact of all negative social media-related experiences (including cyberbullying) on girls *and* boys can be enduring and devastating.[235] Safeguarding against this form of abuse and protecting human rights in a widely accessible digital environment is challenging; but implementation of robust social media policies and procedures are essential priorities to protect all youth athletes in this domain.

Conditions for healthy engagement and optimal performance in elite youth sport

The essential conditions that accentuate positive individual assets and enable motivation and continued participation in youth sport are well described.[236–241] Further, the Personal Assets Framework is a fitting conceptual model to facilitate healthy engagement, development and optimal performance in (this instance) elite youth sport.[242] The below tenets are central to the Personal Assets Framework, duly consider and address the above challenges, threats and opportunities to mitigate risk in elite youth athletes and are thus integral to our proposed paradigm.

Safe, supportive and appropriate competitive settings and environments

All aspects of a sport setting and competition format should be designed and implemented to support the right to health and healthy engagement, mitigate injury/illness risk and optimise athletic performance. Ensuring the environment is free from harassment and abuse (psychological, physical, sexual and neglect) is a parallel priority. Settings and environments that meet these criteria are vital to protect youth athletes' health and well-being and provide a sense of security. Safe and supportive sport settings and environments also encourage exploration, experimentation, development and opportunities to exercise their right to play, while minimising competition-related fear. This is critical in building confidence and autonomy to compete at the highest level.[240 241] Those who provide administrative oversight and accountability are responsible for ensuring this expectation along with providing accessible recourse and delivering suitable responses and prompt remedy, as directed by applicable independent bodies, for youth athletes. However, all administrators and providers—notably including the entire coaching staffs and athletes' health and performance teams—have a role in ongoing prevention and immediate reporting to attain and strictly maintain this safe sport standard.[14 243]

Adolescents in elite sport should also be provided access to diverse contexts that, in part, are aligned with individual needs and expectations. Varied competitive settings and environments foster interest and build resilience for high performance.[244] Notably, competition should be structured to promote clear and consistent boundaries and expectations and provide age-appropriate monitoring, support and supervision.[240 241] Elite youth athletes should also be given opportunities to engage in different social and leadership roles while receiving appropriate mentorship.[245] Whereas providing individualised opportunities for increasingly intricate skill-building is vital, for sustainable performance, this must be in the context of ongoing healthy development of the whole person.[241] Moreover, an environment that continues to foster holistic development empowers adolescents to commit confidently and competently to pursuing specific goals that are challenging and personally meaningful. Finally, the call to integrate family, school and community has been notably echoed in the literature surrounding successful skill acquisition,[246] athlete development[237] and policies for youth development.[240 241]

Individual differences in the timing of maturation have been shown to influence athlete selection for junior national teams and performance, with advanced or delayed maturation serving

as either an opportunity or often a barrier (or no impact) towards success at the senior elite level. Whereas there is some evidence that late developing athletes may be more likely to successfully transition to the adult or professional level, conversion rates at the endpoint can be misleading.[247 248] Nonetheless, sports emphasising greater size, strength and power generally select male and female athletes who mature in advance of their same-age peers (eg, basketball, tennis, soccer), whereas sports placing a greater emphasis on linearity of physique and/or aesthetic ideals (eg, diving, gymnastics, ballet) tend to favour those delayed in maturation.[249] Maturity selection biases emerge at the onset of puberty, increase in magnitude with age and level of competition and exist and operate independent of related phenomena, such as the relative age effect.[250–252] Those involved in youth development programmes can, however, recognise individual differences in growth and maturity, fittingly adjust their respective assessments and expectations and accordingly provide optimal learning settings, competition formats and overall environments that support, aptly challenge and nurture early and late-maturing youth. Related initiatives, such as bio-banding (ie, maturity-matched competitions) and 'futures programmes' (ie, selective competitions for late-maturing players), have produced promising initial results for early and late-maturing athletes and should be considered for further investigation and potential implementation.[247]

Social ecosystems and quality relationships

Optimal developmental experiences for adolescents are fostered by social ecosystems characterised by (a) caring climates, (b) supportive adult relationships, (c) opportunities for belonging, (d) positive social norms and values and (e) support for efficacy, mattering and self-esteem.[240 241] The underlying social forces that markedly underpin youth athletes in a competitive ecosystem typically include robust personal relationships with coaches, parents and peer and team dynamics.[253] Likewise, essential mastery and autonomy-supportive motivational environments are largely attributable to those healthy rapports and behaviours valued and explicitly displayed in competitive settings.[254–256] At the individual level, these pivotal relationships should facilitate the fulfilment of basic psychosocial needs and personal assets, so that athletes develop initiative, autonomy and character that compel healthy and ethical decisions about their involvement in elite sport,[244 257] whereas, with a team, factors such as normative expectations, motivational climate and perceptions of cohesion will influence youth athletes' experiences and performance in sport. Moreover, effective development ecosystems for youth athletes within a team or competitive sporting club[258–260] consistently nurture a sense of belonging and ensure that communication and collaboration across the individuals involved (eg, administrators, coaches, athletes) are transparent and constructive. Collectively, these connections in competitive settings and environments will directly impact youth confidence and sport performance.[261]

Coaches' interactions with their athletes are among the most powerful influences on the quality of athletes' experiences.[262 263] Accordingly, coaches that show genuine interest in their athletes, promote autonomy-supportive relationships and consistently demonstrate transformational coaching behaviours (eg, display vulnerability and humility, provide inspirational motivation and confidence in athletes' potential and elicit athlete input and sharing in the decision-making) measurably foster positive coach-athlete interactions and thus enhanced performance and well-being.[264–266] Correspondingly, the ability of a coach to effectively and consistently nurture elite youth athletes relies on adaptable and caring interpersonal behaviours primarily focused on athletes' values, emotions and goals that are inherently aligned with each athlete's timing and status of maturation.

Personal engagement

Elite youth athletes must be afforded opportunities to make decisions on engaging in activities and in ways that promote their positive individual assets and skills. This provides reinforcement that they are capable and effective. Moreover, intensive training and diverse skill development should be complemented by integrating suitable and enjoyable play pursuits.[267] Sustainable personal engagement is further underpinned when youth athletes feel they relate to others, are working cooperatively towards a shared cause and that their advanced sport participation is governed by moral behaviours that include courage, honesty and empathy (ie, character).

Transitioning to athlete autonomy

Healthy and supportive relationships with key influential adults are essential to youth athletes in successfully navigating inherent increasingly complex and demanding sport environments. These select and trusted individuals must continue to maintain an optimal balance between measured autonomy granting and the amount and type of support provided to help even elite athletes gain and uphold assurance in their abilities.[268] More advanced interactions and situations can be gradually introduced as individual athletes mature and their respective capabilities and confidence improve. An ongoing objective appraisal of autonomy readiness will help to clarify the corresponding level of suitable support and enable a healthy and sustainable transition to progressively equip and encourage the elite youth athlete to act more independently.

Overall, our corresponding scoping review[269] closely aligns with these principles on positively engaging and impacting elite youth athletes in sport, emphasising the fundamentals of the Personal Assets Framework. First, it recognised the significance of the activities in which these athletes participate, emphasising personal engagement. Second, our review highlighted the importance of fostering quality supportive relationships with those immediately involved in developing elite youth athletes, such as coaches and finally, it underscored the relevance of creating appropriate physical and nurturing competitive sport environments that are not exclusively focused on rankings and performance. This encompassing ecological approach is aptly variable and responsive to broad changing needs across adolescence and sport participation and is central to our proposed contemporary paradigm for elite youth athletes.

MENTAL HEALTH AND SAFEGUARDING FOR THE ELITE YOUTH ATHLETE

The IOC is committed to strengthening safe sport across the Olympic Movement to protect physical and mental health and well-being, while concomitantly supporting elite sport competitions.[23] Moreover, providing elite youth athletes with the right to participate, enjoy and develop through sport in a safe and inclusive environment, free from all forms of harassment and abuse, is outlined by the International Safeguards for Children in Sport,[270] and it is primarily underpinned by the obligation of all sporting institutions to respect internationally recognised human rights and child rights in particular.

Mental health

Achieving and maintaining a fundamental and resilient level of mental health in high-level sport is not trivial.[271] Beyond performance outcomes and striving to 'win' in highly competitive contexts, elite youth athletes must contend with other *sport-related* stressors that also challenge mental health, including pressure to perform and maladaptive perfectionism,[272–274] early sport specialisation,[94 275] injuries, illness and burnout[52 141 171] and risk of harassment and abuse.[276] Consistent with other areas of sports medicine, prevention and early involvement should be prioritised in elite youth sport to respectively reduce general and sport-specific risk factors for mental ill-health and to provide evidence-informed timely interventions for those at risk or already experiencing mental health symptoms or disorders.[277] While untested in elite sport, the clinical and cost-effectiveness of early intervention for mental health in the general community is well-established.[278 279]

Improving mental health awareness and literacy among elite youth athletes and their entourage is critical to promoting and protecting mental health. These efforts are designed to (a) highlight early indications of mental health strain (such as anxiety, depression, disordered eating/eating disorder), (b) decrease the stigma associated with mental disorders and (c) increase the likelihood of seeking professional help for mental ill-health. With elite youth athletes being adept at masking their psychological distress in highly competitive contexts where mental toughness is prized and seeking help is perceived as showing weakness, this approach is highly warranted.[280] Beyond increasing mental health awareness, early detection and intervention for emerging mental health signs and symptoms is necessary to prevent the onset of mental disorders or reduce the severity, duration or impact of such conditions.[281 282] In the absence of research on the effectiveness of interventions for mental health in elite youth sport, practitioners are encouraged to refer to the IOC Consensus Statement on Mental Health in Elite Athletes[271] and Mental Health in Elite Athletes Toolkit.[281] Moreover, a broader perspective that also considers ecological factors can reduce the tendency to focus exclusively on and, therefore, potentially *pathologise* the individual athlete when other factors within the sporting context may be contributing to their mental health challenges.[283 284]

Safeguarding across the development continuum

Harassment and abuse is recognisably present in elite-level sports, with an alarming prevalence of psychological, physical and sexual violence and neglect affecting those under age 18.[8 9] This purportedly extends as well to the YOG[10 17] and can likewise emerge from within adolescent peer networks.[285] Notably, these forms of harassment and abuse are often co-occurring and can have numerous lasting negative effects on athletic and whole-person development and long-term well-being.[9]

The coach–athlete balance of power is also considered a key contributing risk factor in sport-related abusive relationships.[286] In elite sports, where the coach–athlete relationship is central and progressively more complex, youth athletes are notably vulnerable to abuse.[19] Moreover, there is a widely recognised and accepted increased dependence of youth athletes on their coaches (and expanded entourage) as they progress athletically and commit to greater levels and frequency of training and international competition. This escalating emphasis on adult support and control is often bolstered as youth athletes achieve success in their sport. Coincident with the corresponding 'stage of imminent achievement' during puberty is also the proposed period of peak vulnerability of youth athletes to grooming and sexual abuse.[287] Accordingly, maintaining healthy communication and an apt balance of power amid all relationships (interpersonal and organisational) is a justified priority.[268] Thus, all those closely working with and overseeing elite youth athletes should be sensitive and responsive to the everchanging and diverse safeguarding needs and opportunities in addressing risks across the dynamic continuums of adolescent athletic and maturational development.

AGE ELIGIBILITY

Is age eligibility the solution—*or part of the problem*?

Any resolution on AER standards and efficacy for participation in the Olympic Games, YOGs and other elite-level competitions must first consider the advantages, disadvantages and practical feasibility of AERs. Deliberation should also align with optimising athlete readiness, resilience and healthy sustainability across the adolescent continuum while objectively considering practical challenges and validity of available age determination methods.[96 288] Age eligibility in competitive youth sports is generally instituted by chronological age (eg, 14 years and under, 16 years and under, etc and 15 to 18 years for the YOG). However, an appropriate age for youth competing against adults in open-age sport such as the Olympic Games is the central issue here. While the prevalence of age cheating may be greater in the former, this consensus statement underscores how the corresponding impact of growth and maturation on short and long-term health, well-being and safety across adolescence is potentially more profound in the latter. Nonetheless, it would be premature to make or confidently speculate on a valid suitable AER recommendation. Moreover, even with a viable and acceptable standard for age determination (notable practical impediments are described below), age eligibility per se would not be the absolute solution to adequately mitigate corresponding risks for elite youth athletes.

Age determination in youth athletes remains a concern for professional sports academies and international sport governing bodies that organise high-profile sporting events stratified by chronological age.[96] The exposure and status of such events and the rewards and prestige associated with winning these competitions are considerable. Moreover, the professionalisation of youth sports and financial incentives associated with identifying and procuring highly skilled youth athletes may lead some organisations and agents to misrepresent the ages of their athletes, which is arguably instrumental violence and thus a form of abuse.[289] Age manipulation may occur as an act of intentional deception; however, in some instances, the birth records of the child may not be available. Athletes who are biologically and/or chronologically older than their age group cohorts may possess one or more advantages in experience, training age, morphological, physiological and psychological characteristics and athletic aptitude. In combat and collision sports, older and/or physically more mature athletes may also present significant greater risk to their younger and/or less mature peers. Similarly, underage athletes competing in an older age group may be exposed to training practices and/or competitive environments that present increased physical and psychological risk.

When chronological age cannot be verified, traditional and novel strategies to determine age group eligibility generally rely on singular estimates of biological maturation and employ absolute exclusion criteria.[290 291] However, these approximations have limited validity and reliability as proxies. Although such strategies are well intentioned, they do not account for individual

variability in the timing and tempo of maturation and have the potential to exclude athletes who are age eligible yet advanced or delayed in growth and maturation. Preferably, early birth registration and/or subsequent multiple indices and assessments of maturational status and growth over time, combined with a likelihood ratio approach to estimating chronological age (ie, the probability of the athlete of a given reported age attaining a specific biological age), should be considered to ascertain age eligibility.[288 292]

International Federations

Standardised AERs across the IFs for all youth athletes aiming to participate in the Olympic Games could be perceived as a seamless resolution. However, the practical scientific and clinical evidence that would warrant and support the setting of a specific cut-off chronological age valid for all sports within the variable and comparably higher risk adolescence continuum is not presently available. Likewise, evidence-informed justification for AER exceptions in individual sports cannot at this time be substantiated either. Notably, the current discipline-specific AERs reported by the IFs and highlighted in figure 3 had few supporting rationales and thus are not detailed; nor is the representation all-inclusive, as age requirements in certain instances remain somewhat fluid. Nevertheless, if an IF systematically considers and implements an AER as an informed transparent policy measure to rightfully safeguard those youth athletes below a selected age threshold, such an AER alone would be insufficient to aptly address the risks faced by elite youth athletes below *and* above the respective AER. Persistent parallel efforts to engage, support and protect each athlete as outlined in this consensus take precedence and remain imperative. Likewise, constant unbiased monitoring and assessment of individual athletic and sport ecosystem readiness, performance, resilience and sustainability and ongoing validation by corresponding increasingly informed models will objectively confirm or refute the continued efficacy of any IF AER policy.

Youth Olympic Games

The YOG current rule to only allow athletes in a fixed age band (15–18 years) to compete is less about mitigating risk related to age, growth and development and more of a deliberate opportunity to provide this subgroup of elite youth athletes with education, exposure to the ideals of Olympism and a shared celebration of individual and local cultures. However, for some, the YOG has become a highly competitive steppingstone and perceived pathway to the Olympic Games. Correspondingly, a consequent disproportionate representation of older athletes (especially with taller and heavier male competitors) participating at the YOG could elevate injury and other risks for the less prevalent younger minors.[293] Whereas the YOG is currently undergoing close review by the IOC, caution is warranted for unintended consequences if the AER is adjusted or further restricted for the YOG to solely better align with the IF World Championships and Olympic Games. More suitably, stressing and maintaining the intended objectives of the YOG and a more balanced distribution of birth years across all events may help to realign respective national perspectives for elite youth athlete development and YOG participation.

IMPLEMENTING A CONTEMPORARY ELITE YOUTH ATHLETE PARADIGM

The collective guidelines and recommendations presented in this consensus statement constitute a rational, evidence-informed contemporary paradigm with practical steps to support elite youth athletes in safely and favourably managing training and international sport competition. While mitigating risk is a fundamental priority, so too is defining a sustainable, individualised and long-term strategy that respects human rights, encourages personal engagement, health and well-being and cultivates sound athlete and person development. To fully realise these objectives, our emerging proposed model and outcomes corresponding to our recommendations will be aptly refined from ongoing efforts by the IOC to elicit feedback and incorporate the voice from Olympians who participated as under 18 years in the Olympic Games, past YOG participants and other elite youth athletes who did not make it to the YOG or Olympic Games. Moreover, the dissemination and operational framework needs to align with and reach the relevant ecological context across all constituents, hierarchical levels of implementation and applications.[294] Thus, our parallel aim is to engage, inform and empower the National Olympic Committees and IFs in this collaborative initiative.

To enable and cultivate this contemporary athlete-centred paradigm, we recommend developing, implementing and/or widely promoting:

1. A centralised and comprehensive learning hub specific to youth athletes and their health with dedicated portals for the athletes and others, such as IFs, National Olympic Committees, coaches and parents.
2. Systematic, evidence-informed education and accreditation requirements (including requisites for regular updates and renewal) for coaches who work with youth athletes.
3. Safeguarding strategies and frameworks (with ongoing monitoring and tracking, accountability and prompt remedy) that are specific to youth athletes' needs and aligned with international human rights standards and other IOC child rights initiatives.
4. Youth athlete safeguarding-specific Codes of Conduct and accompanying child-friendly versions to clarify child-centred compliance and accountability.
5. Complementary and flexible competition formats and pathways that uplift fairly and consistently early and late-maturing youth athletes and more optimally enhance their athletic development.
6. Clear definitions, processes and accompanying strategies to promote and support the mental and psycho-social well-being of youth athletes.
7. A framework for informing and guiding parents, coaches and relevant others specific to appropriate expectations and pertinent needs for youth athletes, considering varying individual timing, tempo and trajectory of growth, maturation and athletic development.
8. The importance of adult–youth interactions and healthy relationships that cultivate and amplify the unique strengths and assets of youth athletes.
9. Appropriate nutrition (including macro and micronutrients, energy intake and hydration) considerations and priorities that are central to healthy growth and development and optimal training/competition across adolescence.

MOVING FORWARD—A CALL TO ACTION

To extend and strengthen the evidence base applicable to healthy, sustainable and successful participation and advancement across adolescence in elite youth athletes and bolster implementation of the above paradigm while pursuing valid and acceptable age eligibility standards if/as warranted and achievable, our immediate call to action is to

1. Continue to develop, evaluate and improve complementary evidenced-informed internal and public-facing guidelines for best practices specifically designed for elite-sport entry at the international level and continuing progressively forward.
2. Encourage research and promote corresponding translation priorities (eg, specific to injury, mental health and dropout risks and contributing factors as well as sensitive and specific early detection and responsive mitigation strategies) utilising a contemporary multidomain, complex biological and psychosocial system predictive modelling approach.[295 296]

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