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Lukas Arenas[1] · Sabrina Skorski[1] · Tim Meyer[1] · Monika Frenger[2]
[1] Institute of Sport and Preventive Medicine, Saarland University, Saarbrücken, Germany
[2] Department Economics and Sociology of Sport, Saarland University, Saarbrücken, Germany

Evidence at play: evidence-based practices and barriers in biological maturation assessment among German football academies

Introduction

Elite youth football academies function as an essential strategic component within football organizations, primarily concentrating on the development of young talented players for their first team and the generation of revenue through player transfers (Balliauw, Bosmans, & Pauwels, 2022; Stratton, Reilly, Williams, & Richardson, 2004). Their initiatives, often referred to as talent identification (TID) and talent development (TD) programs, play a critical role in pursuing a sustainable and equitable approach to talent selection and development by mitigating the systemic selection bias of favoring early over late maturing players (Konarski et al., 2021; Lüdin, Donath, Cobley, Mann, & Romann, 2022; Towlson et al., 2019). The context within elite sports is characterized by its unique dynamic and continuously evolving nature, necessitating adaptable strategies and interventions for its development (Tee et al., 2018). To ensure sustainable player development, it is crucial for key stakeholders, including management, coaches, scouts, medical and sport science staff, within youth academies to integrate and promote adaptive practices as core elements of their organizational culture (Johnson, Williams, Bekker, Bradley, & Cumming, 2023a; Ratten, 2016; Reeves, Enright, Dowling, & Roberts, 2018). The pivotal role of organizational culture and resource allocation becomes apparent in translating research knowledge into evidence-based practices (EBP) within a high-performance environment (Akenhead & Nassis, 2016; Fullagar et al., 2019a; Houtmeyers et al., 2021; Morris, Tod, & Oliver, 2015; Relvas, Littlewood, Nesti, Gilbourne, & Richardson, 2010; Weston, 2018). EBP refers to the systematic integration of staff expertise, athlete perspectives, and research findings into decision-making processes, facilitating informed strategies that enhance training, performance, and player development (Fullagar, McCall, Impellizzeri, Favero, & Coutts, 2019b). Such approaches have gained importance for its contribution to improved outcomes (Ramalho & Petrica, 2023). Implementation of EBP not only relies on the organization's financial resources but also on its commitment to sport science and a culture that supports EBP adoption (Cumming, 2018; Cumming, Lloyd, Oliver, Eisenmann, & Malina, 2017; Fullagar et al., 2019b; Houtmeyers et al., 2021). In the context of youth football development there is growing evidence of the benefits of incorporating and acknowledging biological maturation, offering potential advantages in terms of talent identification, injury prevention, and the long-term development of homegrown players (Hall et al., 2022; Hill, John, McGee, & Cumming, 2023; Lüdin, Donath, Cobley, & Romann, 2021; Monasterio et al., 2024; Monasterio et al., 2021a; Towlson, Cobley, Parkin, & Lovell, 2018) . Biological maturation can be defined in terms of status, tempo, and timing (Cumming et al., 2017). Several approaches are available to evaluate these aspects, each presenting distinct strength and limitations. Among these, skeletal age is widely regarded as the most reliable indicator, applicable from infancy through to adulthood (Leyhr et al., 2020). Alternatively, noninvasive assessments of maturity status and timing, derived from anthropometric data are becoming increasingly popular (Arenas, Frenger, Skorski, & Meyer, 2023; Salter, De Ste Croix, Hughes, Weston, & Towlson, 2021). These approaches can be integrated into standard growth monitoring practices, thus, enabling grouping and assessment of players based on their biological maturation status rather than their chronological age, a process currently known as "bio-banding" (Cumming, 2018; Cumming et al., 2017). This strategic reorganization aims to minimize significant within-group variances in athlete performance resulting from variations in maturation timing within age-groups (Towlson et al., 2018). Research has confirmed the effectiveness of bio-banding in establishing more equitable playing conditions by reducing maturity-related disparities in stature, body mass, and key

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performance variables within groups (MacMaster et al., 2021). Bio-banding has shown significant benefits for both early and late maturing players in youth football, enhancing their technical and tactical development, creating more opportunities for skill demonstration and reducing injury risk perception (Cumming et al., 2018). Players have generally recognized its value, reporting positive attitudes towards bio-banding when properly educated about the approach (Bradley et al., 2019; Cumming et al., 2018). It creates an environment for more accurately assessing players' abilities, reducing the oversight of talent (Towlson, Watson, Cumming, Salter, & Toner, 2023).

Despite evidence indicating that key stakeholders within elite youth football academies in both Germany and the UK acknowledge the importance of considering biological maturation in long-term player development, as well as in general load management and injury prevention (Arenas et al., 2023; Salter et al., 2021; Towlson et al., 2021), operational challenges are limiting the widespread implementation (Arenas et al., 2023; Salter et al., 2021). Although the assessment of biological maturation is a mandatory component of the Premier League's Elite Player Performance Plan (Premier Leauge, 2011), integrating it into the training process presents various challenges, as highlighted by a recent UK survey that emphasized logistical and time constraints for implementation (Salter et al., 2021). While the potential advantages of biological maturation considerations for training and competitive adjustments are also acknowledged from key stakeholders within German youth football academies, the adoption of such practices remain very limited and lacks consistency (Arenas et al., 2023; Salter et al., 2021; Towlson et al., 2021).

Therefore, this study aims to investigate the relationship between German football academies organizational culture of valuing EBP and their implementation of biological maturation in the development process of youth players. Additionally, the survey aims to uncover perceived barriers hindering the adoption of biological maturation assessments. The gathered data hold the potential to provide valuable insights into variations in the incorporation of biological maturation analysis across German youth academies, potentially highlighting areas for improvement and facilitating further implementation of biological maturation considerations in football academies.

Materials and methods

Design and participants

The survey was constructed based on previous research, encompassing training load (Akenhead & Nassis, 2016; Salter et al., 2021; Weston, 2018), recent advancements in biological maturation assessment, and the application of bio-banding formats (Cumming et al., 2017; Rommers et al., 2020; Teunissen et al., 2020). Additionally, it incorporated surveys related to personnel structures in football (Droste et al., 2021; Gonzalez-Balzar, 2007). Between March and May 2022, a cross-sectional design was applied and an online survey distributed to sport science and medicine staff working within all 56 elite male German football academies. Respondents, representing their respective clubs, completed the survey to prevent clustering. In total, 46 respondents completed the questionnaire, resulting in an 82% response rate. However, six of these respondents did not fully complete the questionnaire, leaving us with 40 complete responses for the final analysis, representing a complete response rate of 71.4%. The participants included staff members from First League ($n = 12$), Second League ($n = 15$), Third League ($n = 8$), and Fourth League ($n = 5$) German football academies. Among the participants, 21 worked as strength and conditioning coaches (52%), 16 as head of sport science and medicine (40%), and the remaining participants worked as head coach, assistant coach, and rehabilitation coach, respectively. On average, the participants had 5.9 ± 5.0 years of experience in the field of elite football, with a minimum of 0.5 years and a maximum of 25 years.

Survey

The survey consisted of five sections: (1) eligibility questions, (2) demographic data and club information, (3) club's belief on the benefit of evidence-based practice, (4) maturation: assessment and monitoring practices, (5) maturation: use of data—report and feedback. The survey questions were structured as either multiple choice or Likert scale, with all scales being unipolar and including four to five labeled points (Krosnick, & Presser, 2009; Norman, 2010). To guarantee the reliability and accuracy of the data, the construction of the questionnaire incorporated the Questionnaire Appraisal System (QAS-99; Willis & Lessler, 1999). The complete questionnaire is provided in the appendix, and the content validity process is described in detail elsewhere (Arenas et al., 2023). Ethical approval for this research was granted by the University of Saarbrucken Institutional Research Ethics Review Board (22–03).

Statistical analysis

In this publication, we analyzed sections (1), (2), (3), and (4) by exporting SoSci survey responses into R-Studio (version 2022.07.0, Posit, PBC, Boston, MA, USA). Frequency analysis was conducted on the responses, following established guidelines (Krosnick et al., 2009). Numeric variables were assigned to Likert scale data and parametric statistics were utilized for data analysis (Norman, 2010; Salter et al., 2021; Weston, 2018). To assess the club's belief in the benefits of EBP, we calculated an overall EBP index value according to a previous investigation (Houtmeyers et al., 2021). In the evaluation of influencing barriers, both a Structural Barrier Index and an Operational Barrier Index were computed. Independent sample t-test were employed to investigate differences between participants conducting biological maturation assessments and their corresponding index values. All statistical analyses maintained a significance level of $p < 0.05$ and were performed using the dplyr package, with visualization using the Likert and ggplot package. To ensure the accuracy and validity of our

interpretation of the questionnaire data, we followed the literature's recommendation to calculate Cronbach's α for each concept rather than the entire test or scale (Tavakol & Dennick, 2011). Following a retrospective analysis of responses evaluating similar constructs, we obtained Cronbach's α values rated as "excellent" for the club's belief in the benefits of EBP (α = 0.81, 95% confidence interval [CI] 0.69–0.89) and "good" for the perceived barriers to the implementation of biological maturation assessment (α = 0.77, 95% CI 0.65–0.87).

Results

Club belief on the benefit of evidence-based practice

Figure 1 displays a heatmap representing responses to the five Likert scale questions that evaluated the club's belief in the benefits of EBP. The participants' average response regarding their club's belief in the benefits of EBP was 3.68 ± 0.971 on a 5-point Likert scale with a range of 1.8–3.40 for Q1 (mean of 2.87 ± 0.5) and with a range of 4.2–4.80 for Q4 (mean of 4.35 ± 0.21).

Figure 2 displays a raincloud plot that illustrates the distribution, central tendency, and variability of EBP index scores across respondents' roles, grouped as strength and conditioning coaches (n = 22), head of sport science and medicine (n = 16) and coaching staff (n = 2). The coaching staff exhibited a mean EBP index of 4.00 ± 0.57, with a median of 4.00 and scores ranging from 3.6 to 4.4. The head of sport science and medicine group had a mean EBP index of 3.89 ± 0.71, with a median of 4.1, and scores between 1.8 and 4.8, showing the greatest variability. Strength and conditioning coaches recorded the lowest mean EBP index at 3.49 ± 0.7, with a median of 3.7 and scores ranging from 2.4 to 4.4.

Figure 3 displays the results of a t-test, aiming to assess the differentiation between respondent groups that perform biological maturation measurements based on their EBP index scores. The analysis reveals a statistically significant difference (p-value = 0.035) between these two groups. Specifically, the group engaged in biological maturation assessment, comprising 20 respondents, exhibits a mean EBP index of 3.91 ± 0.65, while the group refraining from such assessments reports a mean EBP index of 3.44 ± 0.71. The logistic regression analysis reveals that the EBP index hast a significant impact on the likelihood of implementing biological maturation assessments. The positive coefficient of 1.07 for the EBP index suggests that each additional point on the index leads to an increase in the log-odds of conducting biological maturation assessments. In particular, the odds ratio for the EBP index is 2.90, meaning that a one-unit rise in the index corresponds to a 2.90-fold increase in the likelihood of implementing biological maturation assessments. Furthermore, the analysis of variance (ANOVA) reveals no statistically significant difference in the EBP index across the different leagues, suggesting that the league level does not have a meaningful influence on the EBP index.

Figure 4 displays the results of a t-test, aiming to evaluate the distinction between practitioner groups engaged in biological maturation measurements and their perceived barriers expressed as an index value for operational and structural barriers. An overarching structural barrier index was formulated by incorporating barrier perceptions related to staffing numbers, infrastructure, and financial budget. Simultaneously, the comprehensive operational barrier index was established by integrating barrier perceptions regarding management support, coaching support, and staff competence. The analysis indicates a statistically significant difference (p-value = 0.021) between these two groups, demonstrating a significant higher perception of structural barriers when not conducting biological maturation assessments. However,

Abstract

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L. Arenas · S. Skorski · T. Meyer · M. Frenger

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Abstract

Purpose. This study examined the extent to which German male football academies adopt evidence-based practices (EBP) and their impact on the execution of biological maturation assessments. It also explored perceived barriers to implementing these assessments.

Methods. With a 71.4% completion rate, 40 support staff members from German male football academies completed an online survey. The survey included questions on clubs' beliefs about EBP, maturation assessment and monitoring practices, and data utilization. Responses were structured as multiple-choice or unipolar Likert scale questions with four to five labeled points. A magnitude-based decision approach was used to interpret findings.

Results. Results indicate a strong integration of EBP within German football academies, reflected in an EBP index of 3.66 ± 0.89 on a 5-point Likert scale. Significant differences (p = 0.035) were observed between participants conducting biological maturation assessments (3.91 ± 0.65) and those who do not (3.44 ± 0.71). Time constraints (68%) and staffing limitations were identified as primary barriers.

Conclusion. The findings emphasize the positive adoption of evidence-based practices in German football academies, with higher EBP index scores linked to conducting biological maturation assessments. The higher EBP index scores among those conducting biological maturation assessments highlight the crucial role of organizational culture in implementation. Structural barriers, contributing to the perceived "time constraints", are key challenges, while staff competence is not a limiting factor. Promoting innovative, solution-oriented practices could help address these barriers, enhance decision-making, and better align processes with long-term player development goals.

Keywords
Youth football · Bio banding · Monitoring · Prevention · Talent development

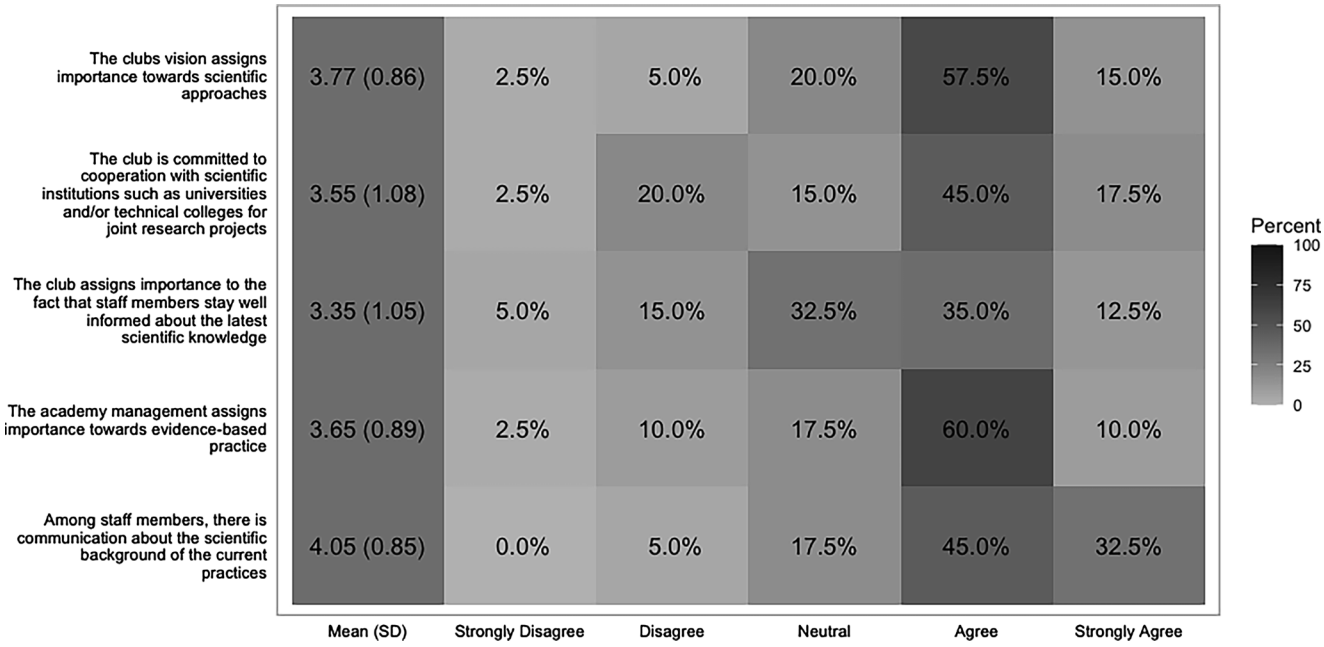

Fig. 1 ▲ Heatmap representing responses to Likert scale questions evaluating clubs' belief in evidence-based practice benefits. Strongly disagree in the point range of 1.00–1.80, disagree 1.81–2.60, neutral 2.61–3.40, agree 3.41–4.20 and strongly agree 4.21–5.00 (Pimentel, 2010). *SD* standard deviation

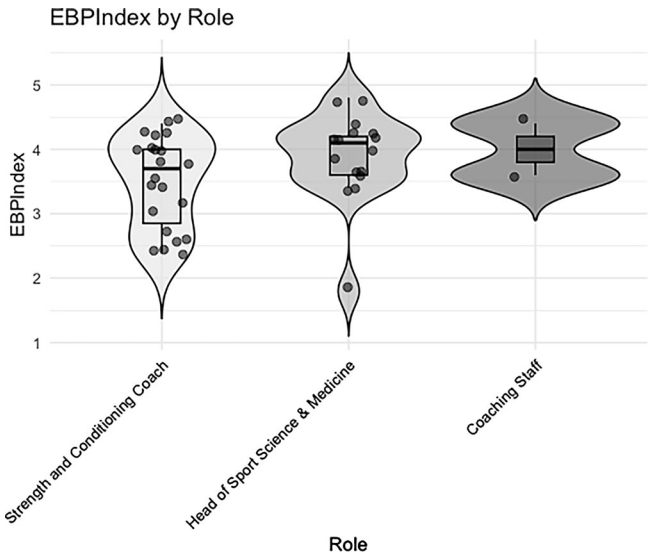

Fig. 2 ◄ Distribution of evidence-based practice (EBP) index scores across respondents' roles grouped as strength and conditioning coach, head of sport science and medicine, and coaching staff

no significant differences were found in the perception of operational barriers between the two groups (p-value = 0.81).

Biological maturation barriers of assessment

Figure 5 shows the responses to the perceived barriers to the implementation of the biological maturation assessment in their youth academy. This figure shows a horizontal bar chart illustrating the distribution of agreement scores, ranging from "strongly disagree" to "strongly agree", for each barrier. A consensus among respondents accounting for 68% point to primary barriers perceived, with "time constraints" and "staffing limitations".

Discussion

With a completion rate of 71% from all existing German elite youth football academies, the current rate is comparable to other football survey studies (Akenhead & Nassis, 2016; Salter et al., 2021; Weston, 2018). This study aimed to achieve multiple objectives. First, it sought to examine the attitudes of German football academies EBP and the impact of this attitude on the implementation of biological maturation assessments. Additionally, the study aimed to analyze the perceived barriers that hinder the integration of biological maturation assessment in German academies. The growing body of literature and the increasing prevalence of biological maturation assessment in youth development across various sports emphasize the recognized importance of integrating this approach for sustainable long-term player development (Giudicelli, Luz, Sogut, & Massart, 2020; Mitchell, Haase, & Cumming, 2021; Patel, McGregor, Williams, Cumming, & Williams, 2021). Several research groups have highlighted the importance of considering biological maturation in load management and injury prevention for adolescent athletes (Lacome, Simpson, Cholley, Lambert, & Buchheit, 2018; Monasterio et al., 2021b; Towlson et al., 2021). However, the limited adoption and inconsistent consideration of biological maturation in training and

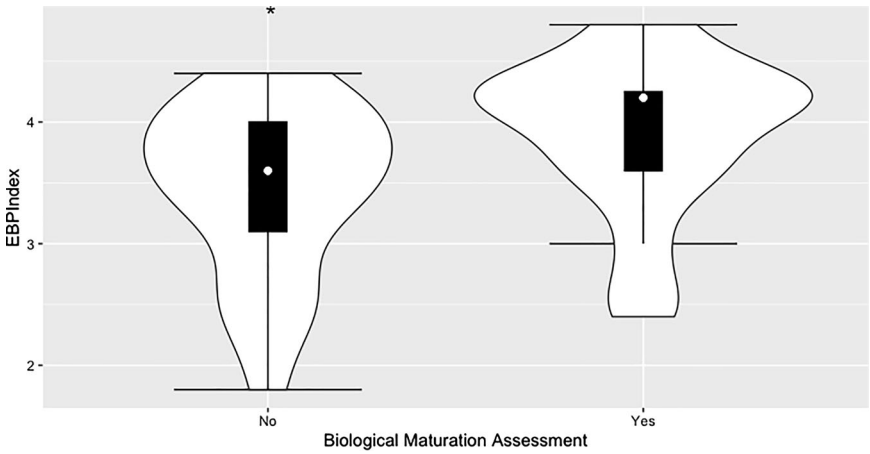

Fig. 3 ▲ Differential evidence-based practice (EBP) index scores in respondents' groups conducting biological maturation assessment

competitive fixtures in German elite youth academies indicate structural and operational barriers to their day-to-day operational behavior (Arenas et al., 2023).

Impact of club belief on the benefit of EBP on biological maturation assessment

The study's findings emphasize the adoption of EBP within German football academies, as indicated by an EBP index of 3.66 ± 0.89 on a 5-point Likert scale (Pimental, 2010). These results align with the attitudes of European soccer clubs towards evidence-based working practices, as shown in a previous survey (Houtmeyers et al., 2021). The analysis identified a statistically significant difference among respondents conducting biological maturation assessments. A higher EBP index appear to increase the likelihood of assessing biological maturation. Interestingly, league affiliation does not significantly influence the outcome, suggesting that organizational practices are shaped primarily by cultural attitudes and philosophies rather than financial resourced associated with league status. This supports prior research demonstrating that organizational culture has a greater influence than financial capacity (Fullagar et al., 2019a; Houtmeyers et al., 2021). The findings indicate that the successful implementation of biological maturation assessments relies on an organization's commitment to sport science and a supportive cultural environment rather than its financial capabilities. The variation in EBP agreement levels, ranging from 1.8 to 3.40 for Q1 and 4.2 to 4.80 for Q4, underscores the need for more in-depth individual case analyses and evaluations to gain a deeper understanding of attitudes and practices due to the substantial heterogeneity observed. An examination of the individual EBP index items reveals key cultural factors that could be relevant for implementation. Participants expressed a high level of agreement (4.05 ± 0.85) with regards to effectively communicating the scientific basis of current practices. Effective communication and collaboration are pivotal in facilitating knowledge transfer, ensuring a proper understanding and implementation of EBP (Bartlett & Drust, 2021; Verhagen, Voogt, Bruinsma, & Finch, 2014), which impact player availability and development (Johnson et al., 2023a). This collective perspective is further support with an agreement of 3.77 ± 0.86 regarding the item that "clubs emphasize the importance of scientific approaches". Similarly, an agreement score of 3.65 ± 0.89 is reported for the belief that "academy management places significance on evidence-based practices". Academy managers play a critical role in ensuring that work practices are adopted, developed, and implemented into existing workflows and organizational culture (Ratten, 2016). Despite the high level of agreement towards EBP, previous survey results on youth football academies in Germany highlight a considerable gap in regular assessment and incorporating these results into their load management for training and competitive fixtures (Arenas et al., 2023).

Exploring behavioral change models, such as the capability (C), opportunity (O), and motivation (COM-B) model, can help to explain the discrepancy between the perceived significance of EBP towards biological maturation assessment and its limited implementation. The COM-B model serves as a diagnostic tool to identify barriers and facilitators to behavior change. It describes an interactive and interdependent relationship between its components for an individual to engage in a specific behavior. Motivation is influenced by factors such as personal beliefs and attitudes. The survey results indicate a strong motivation of the participating sporting organization, as indicated by their EBP index values, which demonstrates a positive belief and attitude towards EBP regarding the assessment and implementation of biological maturation evaluation. This aligns with recent findings on the recognition of biological maturation assessment within German football academies (Arenas et al., 2023). To successfully execute a desired behavior, the necessary capability and opportunity, including knowledge and required resources as time, must be present, given the interdependent nature of these components. The subsequent section will analyze the perceived barriers associated with implementing biological maturation in greater depth, focusing on the capability and opportunity components.

Perceived barriers to biological maturation assessment

The survey results provide valuable insights into the challenges faced by practitioners in German youth academies when incorporating biological maturation into their academy programs. A significant majority of respondents, comprising 68%, expressed consensus on the primary hurdles they face, which include "time constraints" and "staffing

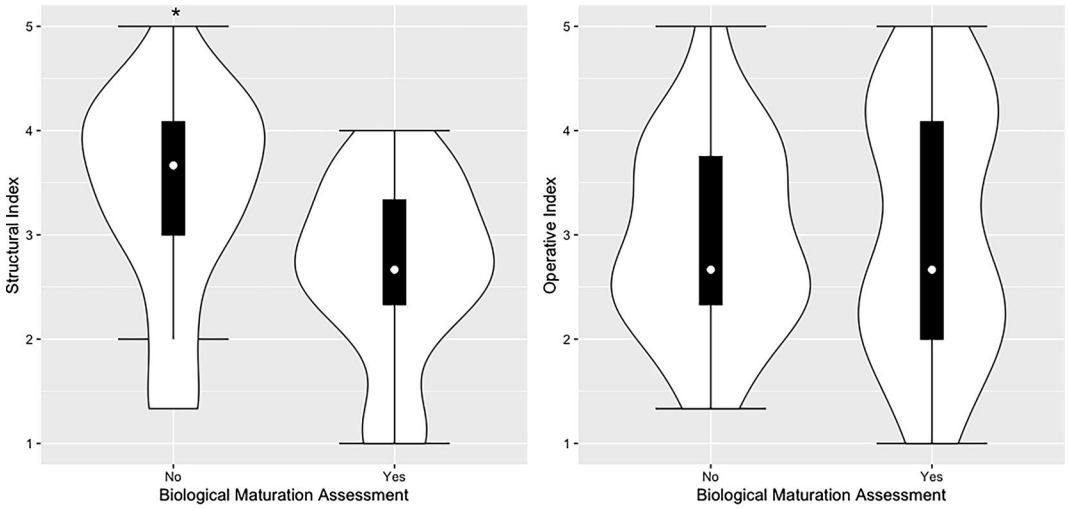

Fig. 4 ◀ Differential structural and operational index scores in respondents' groups conducting biological maturation assessment

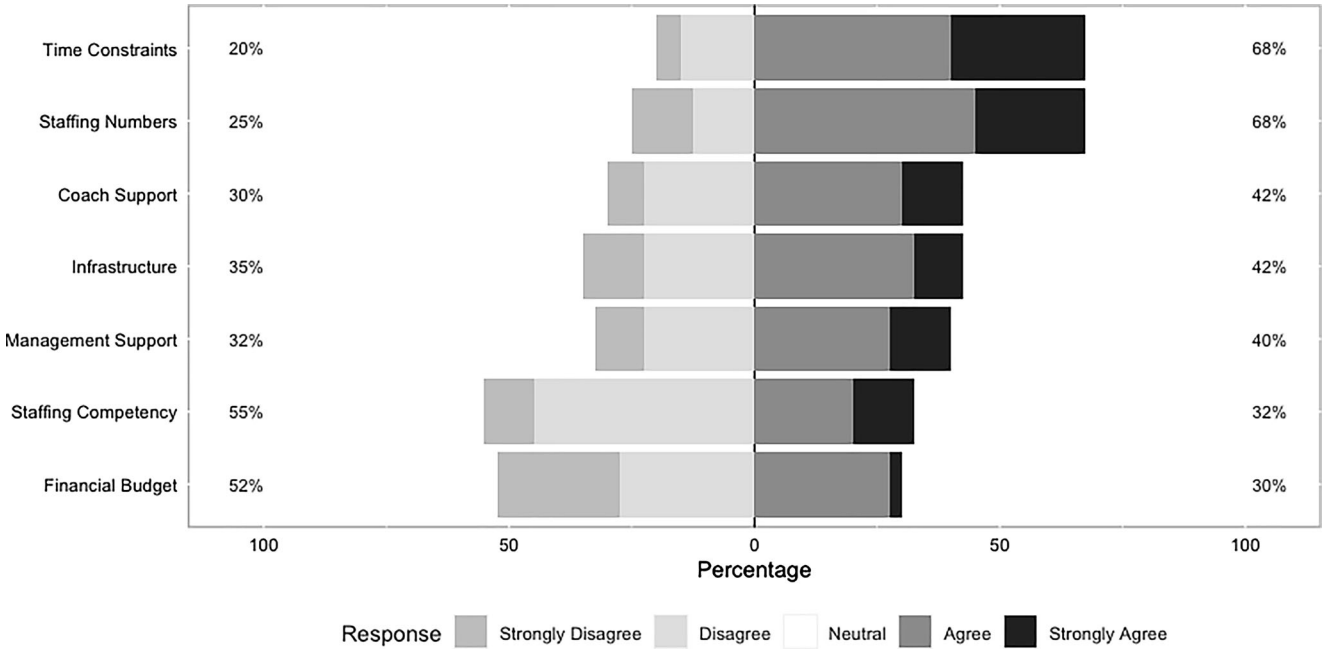

Fig. 5 ▲ Distribution of perceived agreement levels on barriers to implementing biological maturation assessment in German youth football academies

limitations". This aligns with findings from a UK survey, which also identified logistical challenges, specifically towards time constraints and staff shortages, as the primary barrier to successful implementation (Towlson et al., 2023).

Conducting a t-test to assess the distinction between practitioner groups engaged in biological maturation assessment and their perceived barriers, expressed as an index value for operational and structural challenges, revealed a statistically significant difference (p-value = 0.021). This difference indicates a notably higher perception of structural barriers among respondents not actively conducting biological maturation assessments. The findings suggest that structural barriers may underpin the perceived "time constraints" as the primary barrier to implementing biological maturation assessments. This indicates that time-related challenges may not stem from a lack of time itself but rather from underlying structural limitations, which reduce the available resources and capacity to integrate these assessments effectively. Addressing these structural issues could mitigate the perceived time-related barriers and support wider adoption. The interdependent relationship between the COM-B components further highlights that perceived time constraints and staffing limitations align with missing environmental factors, which fall under the opportunity component.

The perceived time constraints can cause limited opportunities for reflection within the fast-paced environment of high-performance sport, further hindering the implementation of EBP. This shortage of reflective time can impede the ability of sports practitioners to translate their practical experiences into valuable individual and organizational

knowledge for driving further organizational development (Joachim, Schulenkorf, Schlenker, & Frawley, 2020). To overcome these challenges, iterative approaches gradually finding their way into sports management practice (Joachim et al., 2020). These methodologies foster a culture of innovation and collaboration within sport organizations by providing efficient, solution-oriented frameworks for problem-solving. They empower practitioners to reframe obstacles through multidimensional thinking, rapid prototyping, and continuous testing and refinement, enabling more adaptive and effective decision-making processes (Joachim et al., 2020). While research in the field of sport management is limited, case studies have illustrated the effectiveness of these methods in reducing injury susceptibility among adolescent athletes through improved multidisciplinary collaboration (Johnson, Williams, Bradley, & Cumming, 2023b; Tee et al., 2018). Implementing iterative approaches could be a starting point to address the time constraint barriers identified in this study, making it a valuable approach for promoting EBP in sports organizations and support further development. Additionally, it is noteworthy that staffing competence was not identified as a major barrier, suggesting that the capability competent of the COM-B framework is not a limiting factor, as respondents possess the necessary skills to implement biological maturation assessments.

However, it is crucial to acknowledge the limitations of this study. While obtaining 40 responses from a finite pool of German youth football academies represent a commendable response rate and is comparable to other surveys in the football domain, only 16 participants (40%) held responsibilities for overseeing the entirety of the sports science and medicine department. This limitation may have restricted the comprehensiveness of insights into the adoption and application of biological maturation assessments. Additionally, it is imperative to recognize that the survey might exhibit a bias towards practitioners actively involved in biological maturation assessment. The underrepresentation of participants from the lower tiers of the German leagues has the potential to skew the results, possibly portraying a more favorable picture of maturation assessment practices in the participating clubs than is representative of the broader youth academy landscape. Furthermore, the answers may be subject to social desirability, self-esteem, and self-legitimization biases. The respondents' high level of agreement with EBP and the indication of lack of time and staffing limitations imply that other issues take priority over the implementation of biological maturation. This suggest a discrepancy between the positive statements about EBP and the actual prioritization of EBP in the allocation of resources, although it is attributed a high level of importance by key stakeholders in the academy context. The interactive and interdependent relationship between capability, opportunity, and motivation to engage in a particular behavior point to the complexity of further analysis of facilitators and barriers in the implementation of EBP. To provide a more detailed understanding of behavior change processes, the components of the COM-B model can be further elaborated using the Theoretical Domain Framework. While the COM-B model provides a broad structure for behavior change intervention, the TDF breaks down each component of the COM-B into 14 more specific domains. The combined use of TDF and COM-B facilitates the development of targeted interventions by identifying specific areas for improvement within each COM-B component. The survey results on attitudes towards EBP and the use of biological maturation assessment in German youth academies can inform more comprehensive research that examines the TDF components of the COM-B framework to further identify the facilitators and barriers of behavior change towards implementing biological maturation in these settings.

Conclusion

The study highlights a positive trend in the adoption of evidence-based practices (EBP) within German football academies, as indicated by a satisfactory EBP index. The analysis reveals a significant association between practitioners engaged in biological maturation assessments and higher EBP index scores, emphasizing the potential impact of organizational culture and believes on incorporating biological maturation considerations in their player development program.

However, the study also identifies significant barriers, particularly structural ones, hindering the effective implementation of biological maturation assessments. Time constraints further influenced by staffing limitations emerge as a primary barrier, underscoring the need for targeted strategies to overcome these hurdles. Notably, staffing competence was not identified as an obstacle.

The findings emphasize the complexity of integrating EBP and biological maturation assessments into daily operational behavior. Recommendations include promoting a culture of innovation and shifting current work practices to more iterative methods that allow time and opportunity for reflection to enhance the overall effectiveness of youth developmental programs.

Despite the limitations inherent in the study's sample size and potential bias, the findings contribute valuable insights to the current state of biological maturation assessment in German football academies. The call for more comprehensive research that considers both structural and operational dimensions underscores the ongoing need for refining and optimizing youth development practices. Such research can also serve as a tool to further identify barriers and facilitators to behavior change, thereby, promoting broader implementation of these practices.

Corresponding address

Lukas Arenas
Institute of Sport and Preventive Medicine,
Saarland University
Saarbrücken, Germany
Arenas.lukas@gmx.de

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Declarations

Conflict of interest. L. Arenas, S. Skorski, T. Meyer and M. Frenger declare that they have no competing interests.

For this article no studies with human participants or animals were performed by any of the authors. All studies mentioned were in accordance with the ethical standards indicated in each case.

Appendix

Survey introduction

The development of home-grown players can be considered as a key strategic issue for youth football academies. Talented and maturing children are a unique population, which are exposed to high training loads with a necessity of a developmental training program including load monitoring, injury surveillance and -prevention. Research suggests that players going through their adolescent growth spurt are exposed to a period of increased injury risk and that training load should be more carefully adjusted. Therefore, it has become increasingly common to utilize noninvasive somatic equations to estimate maturity-status and -timing. The practices and perspectives of training load and biological maturity monitoring of German football academies represent a valued addition to the literature, as the current research towards German youth football is very sparse.

Therefore, the first aim of this study is to provide an overview of the current practices towards load and maturity monitoring by surveying practitioners of German football academies. The second aim is to examine how these practices are impacted by the club belief on the benefit of evidence-based practice and the personnel structure of the sports science and sports medicine department. This information may provide more insight into the existing differences in implementation between elite German clubs.

This questionnaire is conducted by Saarland University and has been approved by the Ethics Committee of the Faculty of Human Sciences. The information provided by you in this questionnaire will be used for research purposes. It will not be used in a manner which would allow identification of your individual responses. Please note, you are under no obligation to participate and that you are free to withdraw at any point without giving reason.

Yours sincerely,
Lukas Arenas
PhD Researcher
Institute of Sports and Preventive Medicine

Survey data privacy

1. I hereby consent to the anonymous collection and storage of data within the scope of this study on the servers of SoSci Survey GmbH in accordance with Art. 28 DSGVO on technical equipment of the hoster PartnerGate GmbH (Munich).
2. The consent to the collection and processing of the data is irrevocable, since due to the anonymous form of the survey no participant-related deletion can be carried out.
3. I agree that my data will be deleted after completion or discontinuation of the study, after they have been stored for at least ten years.

The questionnaire will start as soon as you click on 'Yes' and thus agree to the above procedure and consent to study participation.

By clicking Yes, I declare that I agree with the above procedure, and I consent to participate in this study.

a. Yes (to qualify)
b. No

To make sure that your answers can be used for our evaluation we would like to ask you to answer the following questions.

Eligibility question

1. Are you currently working with youth players of a German Bundesliga academy?
   a. Yes (to qualify)
   b. No
2. Have you already completed this survey?
   a. Yes
   b. No (to qualify)
3. Has an academy employee already answered the survey?
   a. Yes
   b. No (to qualify)

Gender reference

For reasons of better readability, the language forms male, female and diverse (m/f/d) are not used simultaneously. All references to persons apply equally to all genders.

Demographic data and club information

1. What is your primarily role within the club?
   a. Academy Manager
   b. Head of Sport Science and Medicine
   c. Head Coach
   d. Assistant Coach
   e. Strength and Conditioning Coach
   f. Rehabilitation Coach
   g. Sport Science support
   h. Physiotherapist/Sports Therapist
   i. Doctor
   j. Other: _____
2. How much professional experience do you have in elite youth development football?
3. Which age group are you primarily responsible for?
   a. Foundation (U8–U11)
   b. Youth Development Phase (U12–U15)
   c. Professional Development Phase (U16–U19)
   d. Senior (U23)
4. Which professional league is your employer's first squad competing in?
   a. Bundesliga
   b. Second Bundesliga
   c. Third League
   d. Fourth League

e. Fifth League

5. Specify the total amount of Full-Trained, Diploma, BSc., MSc. or PhD employees of Physiotherapist/Sports Therapist, Sports Scientist/Strength and Conditioning Coach/Rehabilitation Coach working at least part-time (20 h) up to full time at the youth academy
   a. ≤ 6
   b. 7–12
   c. ≥ 13
6. Was there a COVID-19-related reduction in staff of Physiotherapist/Sports Therapist and/or Sports Scientist/Strength and Conditioning Coach/Rehabilitation Coach?
   a. Yes (if Yes continue with Question 4.)
   b. No
7. Has there already been a return to the pre-COVID 19 staffing situation of Physiotherapist/Sports Therapist and Sports Scientist/Strength and Conditioning Coach/Rehabilitation Coach?
   a. Yes
   b. No

Definitions of concepts

In the following sections we will talk about different concepts. In order to establish a general understanding of these concepts, they will be defined beforehand.

Club belief on the benefit of evidence-based practice

Evidence-Based Practice definition: "The integration of staff members' expertise, athlete values and research evidence in decision-making" (Fullagar et al., 2019b).

1. Please indicate your level of agreement on the following statements: (1 = Strongly disagree; 2 = Disagree; 3 = Neither agree or disagree; 4 = Agree; 5 = Strongly agree)
   a. The academy management assigns importance towards evidence-based practice
   b. The club's vision assigns importance towards scientific approaches
   c. The club assigns importance to the fact that staff members stay well informed about the latest scientific knowledge
   d. Among staff members, there is communication about the scientific background of the current practices
   e. The club is committed to cooperation with scientific institutions such as universities and/or technical colleges for joint research projects (not meant is a cooperation with scientific institutions as a service provider for diagnostics or similar from)

Maturation: assessment and monitoring practices

Maturation definition: "Process that characterizes human growth and development, including individual variations in time and rate at which this process occurs" (Cumming et al., 2017).

1. Does your club regularly estimate player maturation status?
   a. Yes
   b. No (If no, continue at Section 5. Maturity: use of data-report and feedback with Question 8.)
2. How often does your club estimate the maturity status of players at the Youth Development Phase (U12–U15)
   a. Monthly
   b. Quarterly
   c. Half-yearly
   d. Yearly
3. Does a more frequent estimate of biological maturity occur when assuming a player is in an accelerated growth phase?
   a. Yes
   b. No
4. What approach do you use to estimate timing and tempo of maturation status? Tick all that apply
   a. Prediction of Adult Height:
      1. Khamis-Roche
      2. Beunen-Malina
      3. Cumulative Height Velocity Curves
   b. Maturation Offset:
      1. Mirwald et al. Maturity Offset
      2. Moore et al. Redeveloped Maturity Offset
      3. Other
   c. Skeletal Maturity:
      1. Fels
      2. Tanner-Whitehouse
      3. Greulich-Pyle
      4. Other: _____
5. Who is primarily responsible for estimating timing and tempo of maturation status?
   a. Academy Manager
   b. Lead Coach
   c. Age group coaches
   d. Medical staff/Doctor/Physiotherapist/Sports Therapist
   e. Sport Science staff—Sport Scientist/Strength and Conditioning Coach
   f. Intern/Student
   g. Other: _____

Maturation: use of data report and feedback

1. If using maturation status to group players for training and/or matches, how frequently are training session/matches adjusted due to maturation status (1 = Never; 2 = Rarely; 3 = Occasionally; 4 = Moderate amount; 5 = A great deal).
   a. Pitch-based sessions
   b. Gym based sessions
   c. Recovery sessions
   d. Competitive fixtures (Formal games program)
   e. Specifically arranged tournaments (e.g. Bio-Banded tournaments)
2. What elements of the pitch-based session are adjusted based on the estimate of biological maturity? (Check all that apply; multiple answers possible) (1 = Never; 2 = Rarely; 3 = Occasionally; 4 = Moderate amount; 5 = A great deal).
   a. Participants
   b. Session
   c. Session intensity
   d. Intensity of individual parts of the session
3. What elements of the gym-based session are adjusted based on the estimate of biological maturity? (Check all that apply; multiple answers possible) (1 = Never; 2 = Rarely; 3 = Occasionally; 4 = Moderate amount; 5 = A great deal).
   a. Participants
   b. Session duration
   c. Session intensity

   d. Intensity of individual parts of the session
   Definitions of coaching staff: Includes medical, therapeutic, psychological, technical, analytical, physiological, and nutritional personnel.
4. Who is the information from estimations of maturity status reported to? (Check all that apply; multiple answers possible).
   a. Senior Management
   b. Academy Manager
   c. Head Coach
   d. Age group coaches
   e. Medical staff—Doctor/Physiotherapist/Sports Therapist
   f. Sport Science staff—Sport Scientist/Strength and Conditioning Coach/Rehabilitation Coach
   g. Player
   h. Parent/Guardian
   i. Other: _____
5. What is the format of these maturity estimation reports? (Check all that apply; multiple answers possible).
   a. Verbal communication via meeting
   b. Written report
   c. Infographic
   d. Visual representation—Chart/Graph/Excel/Power BI
   e. Other: _____
6. What information is shared with the functional team in the biological maturity estimation report?
7. Please indicate your level of agreement on the following statements (1 = Strongly disagree; 2 = Disagree; 3 = Neither agree or disagree; 4 = Agree; 5 = Strongly agree).
   a. The maturity estimation reports are communicated in a comprehensive manner
   b. The maturity estimation reports are understood from the coaching staff
   c. The maturity estimation reports are communicated with practical advice for training planning
8. Please indicate your perceived level of importance of the estimation of maturation status of players at the Youth Development Phase (U12–U15) (1 = Not important; 2 = Slightly important; 3 = Neutral; 4 = Moderately important; 5 = Very important).
   a. For the overall player development
   b. Load management
   c. Injury prevention
   d. Bio-banding training sessions
   e. Bio-banding matches/competitions
   f. Player recruitment
   g. Player retention
   h. Forecasting
   i. Player feedback
   j. Coach feedback
   k. Reports to parents
9. Please indicate your perceived level of the following barriers you faced when looking to implement the estimation of maturation status at the Youth Developmental Phase (U12–U15) (1 = Strongly agree; 2 = Agree; 3 = Neither agree or disagree; 4 = Disagree; 5 = Strongly disagree).
   a. Financial budget
   b. Staffing numbers
   c. Staffing competency
   d. Resources/Infrastructure
   e. Management support
   f. Coach support
   g. Time constraints

References

Akenhead, R., & Nassis, G. P. (2016). Training load and player monitoring in high-level football: current practice and perceptions. *International Journal of Sports Physiology and Performance*, *11*(5), 587–593. https://doi.org/10.1123/ijspp.2015-0331.

Arenas, L., Frenger, M., Skorski, S., & Meyer, T. (2023). Survey of the current practices of German football academies towards biological maturation assessment. *Science and Medicine in Football*. https://doi.org/10.1080/24733938.2023.2270563.

Ballіauw, M., Bosmans, J., & Pauwels, D. (2022). Does the quality of a youth academy impact a football player's market value? *Sport, Business and Management: An International Journal*, *12*(3), 269–283. https://doi.org/10.1108/SBM-02-2021-0011.

Bartlett, J. D., & Drust, B. (2021). A framework for effective knowledge translation and performance delivery of Sport Scientists in professional sport. *European Journal of Sport Science*, *21*(11), 1579–1587. https://doi.org/10.1080/17461391.2020.1842511.

Bradley, B., Johnson, D., Hill, M., McGee, D., Kana-ah, A., Sharpin, C., Sharp, P., Kelly, A., Cumming, S. P., & Malina, R. M. (2019). Bio-banding in academy football: player's perceptions of a maturity matched tournament. *Annals of Human Biology*, *46*(5), 400–408. https://doi.org/10.1080/03014460.2019.1640284.

Cumming, S. P. (2018). A game plan for growth: how football is leading the way in the consideration of biological maturation in young male athletes. *Annals of Human Biology*, *45*(5), 373–375. https://doi.org/10.1080/03014460.2018.1513560.

Cumming, S. P., Lloyd, R. S., Oliver, J. L., Eisenmann, J. C., & Malina, R. M. (2017). Bio-banding in sport: applications to competition, talent identification, and strength and conditioning of youth athletes. *Strength & Conditioning Journal*, *39*(2), 34–47. https://doi.org/10.1519/SSC.0000000000000281.

Cumming, S. P., Brown, D. J., Mitchell, S., Bunce, J., Hunt, D., Hedges, C., Crane, G., Gross, A., Scott, S., Franklin, E., Breakspear, D., Dennison, L., White, P., Cain, A., Eisenmann, J. C., & Malina, R. M. (2018). Premier League academy soccer players' experiences of competing in a tournament bio-banded for biological maturation. *Journal of Sports Sciences*, *36*(7), 757–765. https://doi.org/10.1080/02640414.2017.1340656.

Droste, J.-N., Fisser, S., Gebhardt, M., Edler, C., Lippie, E., McAleer, S., Del Vescovo, R., Bloch, H., & Riepenhof, H. (2021). Employees in professional European football: comparison of the personnel structure in sports medicine, sports sciences and physiotherapy between Bundesliga, La Liga, Serie A and Premier League. *Sportverletzung Sportschaden : Organ Der Gesellschaft Fur Orthopadisch-Traumatologische Sportmedizin*, *35*(3), 147–153. https://doi.org/10.1055/a-1386-6932.

Fullagar, H. H. K., Harper, L. D., Govus, A., McCunn, R., Eisenmann, J., & McCall, A. (2019a). Practitioner perceptions of evidence-based practice in elite sport in the United States of America. *Journal of Strength and Conditioning Research*, *33*(11), 2897–2904. https://doi.org/10.1519/JSC.0000000000003348.

Fullagar, H. H. K., McCall, A., Impellizzeri, F. M., Favero, T., & Coutts, A. J. (2019b). The translation of sport science research to the field: a current opinion and overview on the perceptions of practitioners, researchers and coaches. *Sports Medicine*, *49*(12), 1817–1824. https://doi.org/10.1007/s40279-019-01139-0.

Giudicelli, B. B., Luz, L. G. O., Sogut, M., & Massart, A. G. (2020). Bio-banding in judo: the mediation role of anthropometric variables on the maturation effect. *International journal of environmental research and public health*. https://doi.org/10.3390/ijerph17010361.

Gonzalez-Balzar, P. (2007). *Konditionstraining und sportmedizinische Betreuung in der 1. Fußballbundesliga*. Universität Hamburg.

Hall, E. C. R., Larruskain, J., Gil, S. M., Lekue, J. A., Baumert, P., Rienzi, E., Moreno, S., Tannure, M., Murtagh, C. F., Ade, J. D., Squires, P., Orme, P., Anderson, L., Whitworth-Turner, C. M., Morton, J. P., Drust, B., Williams, A. G., & Erskine, R. M. (2022). Injury risk is greater in physically mature versus biologically younger male soccer players from academies in different countries. *Physical Therapy in Sport*, *55*, 111–118. https://doi.org/10.1016/j.ptsp.2022.03.006.

Hill, M., John, T., McGee, D., & Cumming, S. P. (2023). Beyond the coaches eye: understanding the 'how' and 'why' of maturity selection biases in male academy soccer. *International Journal of Sports Science & Coaching*. https://doi.org/10.1177/17479541231186673.

Houtmeyers, K. C., Vanrenterghem, J., Jaspers, A., Ruf, L., Brink, M. S., & Helsen, W. F. (2021). Load monitoring practice in European elite football and the impact of club culture and financial resources. *Frontiers in Sports and Active Living*,

3, 1–10. https://doi.org/10.3389/fspor.2021.679824.

Joachim, G., Schulenkorf, N., Schlenker, K., & Frawley, S. (2020). Design thinking and sport for development: enhancing organizational innovation. *Managing Sport and Leisure*, *25*(3), 175–202. https://doi.org/10.1080/23750472.2019.1611471.

Johnson, D., Williams, S., Bekker, S., Bradley, B., & Cumming, S. (2023a). English academy football practitioners' perceptions of training load, maturation and injury risk: a club case study. *International Journal of Sports Science & Coaching*. https://doi.org/10.1177/17479541231188071.

Johnson, D., Williams, S., Bradley, B., & Cumming, S. P. (2023b). Can we reduce injury risk during the adolescent growth spurt? An iterative sequence of prevention in male academy footballers. *Annals of Human Biology*, *50*(1), 452–460. https://doi.org/10.1080/03014460.2023.2261854.

Konarski, J., Krzykała, M., Skrzypczak, M., Nowakowska, M., Coelho-e-Silva, M., Cumming, S., & Malina, R. (2021). Characteristics of select and non-select U15 male soccer players. *Biology of Sport*, *38*(4), 535–544. https://doi.org/10.5114/biolsport.2021.101126.

Krosnick, J., & Presser, S. (2009). Question and questionnaire design. In *Handbook of survey research* 2nd edn. Elsevier.

Lacome, M., Simpson, B. M., Cholley, Y., Lambert, P., & Buchheit, M. (2018). Small-sided games in elite soccer: does one size fit all? *International Journal of Sports Physiology and Performance*, *13*(5), 568–576. https://doi.org/10.1123/ijspp.2017-0214.

Leyhr, D., Murr, D., Basten, L., Eichler, K., Hauser, T., Lüdin, D., Romann, M., Sardo, G., & Höner, O. (2020). Biological maturity status in elite youth soccer players: a comparison of pragmatic diagnostics with magnetic resonance imaging. *Frontiers in Sports and Active Living*, *2*, 1–12. https://doi.org/10.3389/fspor.2020.587861.

Lüdin, D., Donath, L., Cobley, S., & Romann, M. (2021). Effect of bio-banding on physiological and technical-tactical key performance indicators in youth elite soccer. *European Journal of Sport Science*, *0*(0), 1–9. https://doi.org/10.1080/17461391.2021.1974100.

Lüdin, D., Donath, L., Cobley, S., Mann, D., & Romann, M. (2022). Player-labelling as a solution to overcome maturation selection biases in youth football. *Journal of Sports Sciences*, *40*(14), 1641–1647. https://doi.org/10.1080/02640414.2022.2099077.

MacMaster, C., Portas, M., Parkin, G., Cumming, S., Wilcox, C., & Towlson, C. (2021). The effect of bio-banding on the anthropometric, physical fitness and functional movement characteristics of academy soccer players. *PLOS ONE*, *16*(11), e260136. https://doi.org/10.1371/journal.pone.0260136.

Mitchell, S. B., Haase, A. M., & Cumming, S. P. (2021). On-time maturation in female adolescent ballet dancers: learning from lived experiences. *Journal of Early Adolescence*, *0*(0), 1–29. https://doi.org/10.1177/02724316211036752.

Monasterio, X., Gil, S. M., Bidaurrazaga-Letona, I., Lekue, J. A., Santisteban, J., Diaz-Beitia, G., Martin-Garetxana, I., Bikandi, E., & Larruskain, J. (2021a). Injuries according to the percentage of adult height in an elite soccer academy. *Journal of Science and Medicine in Sport*, *24*(3), 218–223. https://doi.org/10.1016/j.jsams.2020.08.004.

Monasterio, X., Gil, S. M., Bidaurrazaga-Letona, I., Lekue, J. A., Santisteban, J. M., Diaz-Beitia, G., Lee, D.-J., Zumeta-Olaskoaga, L., Martin-Garetxana, I., Bikandi, E., & Larruskain, J. (2021b). The burden of injuries according to maturity status and timing: A two-decade study with 110 growth curves in an elite football academy. *European Journal of Sport Science*. https://doi.org/10.1080/17461391.2021.2006316.

Monasterio, X., Cumming, S., Larruskain, J., Johnson, D. M., Gil, S. M., Bidaurrazaga-Letona, I., Lekue, J. A., Diaz-Beitia, G., Santisteban, J. M., & Williams, S. (2024). The combined effects of growth and maturity status on injury risk in an elite football academy. *Biology of Sport*. https://doi.org/10.5114/biolsport.2024.129472.

Morris, R., Tod, D., & Oliver, E. (2015). An analysis of organizational structure and transition outcomes in the youth-to-senior professional soccer transition. *Journal of Applied Sport Psychology*, *27*(2), 216–234. https://doi.org/10.1080/10413200.2014.980015.

Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in Health Sciences Education*, *15*(5), 625–632. https://doi.org/10.1007/s10459-010-9222-y.

Patel, T. S., McGregor, A., Williams, K., Cumming, S. P., & Williams, S. (2021). The influence of growth and training loads on injury risk in competitive trampoline gymnasts. *Journal of Sports Sciences*, *00*(00), 1–10. https://doi.org/10.1080/02640414.2021.1948259.

Pimental, J. (2010). A note on the usage of Likert scaling for research data analysis. *USM R&D Journal*, *18*, 109–112.

Premier Leauge (2011). *Elite player performance plan*

Ramalho, A., & Petrica, J. (2023). Knowledge in motion: a comprehensive review of evidence-based human kinetics. *International Journal of Environmental Research and Public Health*, *20*(11), 6020. https://doi.org/10.3390/ijerph20116020.

Ratten, V. (2016). Sport innovation management: towards a research agenda. *Innovation*, *18*(3), 238–250. https://doi.org/10.1080/14479338.2016.1244471.

Reeves, M. J., Enright, K. J., Dowling, J., & Roberts, S. J. (2018). Stakeholders' understanding and perceptions of bio-banding in junior-elite football training. *Soccer & Society*, *19*(8), 1–17. https://doi.org/10.1080/14660970.2018.1432384.

Relvas, H., Littlewood, M., Nesti, M., Gilbourne, D., & Richardson, D. (2010). Organizational structures and working practices in elite European professional football clubs: Understanding the relationship between youth and professional domains. *European Sport Management Quarterly*, *10*(2), 165–187. https://doi.org/10.1080/16184740903559891.

Rommers, N., Rössler, R., Goossens, L., Vaeyens, R., Lenoir, M., Witvrouw, E., & D'Hondt, E. (2020). Risk of acute and overuse injuries in youth elite soccer players: body size and growth matter. *Journal of Science and Medicine in Sport*, *23*(3), 246–251. https://doi.org/10.1016/j.jsams.2019.10.001.

Salter, J., De Ste Croix, M. B. A., Hughes, J. D., Weston, M., & Towlson, C. (2021). Monitoring practices of training load and biological maturity in UK soccer academies. *International Journal of Sports Physiology and Performance*, *16*(3), 395–406. https://doi.org/10.1123/ijspp.2019-0624.

Stratton, G., Reilly, T., Williams, A. M., & Richardson, D. (2004). Youth soccer: from science to performance. In *Youth Sports: growth, maturation and talent*. Routledge. https://doi.org/10.4324/9780203644133.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd.

Tee, J. C., Bekker, S., Collins, R., Klingbiel, J., van Rooyen, I., van Wyk, D., Till, K., & Jones, B. (2018). The efficacy of an iterative "sequence of prevention" approach to injury prevention by a multidisciplinary team in professional rugby union. *Journal of Science and Medicine in Sport*, *21*(9), 899–904. https://doi.org/10.1016/j.jsams.2018.02.003.

Teunissen, J. W., Rommers, N., Pion, J., Cumming, S. P., Rössler, R., D'Hondt, E., Lenoir, M., Savelsbergh, G. J. P., & Malina, R. M. (2020). Accuracy of maturity prediction equations in individual elite male football players. *Annals of Human Biology*, *47*(4), 409–416. https://doi.org/10.1080/03014460.2020.1783360.

Towlson, C., Cobley, S., Parkin, G., & Lovell, R. (2018). When does the influence of maturation on anthropometric and physical fitness characteristics increase and subside? *Scandinavian Journal of Medicine & Science in Sports*, *28*(8), 1946–1955. https://doi.org/10.1111/sms.13198.

Towlson, C., Abt, G., Toner, J., Sampaio, J., MacFarlane, N., & Barrett, S. (2019). *Maturity-status' bio-banding' as a tool for ongoing talent (de) selection of academy soccer players using a multi-disciplinary approach*

Towlson, C., Salter, J., Ade, J. D., Enright, K., Harper, L. D., Page, R. M., & Malone, J. J. (2021). Maturity-associated considerations for training load, injury risk, and physical performance in youth soccer: One size does not fit all. *Journal of Sport and Health Science*, *10*(4), 403–412. https://doi.org/10.1016/j.jshs.2020.09.003.

Towlson, C., Watson, D. J., Cumming, S., Salter, J., & Toner, J. (2023). Soccer academy practitioners' perceptions and application of bio-banding. *PLOS ONE*, *18*(1), e274079. https://doi.org/10.1371/journal.pone.0274079.

Verhagen, E., Voogt, N., Bruinsma, A., & Finch, C. F. (2014). A knowledge transfer scheme to bridge the gap between science and practice: An integration of existing research frameworks into a tool for practice. *British Journal of Sports Medicine*, *48*(8), 698–701. https://doi.org/10.1136/bjsports-2013-092241.

Weston, M. (2018). Training load monitoring in elite English soccer: a comparison of practices and perceptions between coaches and practitioners. *Science and Medicine in Football*, *2*(3), 216–224. https://doi.org/10.1080/24733938.2018.1427883.

Willis, G. B., & Lessler, J. T. (1999). *Questionnaire Appraisal System QAS-99*. Research Triangle Institute.