

Clinical Commentary/Current Concept Review

Challenges and Opportunities for Injury Reduction and Performance Development in Elite Youth Team Sport Schools: A Practice-Based Opinion

Filip F Staes, Ph.D.^{1,2,3} , Styn Vereecken, M.Sc.^{1,2,3,4}, Wouter P Timmerman, Ph.D.^{1,2,3} , Camille Tooth, Ph.D.⁵ , Suzanne Gard, M.Sc.^{6,7}, Kobe C Houtmeyers, Ph.D.^{2,8} , Arne Jaspers, Ph.D.^{1,2,3} 

¹ Department of Rehabilitation Sciences, KU Leuven, ² KU Leuven Institute of Sports Science, KU Leuven, ³ KU Leuven Child and Youth Institute, KU Leuven, ⁴ Sports Medical Advice Center, University Hospital Leuven, ⁵ Department of Physical Medicine, Rehabilitation and Sports Traumatology, Sports², FIFA Medical Centre of Excellence, FIMS Collaborative Centre of Sports Medicine, Centre Hospitalier Universitaire de Liège, ⁶ GO2, Sports injury Center for adolescent athletes, Morges, ⁷ HES-SO, University of Applied Sciences, Geneva, ⁸ Department of Movement Sciences, KU Leuven

Keywords: injury prevention, youth athletes, team sports, performance enhancement, multidisciplinary approach

<https://doi.org/10.26603/001c.144053>

International Journal of Sports Physical Therapy

Vol. 20, Issue 10, 2025

Performance enhancement and injury risk reduction are crucial for youth elite athletes. The pursuit of both these goals remains challenging in team sports as individual needs must be balanced with collective training goals. Despite the available evidence on screening, maturation, monitoring, and staff involvement, the optimal approach for enhancing performance while reducing injury risk in young athletes has yet to be defined, and integrating evidence into clinical settings remains a significant challenge.

This clinical commentary aims to share the decision-making process regarding performance enhancement and injury reduction in volleyball players within a youth elite sports school, considering maturation and a context of limited budgets for the use of advanced monitoring tools. A youth elite sports school offers a structured environment that allows young athletes, aged 12-18, to combine education with a sport-specific elite athletic development program supervised by a multidisciplinary team.

The authors address challenges related to preparticipation screening, maturation differentiation, low-budget monitoring, and communication. Based on literature, the daily experiences and project outcomes, opportunities for an integrated approach are identified which offer scalable, evidence-informed solutions to optimize performance development.

Level of Evidence

5

INTRODUCTION

The optimal guidance of elite athletes to achieve maximum performance and to reduce the burden of injuries has been a point of attention for years.^{1,2} Promoting health in sports at high level is all the more important for young athletes, given its impact on athlete development and progression.³ ⁴ Translating knowledge into daily practice to enhance performance and reduce injury risk in youth athletes, remains a challenge despite existing theoretical frameworks on prevention⁵⁻¹¹ and statements on youth development,³ training load,¹² and mental health.¹³

The development of young athletes to elite performers requires the involvement of a multidisciplinary staff. In some countries this is facilitated by selecting promising athletes for elite sports schools. These are structured environments that allow young athletes, aged 12-18, to combine education with a sport-specific athletic development program. In theory, these elite sports school contexts provide the ideal conditions to train and develop athletes. However, the available budget and support staff are often limited, and the staff is not always aware of the latest scientific knowledge and recommendations. As a result, the full potential of such a multidisciplinary approach is not al-

^a Corresponding author:

Filip F Staes, Tervuursevest 101, bus 1501, 3001 Leuven (Belgium), +32 497 81 79 06, filip.staes@kuleuven.be

ways realized, and opportunities to optimize development and athlete well-being remain underexploited.

The main goal of the approach is to optimize the sport-specific development of elite youth athletes by striving for maximal exposure to qualitative training and match activities, while carefully managing exposure and injury risk. This comes with practical and contextual challenges as currently it is still unclear in youth athlete contexts how to optimally screen for individual injury risk factors. In addition, it remains unclear how to best monitor training load and athletes' physical and mental well-being, as well as how to adapt training programs accordingly. In team sports, this is even more complex, as coaches must balance collective training goals with the individual athlete's capacity, while also taking into account the ongoing maturation and puberty process experienced by youth athletes. Together, these factors underscore the need for a structured, yet flexible approach that matches the developmental reality of young athletes within a performance context.

This clinical commentary aims to share the decision-making process regarding performance enhancement and injury reduction in volleyball players within a youth elite sports school, considering maturation and taking into account a context with limited or even absent budgets to implement advanced monitoring tools. The authors first present the setting, followed by some challenges. For each of the challenges presented, existing evidence is provided, information on the steps that were taken in the decision-making process is shared, and the decisions made with regard to a specific challenge are presented. The authors then outline their current approach and discuss how it can be applied to other team environments.

SETTING

The author team has 10 years of experience in developing and helping to implement evidence into decision-making tools for multidisciplinary staff, including physical trainers, coaches, medical doctors, sport physiotherapists and sport psychologists, in an elite youth volleyball sports school in Flanders, Belgium. The focus is on athletes between the ages of 10 and 18, with a particular focus on those aged 11 to 13 years, because this age range is critical for maturity and puberty transition.¹⁴ The athletes train up to 16 hours a week at school, comprising two hours of strength training and 14 hours of volleyball-specific training. Additionally, they train or play matches with their club during the weekend, with a large variability in training and match exposure between clubs.

Very specifically, the context is evidence-based and, whenever possible, uses a data-informed approach. When entering the school, the young athletes and their parents are informed about this approach, so they are fully aware of the goals of the multidisciplinary staff and its way of working.

CHALLENGES

In this section the authors outline four key challenges identified in the context of safeguarding and optimizing youth athletic development within the setting. First, the challenge of screening for individual intrinsic musculoskeletal risk factors highlights the ongoing difficulty of identifying at-risk athletes with sufficient precision and feasibility. Second, tailoring training through maturation-aware approaches underscores the need to account for varying rates of biological development when designing and adjusting training loads. Third, continuous monitoring in a low-budget environment points to the practical constraints faced by stakeholders aiming to track athlete well-being and performance with limited resources. Finally, the challenge of communication between stakeholders, including the athlete, emphasizes the complexity of aligning expectations and actions across schools, clubs, and parents to support the holistic development of young athletes.

CHALLENGE 1: SCREENING FOR INDIVIDUAL INTRINSIC MUSCULOSKELETAL RISK FACTORS

For about 20 years, preparticipation screening has been integrated in (youth) elite sports to identify individual intrinsic risk factors. As the detection of such risk factors has been considered as crucial to prevent and reduce injuries,⁶ preparticipation screening became a rule of thumb in Belgium, including for youth elite athletes. The interpretation of tests originally was based on research findings in adult athletes. However, in 2014, Caine et al.¹⁵ emphasized the difference between youth athletes and adults, for example with regard to growth-related injuries. Pfirrmann et al.¹⁶ illustrated differences in factors contributing to injury risk between youth and adult soccer players.

The team conducted multiple research projects across different cohorts of young athletes who were enrolled in an elite youth volleyball sports school.¹⁷⁻²² The main goal was to understand the relevance of preparticipation screening in relation to injury incidence and performance development. Each cohort consisted of 13 to 46 participants, aged 11 to 16 years. The screening protocols consisted of clinical and functional tests. Clinical tests screened for mobility (e.g. glenohumeral, scapular, knee-to-wall test, etc.) and strength, measured with a handheld dynamometer (e.g. rotator cuff, scapular muscles, hip and knee muscles). Functional tests included squat jumps and counter movement jumps, the Repeated Lateral Step Down Test, the Single Leg Drop Jump, the repeated heel raise test, and the Biering-Sorensen test. The Flamingo Balance Test and the Swiss Ball Knee Balance Test were used to assess balance.

The clinical tests did not detect any significant left-right lower extremity asymmetry (dominant versus non-dominant), indicating that within the young volleyball population, sport-specific clinical adaptations were not yet clearly developed. No consistent relationships were observed between screening parameters and injuries. This observation aligns with findings by Tooth et al. (unpublished data), who also found no clear relationships between upper limb

functional testing and injury incidence in a sample of 300 adolescent volleyball players. The authors further observed considerable variability in the execution of functional movements. This is not surprising given the fact that athletes develop physically at different rates within the age range investigated. McKay et al.²³ indicated that coordination and neuromuscular control are not fully developed at onset of puberty, and sensorimotor function continues to mature throughout adolescence. Quatman-Yates et al.,²⁴ Read et al.,²⁵ and John et al.²⁶ further highlighted that adolescents often experience changes in postural control and other motor skills, sometimes described as adolescent awkwardness, particularly around the time of peak height velocity.²⁷ Test outcomes mainly measure performance, without considering the impact of peak height velocity.

As no robust relationship could be observed between screening outcomes and injury occurrence over multiple cohorts of elite youth volleyball players,¹⁷⁻²² the authors added more performance-oriented tests of the lower limb (Y-Balance Test, Single Hop Test, Triple Crossover Hop Test for Distance, Figure of Eight Test, Tuck Jumps) and upper limb, the latter based on the work of Tooth et al.²⁸ Adding these tests did not significantly alter the outcome. Based on the current findings, the authors agree with Verhagen et al.²⁹ that no single preparticipation screening procedure can predict the risk of injuries, not only in adult athletes, but also in youth athlete populations.

As such, the authors decided it would be better to move away from extensive, one-off preparticipation screening procedures and considered, as suggested by other authors,²⁹⁻³³ introducing multiple screening moments throughout the season, inspired by the IOC consensus statement emphasizing that youth athlete development is unique and that advice should be tailored to the individual.³ However, testing at multiple time points introduces an additional challenge in youth athletes as natural growth and maturation can influence movement quality. It is therefore essential to avoid overestimating the effect of training interventions when interpreting test outcomes.³⁴⁻³⁶ That is why maturation-aware approaches had to be considered.

CHALLENGE 2: TAILORING TRAINING THROUGH MATURATION-AWARE APPROACHES

Consistent with findings of other authors,³⁴⁻³⁶ it was considered that the onset and evolution of biological maturation might be a potential intrinsic factor impacting injury occurrence and athlete development. Modifying training parameters to balance load and load capacity, while also accounting for individual maturation, is particularly challenging in team sport environments. Youth sport teams are still organized according to chronological age, yet often a discrepancy exists between the chronological and biological age.³ Categorizing athletes based on chronological age assumes a linear development trajectory, while in reality, biological maturation follows a highly individual, non-linear path.^{3,15,26}

This mismatch has consequences. Observed performance, whether it is awkwardness or better performance because of advanced physical characteristics, may at some

point be more attributable to biological development, rather than to coaching and training.³ Moreover, injury incidence tends to increase around the time of peak height velocity,³⁷ with the risk varying by injury type. Therefore, documenting maturity status is essential, both to understand development and to inform injury risk mitigation.

Several methods exist to assess maturation.³⁷ Bergeron et al.³ considered biological maturation based on skeletal age, secondary sexual characteristics, and maturity-related anthropometric predictions. However, these authors noted that such methods are not always practical in youth settings due to challenges associated with X-ray radiation, including the need for expert interpretation and ethnic variability, and privacy concerns related to secondary sexual characteristics. Sherar et al.³⁸ introduced an approach to manage biological differences within youth teams. This approach, which was further developed by Rogol et al.,³⁵ is called bio-banding, also known as maturity matching. Using both percentage of predicted adult stature attained at the time of observation and time prediction to peak height velocity as maturity related indicators, groups or bands of youth with similar maturity status are formed, which can then inform training load decisions, help reduce injury risk, and better support individual athlete development.

This approach is particularly relevant for the volleyball school setting, as maturity-related advantages and risks are most pronounced between the ages of 11 and 13, as noted by Chimera et al.³⁹ However, Chimera et al.³⁹ emphasized the logistic complexity of such an approach, as well as potential social risks such as isolation or stigmatization when athletes are separated from their chronological peers. These factors must be carefully managed when integrating bio-banding into team sport environments.

Given its relevance, the physical therapy team wanted to explore the feasibility of applying a bio-banding approach.⁴⁰ This approach was developed to limit jumping activities during volleyball specific training when athletes experienced growth-related complaints or were identified as being at high risk for such complaints. The goal of this approach was to relieve symptoms associated with growth and to better align training demands with the athletes' stage of biological development. Multiple meetings with the staff were necessary to find the most feasible way to introduce such an approach. It was finally agreed that athletes, if needed, could participate in a specific maturity-based training group for two hours a week. This decision was based on three parameters. The first two parameters were the percentage of the 'final estimated adult stature attainment' and the estimation of the 'age of peak height velocity' as described by Towlson et al.⁴¹ Measurements were done three times during the school year. Athletes were labeled as being at risk for growth-related-overuse symptoms when they were between 85% and 96% of their predicted adult height, as described by Jayanthi et al.³¹ Furthermore, players were labeled as being at risk when entering a chronological age within one year from the estimated age of peak height velocity.³¹ The third parameter was the occurrence of subjective reported growth problems. These were documented twice a week. Athletes were advised to

train in the bio-banding group when two out of these three parameters were positive.⁴²

Athletes reported that they enjoyed training with peers of similar maturity status. This led to increased physical and technical challenges, and a noticeable reduction in physical complaints. Coaches also expressed satisfaction with the approach, noting that the maturity-based grouping resulted in a more homogeneous training environment, which facilitated more targeted and effective training. However, it was emphasized that such targeted grouping should only be used during the identified maturity-related risk periods, rather than applied across all sessions. Based on these observations, the multidisciplinary team decided to continue and expand the bio-banding approach to four hours.

CHALLENGE 3: CONTINUOUS MONITORING IN A LIMITED BUDGET ENVIRONMENT

While biological maturity plays a crucial role in guiding athlete development, training adaptations should not be based on maturity status alone. In practice, decisions on training load and recovery should be informed by a broader, continuous monitoring process that includes the time within the season, overall load, recovery status, and athlete psychosocial well-being. Especially in youth sport settings, where individual development trajectories vary greatly, such holistic monitoring is essential to ensure a safe and effective progression.

This shift toward continuous monitoring requires well-considered choices regarding the tools that are to be used. Various methods exist to track training load, including the use of wearable technology to quantify physical activity.^{43, 44} While such technology can offer valuable insights, the financial means to fully implement it are not always available, particularly in youth sport settings. One reason is that monetary investments are often oriented towards senior teams instead of youth teams. Moreover, current wearable devices mainly provide data on overall external load, without capturing the specific internal load on different musculoskeletal structures.⁴⁵ As a result, the research community, private sector, and commercial technology manufacturers are still actively exploring the potential and limitations of these technologies in youth athletes.

In environments where budgets are limited, low-cost solutions can offer meaningful support for athlete development. Even when budgets are available, they are quite often invested in performance-oriented tools, rather than in development and health-related tools, again forcing teams to rely on limited budget approaches.

Subjective measures can play a central role in these contexts. The rate of perceived exertion (RPE) is a widely used and accessible way to capture internal load,⁴⁶ while tools like the affect grid help assess emotional responses across dimensions of pleasure–displeasure and arousal–sleepiness.^{47,48} However, the quality of subjective data depends heavily on the athlete's honesty.⁴⁹ This honesty is influenced by the environment created by coaches, performance staff, parents, and fellow athletes.⁵⁰ When athletes feel that staff members are genuinely interested in their devel-

opment and use their input constructively, they are more likely to respond openly and accurately. Conversely, negative reactions or lack of follow-up can lead to dishonest reporting, disengagement or poor well-being.⁵⁰

To ensure that subjective monitoring is effective, it must be embedded in a culture of trust, mutual respect, bilateral communication, and co-decision making. Athletes must understand the questions, so questions should be appropriately adapted to their age. Athletes should feel that their answers are not just collected but also acted upon. In this sense, subjective data becomes more than just information. It becomes the foundation for meaningful dialogue between staff and athlete. That said, subjective monitoring also requires time and effort from specialized staff for collecting and analyzing data, which brings its own cost and should not be underestimated.

Where possible, subjective data should be complemented by objective measures, such as the number of jumps or speed of throws, to provide a broader and more nuanced understanding of training demands. However, even without these objective tools, consistent and structured subjective monitoring can lead to valuable and contextual insights.

With these principles in mind, a low-cost monitoring framework was tailored to youth athletes. The goal was to enable more continuous monitoring throughout the season by combining different types of data. Systematic follow-up on and recording of injuries, including details about training time lost, was established by the medical team. A tool for monitoring training and match load, perceived recovery, sleep quality, and mental load was introduced through digital self-report forms completed by the athletes on their mobile phones twice a week (on Thursdays and Sundays after the last volleyball activity of that day). A team of physical therapists and sport scientists analyzed the data twice a week and provided targeted feedback to both the athlete and coach.

Another key component of the continuous monitoring in this volleyball setting is the coach and staff observation and interaction with the athletes on a daily basis. Although this information is not quantified, it is a valuable and effective manner that contributes to holistic monitoring of athletes. While the coaches are present at the training sessions, the physical trainer and physiotherapist are systematically present at specific sessions. The information captured through observation, interaction and communication with the athletes can inform the coaches and staff to adjust their planned training, pay closer attention to specific athletes and their data, or spark a conversation between staff members.

The approach allowed to identify not only periods of excessive load, for example during periods of intense competition, but also moments of underload, such as following exams or holidays or periods of disturbed sleep. More importantly, it enabled a more individualized approach to athlete support, grounded in a combination of objective and subjective data, tailored to the realities of a limited budget environment.

CHALLENGE 4: COMMUNICATION BETWEEN STAKEHOLDERS – ALIGNING SCHOOL, CLUB, ATHLETES AND PARENTS.

A key challenge within the context of elite youth sports schools is managing and planning of training load across different environments while ensuring all stakeholders expectations are aligned. Training at a high level cannot be viewed in isolation from the broader context in which these young athletes develop. Academic demands, exams, the influence of social media and, for those living in boarding schools, feelings of homesickness all play a role in determining an athlete's well-being, recovery, and response to training stimuli.⁵¹ While the primary focus of this commentary is not on mental health, its relevance is evident, as supported by a substantial body of literature linking well-being with athletic performance and injury risk.⁵² This is why the staff integrated monitoring tools for mental health and sleep.

In elite sports school settings in Belgium, athletes typically train both at school and with their club and compete during the weekends. These different environments introduce additional complexity, as club matches often result in a significant load spike within a 48-hour window. Moreover, many athletes compete at club level not only with peers but also with older, more mature players, a so-called compete up strategy.⁴⁰ This occurs because athletes in elite school programs tend to be the most skilled of their age group and are therefore often selected for competition in higher age categories where they are surrounded by more mature and potentially more experienced players, resulting in both a higher external and internal load exposure.

Over the years, it was observed that communication between school and club coaches cannot be taken for granted. Training load at school is not always known or considered by clubs, and vice versa. To address this, communication and coordination between the two settings had to be improved. Each week, clubs received updates on their athletes' participation in school training, along with data on perceived exertion, sleep quality, and mental state. If athletes showed signs of fatigue or discomfort, particularly due to growth-related injuries, clubs were advised to reduce weekend load. On Sunday evenings, athletes reported back on their status, enabling school staff to adjust Monday's training accordingly. A shared dashboard was created to track each athlete's profile and evolution. Additionally, and in case a club coach was informed on Friday about the health situation of a player(s) including a potential demand to reduce the weekend load to not aggravate an existing injury, the data from the Sunday questionnaire served as a control.

Weekend load was systematically higher than weekday load, often resulting in increased muscle soreness and stiffness. This imbalance proved difficult to manage, partly because athletes and club coaches tend to prioritize maximum playing time, sometimes at the expense of long-term development. Athletes may fear losing their place in the team if they rest, and they are eager to play the sport they love. Nevertheless, the project led to growing mutual understanding between school and club environments, which en-

couraged us to further develop and continue this collaborative approach.

In addition to schools and clubs, parents represent a third critical and quite often difficult stakeholder group. While the medical team consistently informed parents about injuries, it was found more challenging to involve them in decisions related to training load management. Many parents are actively engaged during weekend matches and often struggle to understand why their child, despite being among the top performers of their generation, is not playing a full match. The idea of strategic rest for long-term development and injury prevention may conflict with their immediate expectations and aspirations or with their beliefs that the more kids train or play, the better they become.

Despite these challenges, the multidisciplinary staff remains committed to involving parents in the development process. Ongoing communication is essential to build shared understanding and trust, particularly when it comes to difficult but necessary decisions such as reducing playing time or modifying training loads. Effective youth athlete development requires more than just expert staff and structured programs. It demands coordinated support and communication across all environments where the athlete lives, learns, and trains.

FROM CHALLENGES TO OPPORTUNITIES: THE TEAM'S CURRENT APPROACH AND FUTURE DEVELOPMENT

The past ten years, the multidisciplinary team has tried to tackle the different challenges to understand the impact of changes on training processes and injuries, while continuously seeking optimization through a step-by-step approach. It is recognized today that coaching (young) athletes should be done through a multidisciplinary approach.⁵³ Reduction of injury risk should be pursued in order to increase training performance and player progression.⁴ Therefore, an optimal balance between load and load capacity is essential. The authors outline the current approach within an elite youth volleyball school.

When young athletes are selected to enter the elite youth sport school, a medical screening is carried out as required by the government, along with a global musculoskeletal screening. The latter is not intended to predict injuries, but to identify physical points of attention that could be beneficial for both performance and athlete's health. These elements are then followed up during the training sessions. Furthermore, maturity status is determined, based on the elements related to the bio-banding approach as previously described. Whenever a young athlete is categorized as "at risk", the athlete is referred to a "bio-banding training group" for four hours a week. As soon as the risk period is over, the athlete returns to the regular training group. For the follow-up of athletes, accessible tools, as described before, are used to collect data on training load and response. The focus is not on data abundance, but on producing meaningful signals and contextual tendency to guide decision-making among team staff mem-

bers. For all athletes, load monitoring is conducted weekly using forms that can be filled in via their mobile phones. After analysis by the medical team, this information is then used to inform club trainers with regard to participation in the volleyball activities scheduled during the weekend, which is mostly competition. At the end of the weekend, trainers and medical staff of the school are informed about the training load in the weekend, potentially sustained injuries and level of recovery, allowing them to adapt individual training load whenever needed within the upcoming week. More detailed and individualized follow-up of young athletes is done whenever warning signs appear based on the collected data. The team member involved depends on the specific issue. If needed, sport psychologists and/or nutritionists can be consulted, or school staff may be contacted. At the end of each school year, a retrospective data analysis is done to evaluate the pros and cons of decisions with regard to performance optimization and injury reduction.

A major difference exists with regard to between- and within-player variability in load and response. Overall, a beneficial tendency regarding the number of injuries was observed. Athletes and trainers responded positively to the bio-banding approach. Weekly communication procedures, based on low-cost monitoring tools, help to build a shared understanding of training progression and athlete needs. This fosters awareness, alignment, and buy-in from all stakeholders. The use of data helps to provide structure, rhythm, and focus on the development process without overwhelming complexity. The bio-banding approach will be continued and expanded. It will consist of four hours of differentiated ball training and two hours will be added, allocated to targeted strength and conditioning sessions, with increased emphasis on addressing individual weak links such as proprioception and physical fitness. This approach aligns with the core principle of bio-banding and its intended practical application, namely to tailor training content to the biological development stage of the athletes in order to optimize performance while safeguarding long-term health.^{40,54}

As such, training and competition conditions are continuously optimized when young athletes are involved in different settings. Based on gradual implementation over the years, staff members have become aware of the importance of approaching the young athlete with the developmental process in mind. A challenge though remains to further involve club coaches as well as parents in order to achieve a truly balanced training and match approach. Keeping in mind that it takes years to become a grown-up elite athlete, creating awareness of the benefit of a long-term perspective is crucial.

TRANSFER TO OTHER CONTEXTS

The core principles and tools described in this elite youth volleyball context can be transferred to other youth team sports where individual development must be safeguarded within increasingly performance-driven environments.

First, the low-cost repeated monitoring procedure can be used in other team contexts. Whatever team context, athletes can easily complete short self-report questionnaires on training load, fatigue, sleep quality, and stress levels via their smartphones.

Second, maturation-aware grouping - like the bio-banding approach - can be adopted in other team contexts. For instance, in teams with higher levels of contact, grouping players by biological rather than chronological age can help limit the risk of contact injuries for late-maturing athletes competing with early developers.

Third, communication loops between stakeholders are essential in any youth sport context, certainly when players have to perform in multiple environments. A shared digital dashboard between school staff, club coaches, athletes and parents help align training load and reduce the risk of overloading a talented athlete who is eager to take every opportunity to perform.

The strength of the approach lies in its simplicity, scalability, and focus on communication. In a context that works with limited budget for monitoring tools, the approach enables optimized individual training load in a team sport context. Crucial in the approach is strong communication in a context of trust. The team must put forward clear priorities, gather meaningful data without collecting an abundance of unnecessary data. As such, these principles can easily be transferred to other team contexts with limited resources.

CONCLUSION

This clinical commentary describes the decision-making process regarding performance enhancement and injury reduction in volleyball players within a youth elite sports school, considering maturation and taking into account a context with no budget to implement advanced monitoring tools. It is important to move from one-off preparticipation screenings to continuous monitoring, taking into account the non-linear growth and maturation process. Bio-banding can be a valuable approach, even if used to a limited extent. Communication and trust between athletes, coaches, clubs, schools, athletes and parents are crucial to making an integrated approach possible. Young athletes must feel safe to share their concerns, certainly in sports where the pool of young talent is limited. With this contribution, the authors wanted to share the decision-making processes, building upon evidence, generating insight into the consequences of the decisions made, but based on a low-cost, integrated approach. As such, it is the authors' hope to inspire other youth sports environments to develop realistic, context-sensitive strategies that prepare young athletes to not only focus on quick wins but work towards becoming the best within their generation.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ACKNOWLEDGEMENTS

The authors wish to thank the athletes and coaches of the 'Topsportschool volleyball' in Leuven, as well as the staff and coordinating members of the Flemish Volleyball Federation. We wish to thank the parents for placing their trust in both the academic and clinical guidance of their children. Thanks also to the medical staff members of the Sports Medical Advice Centre (University Hospitals Leuven, Belgium). Thanks to Prof. Jean-Marie Aerts (Faculty of Bioscience Engineering of the KU Leuven, Belgium) for the collaboration and the assistance of master thesis students.

The Generative Artificial Intelligence Large Language Models ChatGPT-4o (OpenAI, San Francisco, CA, USA) and Microsoft Copilot (Microsoft Corporation, Redmond, WA, USA) were employed to support academic writing refinement.

Submitted: March 15, 2025 CDT. Accepted: August 16, 2025 CDT. Published: October 01, 2025 CDT.

© The Author(s)



This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CCBY-NC-4.0). View this license's legal deed at <https://creativecommons.org/licenses/by-nc/4.0> and legal code at <https://creativecommons.org/licenses/by-nc/4.0/legalcode> for more information.

REFERENCES

1. Bahr R. Demise of the fittest: are we destroying our biggest talents? *Br J Sports Med.* 2014;48(17):1265-1267. doi:[10.1136/bjsports-2014-093832](https://doi.org/10.1136/bjsports-2014-093832)
2. Timmerman WP, Abbiss CR, Lawler NG, Stanley M, Raynor AJ. Athlete monitoring perspectives of sports coaches and support staff: A scoping review. *Int J Sports Sci Coach.* 2024;19(4):1813-1832. doi:[10.1177/17479541241247131](https://doi.org/10.1177/17479541241247131)
3. Bergeron MF, Mountjoy M, Armstrong N, et al. International Olympic Committee consensus statement on youth athletic development. *Br J Sports Med.* 2015;49(13):843-851. doi:[10.1136/bjsports-2015-094962](https://doi.org/10.1136/bjsports-2015-094962)
4. 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 Footb.* 2022;6(4):405-414. doi:[10.1080/24733938.2021.1943756](https://doi.org/10.1080/24733938.2021.1943756)
5. Meeuwisse WH. Assessing causation in sport injury: A multifactorial model. *Clin J Sport Med.* 1994;4(3):166. doi:[10.1097/00042752-199407000-00004](https://doi.org/10.1097/00042752-199407000-00004)
6. Bahr R, Krosshaug T. Understanding injury mechanisms: a key component of preventing injuries in sport. *Br J Sports Med.* 2005;39(6):324-329. doi:[10.1136/bjsm.2005.018341](https://doi.org/10.1136/bjsm.2005.018341)
7. Bittencourt NFN, Meeuwisse WH, Mendonça 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(21):1309-1314. doi:[10.1136/bjsports-2015-095850](https://doi.org/10.1136/bjsports-2015-095850)
8. Gabbett TJ. The training—injury prevention paradox: should athletes be training smarter and harder? *Br J Sports Med.* Published online March 1, 2016. doi:[10.1136/bjsports-2015-095788](https://doi.org/10.1136/bjsports-2015-095788)
9. Vanrenterghem J, Nedergaard NJ, Robinson MA, Drust B. Training Load Monitoring in Team Sports: A Novel Framework Separating Physiological and Biomechanical Load-Adaptation Pathways. *Sports Med.* 2017;47(11):2135-2142. doi:[10.1007/s40279-017-0714-2](https://doi.org/10.1007/s40279-017-0714-2)
10. Windt J, Gabbett TJ. How do training and competition workloads relate to injury? The workload-injury aetiology model. *Br J Sports Med.* 2017;51(5):428-435. doi:[10.1136/bjsports-2016-096040](https://doi.org/10.1136/bjsports-2016-096040)
11. Kalkhoven JT, Watsford ML, Coutts AJ, Edwards WB, Impellizzeri FM. Training Load and Injury: Causal Pathways and Future Directions. *Sports Med.* 2021;51(6):1137-1150. doi:[10.1007/s40279-020-01413-6](https://doi.org/10.1007/s40279-020-01413-6)
12. Soligard T, Schwellnus M, Alonso JM, et al. How much is too much? (Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. *Br J Sports Med.* 2016;50(17):1030-1041. doi:[10.1136/bjsports-2016-096581](https://doi.org/10.1136/bjsports-2016-096581)
13. DiFiori JP, Benjamin HJ, Brenner JS, 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(4):287-288. doi:[10.1136/bjsports-2013-093299](https://doi.org/10.1136/bjsports-2013-093299)
14. Walters BK, Read CR, Estes AR. The effects of resistance training, overtraining, and early specialization on youth athlete injury and development. *J Sports Med Phys Fitness.* 2018;58(9):1339-1348. doi:[10.23736/S0022-4707.17.07409-6](https://doi.org/10.23736/S0022-4707.17.07409-6)
15. Caine D, Purcell L, Maffulli N. The child and adolescent athlete: a review of three potentially serious injuries. *BMC Sports Sci Med Rehabil.* 2014;6:22. doi:[10.1186/2052-1847-6-22](https://doi.org/10.1186/2052-1847-6-22)
16. Pfirrmann D, Herbst M, Ingelfinger P, Simon P, Tug S. Analysis of injury incidences in male professional adult and elite youth soccer players: A systematic review. *J Athl Train.* 2016;51(5):410-424. doi:[10.4085/1062-6050-51.6.03](https://doi.org/10.4085/1062-6050-51.6.03)
17. Buisseret K, Staes F, Vereecken S, KU Leuven. Faculteit Bewegings- en Revalidatiewetenschappen. *Klinische Screening van Het Onderste Kwadrant En 6-Weken Interventie Bij Elite Jeugdspelers Volleybal.* KU Leuven. Faculteit Bewegings- en Revalidatiewetenschappen; 2018.
18. Hervent L, Staes F, Vereecken S, KU Leuven. Faculteit Bewegings- en Revalidatiewetenschappen. *Shoulder Specific Screening Tests and the Effect of a Six-Week Intervention Program in Youth Volleyball Athletes.* KU Leuven. Faculteit Bewegings- en Revalidatiewetenschappen; 2018.

19. Oosterbos M, Staes F, Vereecken S, KU Leuven. Faculteit Bewegings- en Revalidatiewetenschappen. *Effect van Een Individueel, Niet-Gesuperviseerd Oefenprogramma Bij Volleybalatleten van 12 Tot 14 Jaar Ter Voorbereiding Op de Topsportschool Volleybal*. KU Leuven. Faculteit Bewegings- en Revalidatiewetenschappen; 2020.
20. Minten T, Staes F, Vereecken S, Jaspers A, KU Leuven. Faculteit Bewegings- en Revalidatiewetenschappen. *Injury Patterns, Predictability and Training Loss in a Young and Preselected Volleyball Population: Results from a 3-Month Observation Period Using a Retrospective Design*. KU Leuven. Faculteit Bewegings- en Revalidatiewetenschappen; 2022.
21. Leemans M, Staes F, Jaspers A, Houtmeyers K, KU Leuven. Faculteit Bewegings- en Revalidatiewetenschappen. *De Relatie Tussen Screening- En Belastingparameters En Blessures Ter Hoogte van Het Onderste Lidmaat En de Rug Bij Elite Jeugd Volleybalspelers*. KU Leuven. Faculteit Bewegings- en Revalidatiewetenschappen; 2024.
22. Beck L, Staes F, Jaspers A, Houtmeyers K, KU Leuven. Faculteit Bewegings- en Revalidatiewetenschappen. *The Relationship between Upper Quadrant Screening, Training Load and Injury Risk – A Multifactorial Approach*. KU Leuven. Faculteit Bewegings- en Revalidatiewetenschappen; 2024.
23. McKay D, Broderick C, Steinbeck K. The adolescent athlete: A developmental approach to injury risk. *Pediatr Exerc Sci*. 2016;28(4):488-500. doi:[10.1123/pes.2016-0021](https://doi.org/10.1123/pes.2016-0021)
24. 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(9):649-655. doi:[10.1136/bjsm.2010.079616](https://doi.org/10.1136/bjsm.2010.079616)
25. Read PJ, Oliver JL, Myer GD, De Ste Croix MBA, Belshaw A, Lloyd RS. Altered landing mechanics are shown by male youth soccer players at different stages of maturation. *Phys Ther Sport*. 2018;33:48-53. doi:[10.1016/j.ptsp.2018.07.001](https://doi.org/10.1016/j.ptsp.2018.07.001)
26. John C, Rahlf AL, Hamacher D, Zech A. Influence of biological maturity on static and dynamic postural control among male youth soccer players. *Gait Posture*. 2019;68:18-22. doi:[10.1016/j.gaitpost.2018.10.036](https://doi.org/10.1016/j.gaitpost.2018.10.036)
27. Wachholz F, Tiribello F, Mohr M, van Andel S, Federolf P. Adolescent awkwardness: Alterations in temporal control characteristics of posture with maturation and the relation to movement exploration. *Brain Sci*. 2020;10(4):216. doi:[10.3390/brainsci10040216](https://doi.org/10.3390/brainsci10040216)
28. Tooth C, Schwartz C, Ann C, et al. Upper limb functional testing in athletes: A Delphi study. *Shoulder Elb*. 2024;16(1 Suppl):89-99. doi:[10.1177/17585732221101880](https://doi.org/10.1177/17585732221101880)
29. Verhagen E, Dyk N van, Clark N, Shrier I. Do not throw the baby out with the bathwater; screening can identify meaningful risk factors for sports injuries. *Br J Sports Med*. Published online October 1, 2018. doi:[10.1136/bjsports-2017-098547](https://doi.org/10.1136/bjsports-2017-098547)
30. Fonseca ST, Souza TR, Verhagen E, et al. Sports injury forecasting and complexity: A synergetic approach. *Sports Med*. 2020;50(10):1757-1770. doi:[10.1007/s40279-020-01326-4](https://doi.org/10.1007/s40279-020-01326-4)
31. Jayanthi N, Schley S, Cumming SP, et al. Developmental training model for the sport specialized youth athlete: A dynamic strategy for individualizing load-response during maturation. *Sports Health*. 2022;14(1):142-153. doi:[10.1177/19417381211056088](https://doi.org/10.1177/19417381211056088)
32. Tooth C, Schwartz C, Gofflot A, Bornheim S, Croisier JL, Forthomme B. Preseason shoulder screening in volleyball players: is there any change during season? *JSES Int*. 2023;7(4):662-667. doi:[10.1016/j.jseint.2023.03.022](https://doi.org/10.1016/j.jseint.2023.03.022)
33. Schwank A, Blazey P, Asker M, et al. 2022 Bern Consensus Statement on shoulder injury prevention, rehabilitation, and return to sport for athletes at all participation levels. *J Orthop Sports Phys Ther*. 2022;52(1):11-28. doi:[10.2519/jospt.2022.10952](https://doi.org/10.2519/jospt.2022.10952)
34. Meylan C, Cronin J, Oliver J, Hughes M. Talent identification in soccer: The role of maturity status on physical, physiological and technical characteristics. *Int J Sports Sci Coach*. 2010;5(4):571-592. doi:[10.1260/1747-9541.5.4.571](https://doi.org/10.1260/1747-9541.5.4.571)
35. Rogol AD, Cumming SP, Malina RM. Biobanding: A new paradigm for youth sports and training. *Pediatrics*. 2018;142(5):e20180423. doi:[10.1542/peds.2018-0423](https://doi.org/10.1542/peds.2018-0423)
36. Hill M, John T, McGee D, Cumming SP. Beyond the coaches eye: Understanding the “how” and “why” of maturity selection biases in male academy soccer. *Int J Sports Sci Coach*. 2023;18(6):1913-1928. doi:[10.1177/17479541231186673](https://doi.org/10.1177/17479541231186673)
37. Parry GN, Williams S, McKay CD, Johnson DJ, Bergeron MF, Cumming SP. Associations between growth, maturation and injury in youth athletes engaged in elite pathways: a scoping review. *Br J Sports Med*. 2024;58(17):1001-1010. doi:[10.1136/bjsports-2024-108233](https://doi.org/10.1136/bjsports-2024-108233)

38. Sherar LB, Cumming SP, Eisenmann JC, Baxter-Jones ADG, Malina RM. Adolescent biological maturity and physical activity: biology meets behavior. *Pediatr Exerc Sci*. 2010;22(3):332-349. doi:[10.1123/pes.22.3.332](https://doi.org/10.1123/pes.22.3.332)
39. Chimera NJ, Falk B, Klentrou P, Sullivan P. Is biobanding the future of youth sport participation? *Pediatr Exerc Sci*. 2024;36(4):181-191. doi:[10.1123/pes.2024-0021](https://doi.org/10.1123/pes.2024-0021)
40. Cumming SP, Lloyd RS, Oliver JL, Eisenmann JC, Malina RM. Bio-banding in sport: Applications to competition, talent identification, and strength and conditioning of youth athletes. *Strength Cond J*. 2017;39(2):34-47. doi:[10.1519/ssc.0000000000000281](https://doi.org/10.1519/ssc.0000000000000281)
41. Towlson C, Salter J, Ade JD, 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(4):403-412. doi:[10.1016/j.jshs.2020.09.003](https://doi.org/10.1016/j.jshs.2020.09.003)
42. Johnson D, Williams S, Bradley B, Cumming SP. Can we reduce injury risk during the adolescent growth spurt? An iterative sequence of prevention in male academy footballers. *Ann Hum Biol*. 2023;50(1):452-460. doi:[10.1080/03014460.2023.2261854](https://doi.org/10.1080/03014460.2023.2261854)
43. Bourdon PC, Cardinale M, Murray A, et al. Monitoring athlete training loads: Consensus statement. *Int J Sports Physiol Perform*. 2017;12(Suppl 2):S2161-S2170. doi:[10.1123/IJSPP.2017-0208](https://doi.org/10.1123/IJSPP.2017-0208)
44. Jaspers A, Brink MS, Probst SGM, Frencken WGP, Helsen WF. Relationships between training load indicators and training outcomes in professional soccer. *Sports Med*. 2017;47(3):533-544. doi:[10.1007/s40279-016-0591-0](https://doi.org/10.1007/s40279-016-0591-0)
45. Matijevich ES, Branscombe LM, Scott LR, Zelik KE. Ground reaction force metrics are not strongly correlated with tibial bone load when running across speeds and slopes: Implications for science, sport and wearable tech. *PloS One*. 2019;14(1):e0210000. doi:[10.1371/journal.pone.0210000](https://doi.org/10.1371/journal.pone.0210000)
46. Liu H, Yang W, Liu H, et al. A meta-analysis of the criterion-related validity of Session-RPE scales in adolescent athletes. *BMC Sports Sci Med Rehabil*. 2023;15(1):101. doi:[10.1186/s13102-023-00712-5](https://doi.org/10.1186/s13102-023-00712-5)
47. Mellalieu S, Jones C, Wagstaff C, Kemp S, Cross MJ. Measuring psychological load in sport. *Int J Sports Med*. 2021;42(9):782-788. doi:[10.1055/a-1446-9642](https://doi.org/10.1055/a-1446-9642)
48. Russell JA, Weiss A, Mendelsohn GA. Affect grid: A single-item scale of pleasure and arousal. *J Pers Soc Psychol*. 1989;57(3):493-502. doi:[10.1037/0022-3514.57.3.493](https://doi.org/10.1037/0022-3514.57.3.493)
49. Houtmeyers K, Staes F, Vereecken S, Timmerman W, Jaspers A. Waarom subjectieve data nodig zijn. *Sportgericht Vakbl Voor Spec Beweg*. 2024;78(5):20-23.
50. McCall A, Wolfberg A, Ivarsson A, Dupont G, Larocque A, Bilsborough J. A Qualitative study of 11 world-class team-sport athletes' experiences answering subjective questionnaires: A key ingredient for "visible" health and performance monitoring? *Sports Med*. 2023;53(5):1085-1100. doi:[10.1007/s40279-023-01814-3](https://doi.org/10.1007/s40279-023-01814-3)
51. Putukian M, Blauwet C, Currie A, et al. Social media impact on athlete mental health: #RealityCheck. *Br J Sports Med*. Published online February 19, 2024. doi:[10.1136/bjsports-2023-107651](https://doi.org/10.1136/bjsports-2023-107651)
52. McClean ZJ, Pasanen K, Lun V, et al. A biopsychosocial model for understanding training load, fatigue, and musculoskeletal sport injury in university athletes: A scoping review. *J Strength Cond Res*. 2024;38(6):1177. doi:[10.1519/JSC.0000000000004789](https://doi.org/10.1519/JSC.0000000000004789)
53. Myer GD, Jayanthi N, Difiori JP, et al. Sport specialization, part I. *Sports Health*. 2015;7(5):437-442. doi:[10.1177/1941738115598747](https://doi.org/10.1177/1941738115598747)
54. Lloyd RS, Cronin JB, Faigenbaum AD, et al. National Strength and Conditioning Association Position Statement on long-term athletic development. *J Strength Cond Res*. 2016;30(6):1491-1509. doi:[10.1519/JSC.0000000000001387](https://doi.org/10.1519/JSC.0000000000001387)