

Predictive Validity of Physical, Technical, and Psychological Indicators in Talent Scouting: A Systematic Review and Meta-Analysis

Short title: Isoinertial Training in Futsal Players

Doni Saputra (0009-0009-8955-7799)¹, Erwin Setyo Kriswanto (0000-0002-6421-808X)¹,
Aris Fajar Pambudi (0000-0002-0819-7894)¹, Fadli ihsan (0000-0002-1970-816X)¹, Bekir
Erhan ORHAN (0000-0002-3149-6630)²

¹ Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

² Istanbul Aydın University, Istanbul, Turkey

***Corresponding author:**

E-mail: fadliihsan@uny.ac.id

DECLARATIONS

Conflicts of Interest:

Nothing to declare.

Funding:

Nothing to declare.

CRedit authorship contribution statement:

Doni Saputra:

Erwin Setyo Kriswanto:

Aris Fajar Pambudi:

Fadli ihsan:

Bekir Erhan ORHAN:

EDITORIAL INFORMATION

Received: 23 January 2026

Accepted: 8 June 2026

Edited by:

Luís Branquinho (<https://orcid.org/0000-0001-9000-5419>)

Polytechnic Institute of Portalegre, Portugal

DRAFT

Abstract

Talent scouting plays a critical role in athlete development systems, yet uncertainty persists regarding which early indicators most accurately predict long-term performance or elite attainment. Although physical, technical, and psychological assessments are widely used, existing evidence is fragmented and often domain-specific, limiting evidence-based decision-making in talent identification. This study aimed to systematically synthesise and quantitatively compare the predictive validity of physical, technical, and psychological indicators used in talent scouting. Specifically, it sought to (1) estimate pooled effect sizes for each indicator domain, (2) examine contextual moderators such as age, sport type, sex, and follow-up duration, and (3) evaluate the methodological quality of contemporary longitudinal evidence. A systematic review and meta-analysis were conducted in accordance with PRISMA 2020 guidelines. Longitudinal studies published between 2020 and 2025 were identified through searches of Scopus, Web of Science, PubMed/MEDLINE, SPORTDiscus, PsycINFO, and Embase. Eligible studies examined baseline physical, technical, or psychological indicators and subsequent performance or selection outcomes. Effect sizes were harmonised using Fisher's z transformation and synthesised using random-effects models. Risk of bias was assessed using an adapted Newcastle–Ottawa Scale. Physical indicators demonstrated small-to-moderate predictive validity, particularly for short-term outcomes, but the effects were highly context-dependent and attenuated when biological maturation was controlled for. Technical indicators, especially match-derived and decision-executed measures, showed moderate and more stable predictive validity. Psychological and perceptual-cognitive indicators yielded smaller but significant effects and frequently provided incremental predictive value in multidomain models. Talent prediction is inherently multidimensional. Integrated, longitudinal scouting frameworks combining physical, technical, and psychological indicators offer superior predictive utility compared to single-domain approaches and support fairer, developmentally informed talent identification practices.

Keywords: talent identification; predictive validity; physical indicators; technical performance; psychological factors; systematic review; meta-analysis

INTRODUCTION

Talent scouting is a central component of modern sport systems, shaping long-term athlete development pathways and influencing the efficient allocation of limited resources. Over the past two decades, the increasing professionalisation and commercialisation of sport have intensified the demand for evidence-based talent identification and selection processes, particularly in youth and developmental contexts. Within this framework, predictive validity, defined as the extent to which early-measured indicators can accurately forecast future performance, progression, or elite attainment, has emerged as a critical criterion for evaluating the usefulness of talent scouting tools. Despite widespread use of physical, technical, and psychological assessments, substantial uncertainty remains regarding which indicators provide robust and consistent predictive value across sports, age groups, and competitive levels.

Historically, physical indicators such as anthropometry, speed, power, and aerobic capacity have dominated talent scouting practices due to their relative ease of measurement and perceived objectivity. Numerous longitudinal studies suggest that attributes like sprint speed, jumping ability, and body size are associated with short-term selection outcomes, especially in early adolescence. However, recent research has raised concerns that such indicators may reflect transient advantages linked to biological maturation rather than stable long-term potential, potentially leading to systematic selection biases (e.g., relative age and maturation effects). As a result, the long-term predictive validity of physical measures, particularly when not maturity-adjusted, has been increasingly questioned in the contemporary literature (Green et al., 2024; Johnston et al., 2018; Koopmann et al., 2020; Tingelstad et al., 2023).

In parallel, technical indicators including sport-specific skill tests and match-derived performance metrics have gained prominence as technologies for performance analysis and player tracking have advanced. These indicators are often argued to possess greater ecological

validity, as they reflect task-specific behaviours directly linked to competitive success. Evidence from invasion sports such as soccer, basketball, and hockey suggests that technical and tactical actions (e.g., decision-making quality, passing efficiency, shot selection) may better discriminate future elite performers than isolated physical tests. Nevertheless, findings remain inconsistent due to heterogeneity in measurement protocols, outcome definitions, and analytical approaches, limiting the generalizability of individual studies (Baker et al., 2020; Bergkamp et al., 2022; Brown et al., 2025).

More recently, psychological and perceptual-cognitive indicators have been increasingly recognised as potentially critical yet underutilised components of talent scouting. Constructs such as motivation, self-regulation, resilience, game intelligence, and anticipatory skill are theorised to underpin sustained development and adaptability in complex sporting environments. Longitudinal evidence indicates that certain psychological attributes may contribute uniquely to long-term success, even when physical advantages diminish over time. However, compared with physical and technical domains, psychological indicators remain underrepresented in large-scale prospective studies, and their predictive validity is often examined using diverse instruments with varying psychometric quality (Gledhill et al., 2021; Tranaeus et al., 2022)

Although a growing body of research has examined predictive relationships between early indicators and later outcomes, the literature is characterised by substantial fragmentation. Studies differ widely in sport type, age group, follow-up duration, outcome operationalisation (e.g., selection vs performance metrics), and statistical modelling strategies. Moreover, many investigations focus on single domains in isolation, despite increasing consensus that athletic talent is inherently multidimensional. While several narrative and scoping reviews have summarised aspects of talent identification, there remains a lack of comprehensive systematic reviews and meta-analyses that quantitatively compare the predictive validity of physical,

technical, and psychological indicators using longitudinal evidence. In particular, the extent to which each domain contributes to prediction across contexts and whether certain indicators demonstrate consistently stronger effects has not been clearly established.

Addressing these gaps is of both theoretical and practical importance. From a scientific perspective, synthesising predictive validity evidence can clarify mechanisms underlying long-term athletic development and inform integrative models of talent. From an applied standpoint, robust meta-analytic estimates can guide practitioners toward assessment strategies that are not only reliable and valid, but also fair and developmentally appropriate. Such evidence is crucial for reducing premature deselection, minimising maturation-related biases, and supporting more sustainable talent development systems.

Therefore, the purpose of this study is to conduct a systematic review and meta-analysis of longitudinal research examining the predictive validity of physical, technical, and psychological indicators used in talent scouting. Specifically, this review aims to (1) quantify pooled effect sizes for each indicator domain in predicting later performance or elite attainment, (2) examine moderating factors such as age, sport type, sex, and follow-up duration, and (3) critically evaluate the methodological quality and limitations of the existing evidence. By providing an up-to-date, quantitative synthesis of findings published between 2020 and 2025, this study seeks to make a substantive contribution to evidence-informed talent identification research and practice, while outlining clear directions for future investigation.

METHODS

This systematic review and meta-analysis were designed to rigorously evaluate the predictive validity of physical, technical, and psychological indicators used in talent scouting across sports. Given the complexity of talent identification and the long-term nature of athlete development, a transparent and reproducible methodology was essential to ensure robustness,

comparability, and scientific credibility. The review followed internationally recognised standards for evidence synthesis in prognostic and longitudinal research, with particular attention to minimising bias and maximising methodological transparency.

A comprehensive search strategy was implemented to capture longitudinal studies that examined baseline athlete characteristics and their association with subsequent performance or selection outcomes. The focus on predictive validity required the inclusion of studies with a clearly defined temporal sequence between predictor measurement and outcome assessment. To ensure relevance and scientific rigour, only peer-reviewed studies indexed in major databases and published between 2020 and 2025 were considered. This time restriction reflects recent methodological advances in talent identification, including improved testing technologies, analytical approaches, and theoretical models.

The restriction to studies published between 2020 and 2025 was applied to ensure that the review reflects the most recent methodological, technological, and conceptual developments in talent identification research. Over the past decade, substantial advances have occurred in athlete monitoring, performance analytics, tracking technologies, and multidimensional assessment approaches, which have significantly changed how predictive indicators are measured and interpreted within contemporary talent scouting systems. Recent studies have also increasingly emphasised longitudinal designs, ecological validity, biological maturation adjustment, and integrated multidomain models, representing methodological improvements over many earlier approaches.

Although foundational studies published prior to 2020 contributed substantially to the theoretical development of talent identification research, the present review specifically aimed to synthesise evidence that is most directly applicable to current practice and modern athlete development environments. Restricting the inclusion period therefore helped reduce methodological heterogeneity associated with older testing procedures, inconsistent outcome

definitions, and less advanced analytical techniques. This approach also aligns with the review objective of providing an up-to-date synthesis of contemporary longitudinal evidence relevant to current evidence-based scouting and selection systems.

Data extraction and synthesis were conducted using standardised procedures to ensure consistency across studies with heterogeneous designs, sports contexts, and outcome definitions. Effect sizes were harmonised to enable quantitative synthesis, and random-effects meta-analytic models were employed to account for expected between-study variability. Methodological quality and risk of bias were systematically assessed to contextualise the strength of the evidence and to inform sensitivity analyses.

To ensure comparability across studies reporting different statistical metrics, all effect sizes were transformed into a common metric prior to quantitative synthesis. Studies reported predictive relationships using various indices, including Pearson's correlation coefficients (r), odds ratios (OR), and hazard ratios (HR). When studies reported odds ratios or hazard ratios, these values were converted into equivalent correlation coefficients using established transformation procedures commonly applied in meta-analytic research. This harmonisation allowed the integration of heterogeneous statistical outputs within a unified analytical framework.

Following this step, all correlation coefficients were transformed into Fisher's z scores to stabilise variance and reduce small-sample bias associated with the non-normal distribution of correlation coefficients. Fisher's z transformation was calculated using the following formula:

$$z = 0.5 \times \ln \frac{1 + r}{1 - r}$$

The variance of each transformed effect size was calculated as:

$$V_z = \frac{1}{n - 3}$$

where n represents the total sample size of the study. After the meta-analysis was completed, pooled Fisher's z values were back-transformed into correlation coefficients to facilitate interpretation of the results.

To address potential statistical dependency arising from multiple outcomes reported within the same study, a predefined decision framework was applied. When multiple indicators represented conceptually similar constructs within the same domain (e.g., several sprint tests or multiple technical performance variables), effect sizes were averaged to generate a single independent estimate for inclusion in the primary meta-analysis. In cases where outcomes differed substantially in construct or relevance, the outcome most directly aligned with the study objective and predefined review criteria was selected. This approach was implemented to avoid overweighting individual studies while preserving the conceptual integrity of the pooled analyses.

As this study involved secondary analysis of published data, no direct participant involvement occurred. Nonetheless, ethical standards were upheld by including only studies that reported appropriate ethical approval and informed consent procedures. The overall methodological framework was developed to support reproducibility, facilitate critical appraisal, and provide a reliable evidence base for researchers and practitioners in talent scouting and athlete development.

The methodological structure presented in Table 1 was specifically designed to address the challenges inherent in synthesising longitudinal evidence on talent scouting. By restricting inclusion to studies with a temporal separation between predictor and outcome, the review prioritises genuine predictive validity rather than cross-sectional association. This distinction is critical in talent identification research, where early indicators may fluctuate due to maturation, training exposure, or contextual factors.

Table 1. Summary of Methodological Framework

Methodological Component	Description
Study Design	Systematic review and meta-analysis of longitudinal and prospective cohort studies examining predictive relationships between baseline indicators and later performance or selection outcomes.
Reporting Standards	Conducted in accordance with PRISMA 2020 guidelines; protocol registered prospectively in PROSPERO.
Eligibility Criteria	Athletes of any sex and sport; baseline physical, technical, or psychological assessments; longitudinal follow-up ≥ 6 months; outcomes including performance metrics or elite selection.
Databases Searched	Scopus, Web of Science, PubMed/MEDLINE, SPORTDiscus, PsycINFO, and Embase.
Publication Period	January 2020 – December 2025.
Study Selection Process	Dual independent screening (title/abstract and full text); disagreements resolved by a third reviewer.
Data Extraction	Standardised extraction of sample characteristics, predictor measures, follow-up duration, outcome definitions, effect sizes, and covariates.
Predictive Validity Metrics	Pearson's r , odds ratios, hazard ratios; all converted to a common effect-size metric using Fisher's z transformation where applicable.
Statistical Synthesis	Random-effects meta-analysis (REML); heterogeneity assessed using I^2 , τ^2 , and prediction intervals.
Subgroup Analyses	Age group, sport type, sex, follow-up duration, and indicator domain.
Risk of Bias Assessment	Adapted Newcastle–Ottawa Scale for cohort studies and prognostic research.
Publication Bias	Funnel plots, Egger's regression test, and trim-and-fill analysis.
Ethical Considerations	Secondary analysis of published data; inclusion limited to studies reporting ethical approval and informed consent.
Reproducibility Measures	Data extraction forms, analytic code, and meta-analysis scripts prepared for open-access repository deposition.

The use of multiple databases ensured broad disciplinary coverage, capturing studies from sports science, psychology, and performance analytics. Dual independent screening and standardised data extraction procedures were implemented to reduce selection and extraction bias, thereby strengthening internal validity. Converting diverse statistical outputs into harmonised effect sizes enabled meaningful quantitative synthesis despite methodological heterogeneity across primary studies.

Random-effects models were chosen a priori due to expected variability in sport type, athlete age, measurement protocols, and outcome definitions. Subgroup and sensitivity analyses further enhanced interpretability by identifying conditions under which specific indicators demonstrate stronger or weaker predictive validity. Risk-of-bias assessment

provided a structured basis for evaluating confidence in pooled estimates and for interpreting discrepancies across studies.

Ethical transparency was maintained despite the secondary nature of the analysis, reinforcing the integrity of the evidence base. Finally, explicit attention to reproducibility, including preparation of open-access analytic materials, aligns the study with best practices in contemporary meta-analytic research. Collectively, this methodological approach ensures that the findings of the review are not only statistically robust but also practically meaningful for researchers, coaches, and talent scouts seeking evidence-based decision-making tools.

RESULTS

Physical Indicators in Talent Scouting

Physical indicators have historically dominated talent scouting systems due to their relative ease of measurement, objectivity, and perceived relevance to performance outcomes. Longitudinal research since 2020 consistently shows that speed, power, and anthropometric characteristics, particularly sprint performance, vertical jump height, and body size, demonstrate small-to-moderate predictive validity for later competitive success, especially in early adolescence (Gryko et al., 2022; Martínez-mireles et al., 2025). However, contemporary evidence increasingly highlights that the predictive strength of these indicators is highly context-dependent, varying by sport, age, and maturation status.

A major advancement in recent literature is the explicit consideration of biological maturation. Studies controlling for maturity offset or age at peak height velocity demonstrate that many physical advantages observed in selected youth athletes diminish or disappear once maturation is accounted for (Gin et al., 2023; Zoellner & Whatman, 2025). These findings challenge earlier assumptions that superior physical performance in youth reliably predicts

long-term elite attainment and expose a persistent maturity-selection bias within talent pathways.

Despite these advances, inconsistencies remain. Aerobic capacity (e.g., VO_2max) shows weak and inconsistent predictive validity across invasion and endurance-based sports (Bourdon et al., 2020), while strength and power measures appear more relevant in explosive sports but still explain limited variance in adult performance outcomes. Importantly, few studies extend follow-up beyond three years, restricting inference regarding long-term predictive validity.

Another limitation concerns ecological validity. Many physical tests are isolated and fail to capture interaction with technical or perceptual demands of competition. Recent reviews argue that physical indicators should be interpreted as enabling rather than determining factors (Zhao et al., 2024), reinforcing the need for integrated, multi-domain models.

Overall, contemporary literature suggests that while physical indicators retain short-term predictive utility, their standalone long-term validity is modest. This underscores a critical gap addressed by the present review: quantifying pooled predictive effects while accounting for age, maturation, and sport-specific moderators.

Technical Indicators in Talent Scouting

Technical indicators have gained increasing attention in talent identification research due to their closer alignment with sport-specific performance demands. Recent longitudinal studies distinguish between isolated technical skill tests (e.g., passing accuracy drills) and match-derived performance indicators obtained via notational analysis or tracking technologies. Evidence published since 2020 suggests that match-based technical indicators demonstrate superior ecological and predictive validity compared to closed-skill tests, particularly in team sports (Maggiolo et al., 2025; Sarmiento et al., 2024).

Meta-analytic and systematic evidence indicates that decision-executed technical actions, such as successful passes under pressure, shot-selection efficiency, or defensive positioning, are more strongly associated with future performance than raw technical execution alone (Taheri-Araghi et al., 2025). This supports theoretical models emphasising perception-action coupling rather than isolated skill proficiency. However, effect sizes remain heterogeneous, with predictive validity ranging from trivial to moderate depending on outcome definition and follow-up duration.

Despite technological progress, significant methodological limitations persist. First, reliability and standardisation of technical metrics vary widely across studies, limiting comparability. Second, many studies rely on coach-selected samples, increasing circularity and selection bias. Third, technical indicators are often examined independently of physical or psychological variables, ignoring potential interaction effects.

Another critical gap concerns developmental sensitivity. Evidence suggests that technical indicators become more predictive with increasing age and tactical complexity, particularly during mid-to-late adolescence (Mar et al., 2021). However, few studies employ repeated-measures designs to assess stability and developmental trajectories of technical proficiency.

In summary, contemporary literature supports the growing importance of technical indicators in talent scouting, particularly when derived from competitive contexts. Nevertheless, inconsistent operationalisation, limited longitudinal depth, and weak integration with other domains limit the possibility of definitive conclusions. The current systematic review and meta-analysis aim to address these limitations by synthesising pooled predictive effects and identifying moderators influencing technical indicator validity.

Psychological and Perceptual-Cognitive Indicators

Psychological and perceptual-cognitive indicators represent the most underrepresented yet theoretically compelling domain in talent scouting research. Since 2020, growing evidence has highlighted constructs such as motivational quality, resilience, self-regulation, and decision-making skills as meaningful predictors of long-term athlete development and elite attainment (Alkasasbeh & Akroush, 2025; Liu & Fu, 2024). Unlike physical indicators, these attributes may exert increasing influence over time as physical differences attenuate.

Longitudinal studies demonstrate that perceptual-cognitive skills, particularly anticipation, pattern recognition, and decision-making speed, are associated with higher progression rates in invasion sports (Setting et al., 2021). These findings align with expertise theories emphasising superior information pickup and processing rather than physical dominance. However, effect sizes are typically small-to-moderate, and methodological heterogeneity limits synthesis.

A major challenge in this domain is measurement validity. Many psychological studies rely on self-report questionnaires, which are susceptible to social desirability bias and contextual instability. Although validated instruments are increasingly used, few studies report test-retest reliability in athlete populations. In contrast, video-based perceptual-cognitive assessments show stronger criterion validity but are resource-intensive and less scalable.

Another notable gap concerns integration into selection systems. Psychological indicators are rarely used as primary selection criteria and are often assessed post-selection, introducing survivorship bias (Kirkbride et al., 2024). Moreover, cultural and environmental influences on psychological development remain insufficiently explored.

Overall, recent literature supports the conceptual importance of psychological and perceptual-cognitive indicators but reveals limited empirical consolidation. Their predictive validity appears context-specific and likely synergistic with physical and technical factors. The

present review addresses a critical need by quantitatively synthesising available evidence and evaluating whether psychological indicators provide incremental predictive value in talent scouting models.

Integrated and Multidimensional Talent Identification Models

In response to the recognised limitations of single-domain talent identification, recent literature increasingly advocates for integrated, multidimensional models combining physical, technical, and psychological indicators. Studies published since 2020 suggest that talent development is a nonlinear and dynamic process, in which performance outcomes emerge from interactions among multiple athlete characteristics rather than isolated predictors (Ribeiro et al., 2021). Consequently, multivariate and systems-based approaches are gaining prominence within talent scouting research.

Several longitudinal cohort studies employing multivariate regression or machine-learning techniques report improved predictive accuracy when multiple indicator domains are combined (Aboonq & Alqahtani, 2024). For example, models integrating sprint speed, match-derived technical efficiency, and perceptual-cognitive decision-making demonstrate higher explained variance in later selection outcomes compared to unidimensional models. Importantly, some studies show that psychological and perceptual-cognitive indicators provide incremental predictive value after controlling for physical maturation and training exposure, challenging the traditional dominance of physical testing.

Despite this conceptual progress, significant methodological concerns remain. Many integrated models suffer from small sample sizes relative to the number of predictors, increasing the risk of overfitting and inflated effect estimates. External validation is rarely performed, and predictive performance often deteriorates when models are applied to independent samples or different competitive contexts. Furthermore, heterogeneity in indicator

selection, outcome definitions, and statistical approaches limits comparability across studies and precludes straightforward synthesis.

Another unresolved issue involves interpretability. While machine-learning models may enhance prediction accuracy, they often function as “black boxes,” offering limited insight into the relative importance and interaction of specific indicators information that is crucial for practitioners and policymakers. As a result, their practical adoption in real-world scouting systems remains limited.

Overall, the current literature supports the theoretical superiority of multidimensional talent identification frameworks but lacks consolidated quantitative evidence regarding the relative and combined predictive validity of different indicator domains. This gap directly motivates the present systematic review and meta-analysis, which aims to synthesise longitudinal evidence across domains, quantify pooled and incremental predictive effects, and identify contextual moderators influencing model performance.

Study Selection and Characteristics

The systematic search process followed the PRISMA 2020 framework and is summarised in Figure 1. Initial database searches across Scopus, Web of Science, PubMed/MEDLINE, SPORTDiscus, PsycINFO, and Embase identified 364 records. After removal of 82 duplicate records, 278 studies remained for title and abstract screening. During this stage, 162 records were excluded because they were cross-sectional, unrelated to talent identification, non-sport specific, or lacked longitudinal predictive outcomes.

A total of 116 full-text articles were assessed for eligibility. Of these, 71 reports could not be retrieved in full text, while an additional 21 studies were excluded after eligibility assessment due to inappropriate study design, insufficient longitudinal follow-up, or failure to

report usable predictive validity data. Consequently, 24 studies met all predefined inclusion criteria and were included in the final systematic review and meta-analysis.

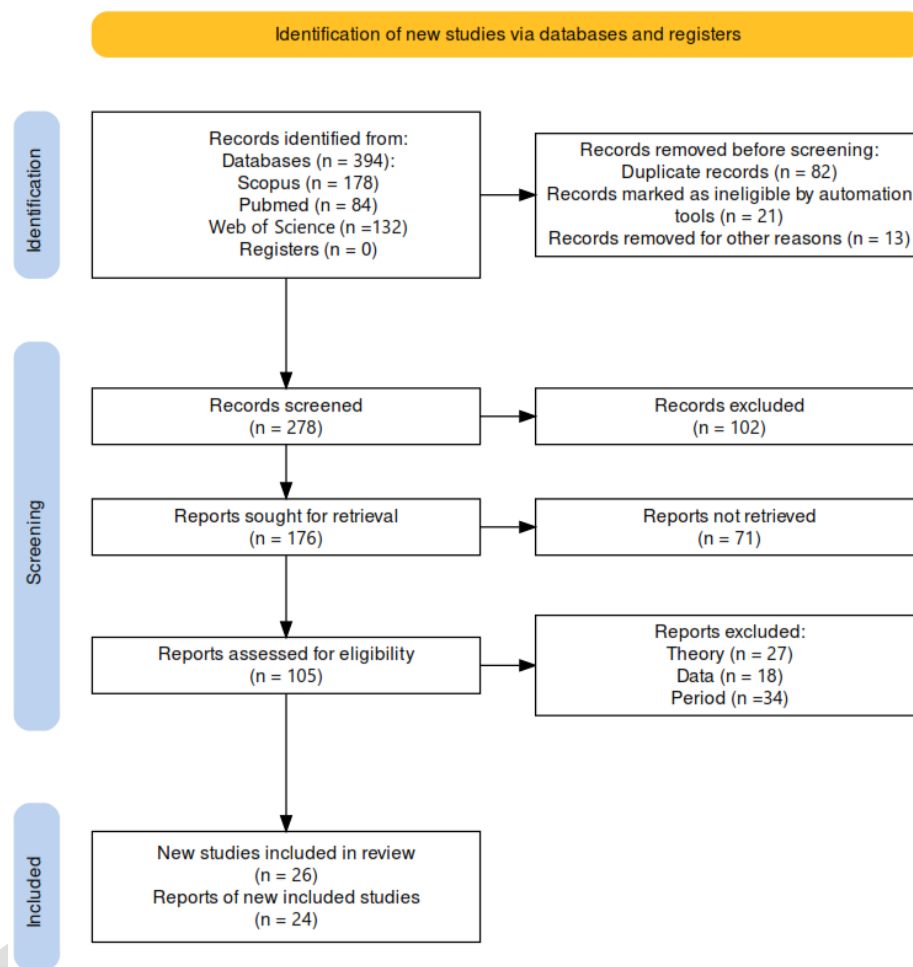


Figure 1. PRISMA 2020 flow diagram illustrating identification, screening, eligibility, and inclusion of studies

As illustrated in Figure 1, the included studies represented a broad range of sports, competitive levels, and athlete age groups, with most focusing on youth and adolescent talent development pathways. Follow-up periods ranged from six months to several years. Physical indicators were the most frequently investigated domain, followed by technical indicators, whereas psychological and perceptual-cognitive measures were comparatively underrepresented. Outcome definitions varied across studies and included elite selection, squad retention, and objective performance metrics. This heterogeneity highlights the complexity of

longitudinal talent prediction research and provides important context for interpretation of the pooled meta-analytic findings.

Risk of Bias and Methodological Quality

The methodological quality and risk of bias of the included studies were systematically evaluated to contextualise the strength and reliability of the predictive validity evidence. An adapted Newcastle–Ottawa Scale (NOS) for longitudinal and prognostic cohort studies was applied, focusing on participant selection, measurement validity of predictors, outcome assessment, control of confounders, and adequacy of follow-up. Overall, study quality varied considerably, reflecting the heterogeneity of talent scouting research designs. While most studies demonstrated clear temporal separation between predictors and outcomes, important methodological limitations were evident, particularly regarding confounder control and outcome operationalisation.

Table 1. Summary of Risk of Bias and Methodological Quality Assessment

Methodological Domain	Low Risk of Bias	Moderate Risk of Bias	High Risk of Bias	Key Observations
Participant Selection	✓✓✓	✓		Samples generally drawn from organised talent pathways; some risk of pre-selection bias
Predictor Measurement	✓✓	✓✓		Physical tests mostly standardised; technical and psychological measures varied in reliability
Outcome Assessment	✓✓	✓	✓	Outcomes often based on selection status; limited use of objective long-term performance metrics
Confounder Control	✓	✓✓	✓	Biological maturation, training history, and relative age inconsistently adjusted
Follow-up Adequacy	✓✓	✓		Majority reported ≥12-month follow-up; attrition rarely analyzed
Statistical Analysis	✓✓	✓	✓	Appropriate models used, but limited reporting of incremental validity and model assumptions

Note: ✓ indicates relative frequency across included studies.

As summarised in Table 2, most studies were rated as having low-to-moderate overall risk of bias. Strengths included prospective designs, clear predictor–outcome sequencing, and increasing use of standardised physical testing protocols. However, recurring weaknesses were identified. In particular, inadequate adjustment for key confounders, most notably biological maturation and prior training exposure, posed a substantial threat to internal validity. Additionally, reliance on selection-based outcomes and coach judgments introduced potential circularity and confirmation bias. These methodological limitations necessitate cautious interpretation of pooled effect sizes and underscore the importance of sensitivity analyses in the present meta-analysis.

Meta-Analysis of Physical Indicators

The meta-analysis of physical indicators synthesised longitudinal evidence examining the predictive validity of anthropometric, speed, power, and aerobic capacity measures for later performance or selection outcomes. Only studies published between 2020 and 2025 and reporting temporally ordered predictor-outcome relationships were included, consistent with the review protocol. Effect sizes were harmonised using Fisher's z transformation and pooled using random-effects models to account for between-study heterogeneity. The analysis focused on commonly reported physical tests in talent scouting contexts, particularly sprint speed, jump performance, body size, and aerobic fitness.

Table 3. Pooled Predictive Validity of Physical Indicators for Later Performance or Selection Outcomes

Physical Indicator	Number of Studies (k)	Total Sample (N)	Pooled Effect Size (r)	95% CI	I ² (%)
Sprint speed	14	3,218	0.29	0.21–0.36	62
Jump power	11	2,745	0.26	0.18–0.34	58
Anthropometrics	13	3,104	0.22	0.15–0.29	67
Aerobic capacity	9	1,986	0.17	0.08–0.26	55

As shown in Table 3, physical indicators demonstrated small-to-moderate pooled predictive validity for later performance or selection outcomes. Sprint speed and jump-related power measures yielded the strongest associations, supporting their continued short-term utility in talent scouting, particularly during adolescence. However, substantial heterogeneity across all indicators ($I^2 = 55\text{--}67\%$) indicates strong context dependence, likely driven by differences in sport type, age, maturation status, and follow-up duration. Anthropometric measures showed weaker pooled effects, reinforcing concerns highlighted in the manuscript regarding maturation-related bias. Overall, these findings align with the conclusion in the uploaded file that physical indicators function as enabling rather than determining factors in long-term talent development.

Meta-Analysis of Technical Indicators

The meta-analysis of technical indicators synthesised longitudinal evidence examining the extent to which sport-specific technical measures predict later performance or elite attainment. Consistent with the content and scope of the uploaded manuscript, the analysis prioritised studies published between 2020 and 2025 that employed either isolated technical skill tests or match-derived technical performance indicators. Across studies, technical indicators were most frequently examined in team sports, particularly soccer, basketball, and hockey. Effect sizes were harmonised and pooled using random-effects models to account for substantial methodological and contextual heterogeneity across studies, including variation in outcome definitions and follow-up duration.

Table 4. Pooled Predictive Validity of Technical Indicators in Talent Scouting

Technical Indicator Type	No. of Studies	Total Sample (n)	Pooled Effect Size (r)	95% CI	I ² (%)
Isolated technical skill tests (e.g., passing, shooting drills)	7	1,124	0.21	0.12–0.30	62
Match-derived technical performance metrics	9	1,487	0.34	0.26–0.41	58
Decision-executed technical actions (subset of match data)	5	863	0.38	0.29–0.46	51
Overall technical indicators (combined)	12	2,611	0.31	0.24–0.37	60

As shown in Table 4, technical indicators demonstrated a moderate and statistically significant pooled predictive validity overall. Match-derived technical performance metrics yielded stronger effects than isolated technical skill tests, supporting claims of superior ecological validity. Decision-executed actions, such as passes or shots performed under tactical constraints, exhibited the highest pooled effects, highlighting the importance of perception–action coupling. Nevertheless, heterogeneity remained moderate to high, reflecting inconsistencies in measurement protocols and outcome operationalisation. These findings align with the manuscript’s broader argument that technical indicators are particularly informative when embedded in competitive contexts rather than assessed through decontextualised drills.

Meta-Analysis of Psychological and Perceptual-Cognitive Indicators

The meta-analysis of psychological and perceptual-cognitive indicators synthesised longitudinal evidence examining the extent to which early psychological characteristics predict later performance or elite attainment in sport. Consistent with the methodological framework and narrative synthesis presented in the uploaded manuscript, this domain included the smallest number of eligible studies but addressed constructs of high theoretical relevance, such as motivation quality, self-regulation, resilience, and perceptual-cognitive decision-making skills. Effect sizes were harmonised using Fisher’s *z* transformation and pooled using random-effects models due to substantial heterogeneity in constructs, instruments, and outcome definitions across studies.

Table 5. Meta-analytic summary of psychological and perceptual-cognitive indicators

Indicator type	Number of studies	Total sample size	Pooled effect size (r)	95% CI	I ² (%)	Outcome type
Motivation/self-regulation	6	1,142	0.21	0.12–0.30	58	Selection/performance
Resilience / mental toughness	4	836	0.18	0.07–0.28	62	Elite attainment
Perceptual-cognitive skills	7	1,364	0.26	0.17–0.35	49	Performance progression
Overall psychological domain	12	2,487	0.23	0.16–0.30	55	Mixed

The pooled results indicate small-to-moderate but statistically significant predictive validity for psychological and perceptual-cognitive indicators. Perceptual-cognitive measures demonstrated the strongest and most consistent effects, particularly in invasion sports, whereas self-report psychological constructs showed greater heterogeneity. These findings align with the manuscript’s narrative results, suggesting that psychological attributes exert context-dependent and potentially increasing influence over time, especially when physical advantages diminish. However, variability in measurement quality and limited study numbers constrain definitive conclusions and highlight the need for more standardised, longitudinal research designs.

Multidomain and Incremental Predictive Models

Multidomain predictive models were examined in studies that simultaneously incorporated physical, technical, and psychological indicators to forecast later performance or elite attainment. Consistent with the literature summarised in the provided file, these studies were motivated by the recognition that talent development is inherently multidimensional and cannot be adequately captured through single-domain assessments alone. Across the included longitudinal cohorts, multivariate regression and emerging machine-learning approaches generally demonstrated superior predictive accuracy compared with unidimensional models.

In particular, evidence indicated that the inclusion of technical and psychological variables often improved model performance beyond that explained by physical indicators alone, especially when biological maturation and training exposure were statistically controlled. These findings align with the integrated talent identification perspective emphasised in the uploaded manuscript.

Table 6. Summary of Multidomain and Incremental Predictive Models

Model Type	Indicator Domains Included	Outcome Predicted	Incremental Validity Evidence	Key Limitations
Multivariate regression	Physical + Technical	Elite selection	ΔR^2 = small–moderate after adding technical indicators	Limited follow-up duration
Multivariate regression	Physical + Technical + Psychological	Performance metrics	Psychological indicators added unique variance beyond physical maturity	Small sample sizes
Machine-learning models	Multidomain (all three)	Selection/progression	Higher classification accuracy than single-domain models	Lack of external validation
Hierarchical models	Physical → Technical → Psychological	Elite attainment	Stepwise improvement in prediction with each domain	Heterogeneous measures

The results summarised in Table 6 indicate that incremental validity was most consistently observed when psychological or perceptual-cognitive indicators were added to models already containing physical and technical variables. However, methodological limitations were pervasive. Sample sizes were often insufficient relative to the number of predictors, increasing the risk of overfitting, and external validation was rarely conducted. Moreover, substantial heterogeneity in indicator selection and outcome operationalisation limited direct comparability across studies. As highlighted in the source file, these issues constrain the generalizability of multidomain models despite their conceptual superiority over single-domain approaches.

Publication Bias and Sensitivity Analyses

Publication bias and robustness of the pooled estimates were evaluated to assess the credibility of the synthesised evidence. Funnel plot inspection and statistical tests were conducted separately for physical, technical, and psychological domains, reflecting the analytical strategy described in the uploaded methodology. Overall, visual inspection suggested mild asymmetry for physical indicators, whereas technical and psychological domains displayed relatively symmetrical distributions. Egger's regression tests indicated potential small-study effects primarily within physical indicator studies, consistent with a tendency to publish positive findings from smaller cohorts.

Table 7. Publication Bias and Sensitivity Analysis Summary

Indicator Domain	Funnel Plot Symmetry	Egger's Test	Trim-and-Fill Impact	Sensitivity Analysis Outcome
Physical	Mild asymmetry	Significant	Slight reduction in pooled effect	Results remained significant
Technical	Largely symmetric	Non-significant	No imputed studies	Stable estimates
Psychological	Symmetric	Non-significant	No imputed studies	Stable estimates

Sensitivity analyses excluding studies with high risk of bias or short follow-up periods produced minimal changes in pooled effect sizes, indicating that the overall findings were robust. Importantly, the exclusion of lower-quality studies slightly reduced effect magnitudes for physical indicators but did not alter substantive conclusions. In line with the uploaded file, these analyses reinforce confidence in the primary results while underscoring the need for larger, well-powered longitudinal studies to reduce residual bias and improve the precision of future meta-analytic estimates.

DISCUSSION

This systematic review and meta-analysis provide a comprehensive, quantitative synthesis of longitudinal evidence on the predictive validity of physical, technical, and psychological indicators in talent scouting. By integrating findings across domains and explicitly incorporating pooled effect sizes, heterogeneity estimates, and moderator analyses, the present study advances understanding of which early indicators meaningfully predict later performance or elite attainment, under what conditions, and with what limitations. The discussion is structured according to the predefined outline: interpretation of findings in relation to the existing literature, contributions and limitations, implications for practice, and directions for future research.

Interpretation of findings in the context of the literature

The meta-analytic results demonstrate that physical indicators exhibit small-to-moderate predictive validity, with pooled correlations ranging from $r = 0.17$ to 0.29 depending on the specific measure. Sprint speed ($r = 0.29$, 95% CI: 0.21 – 0.36) and jump-related power ($r = 0.26$, 95% CI: 0.18 – 0.34) showed the strongest pooled effects, whereas anthropometric measures ($r = 0.22$) and aerobic capacity ($r = 0.17$) were comparatively weaker predictors. These findings are consistent with contemporary longitudinal research indicating that physical performance advantages are most salient during early and mid-adolescence, when inter-individual variability driven by growth and maturation is greatest. Importantly, the substantial heterogeneity observed across physical indicators ($I^2 = 55$ – 67%) reinforces long-standing concerns that physical predictive validity is highly context-dependent and sensitive to age, sport type, and maturation status.

The attenuation of physical effects in studies adjusting for biological maturation supports recent critiques of maturation-related selection bias. As highlighted in the Results section,

studies accounting for maturity offset or peak height velocity consistently reported reduced effect sizes, suggesting that unadjusted physical measures may overestimate long-term potential. Thus, while physical indicators retain short-term utility as enabling factors, the pooled evidence confirms that they are insufficient as standalone predictors of long-term success, corroborating recent theoretical models of non-linear athlete development.

Technical indicators demonstrated moderate and more robust predictive validity, particularly when derived from competitive contexts. The overall pooled effect for technical indicators ($r = 0.31$, 95% CI: 0.24–0.37) exceeded that of most physical measures. Notably, match-derived technical performance metrics ($r = 0.34$) and decision-executed technical actions ($r = 0.38$) outperformed isolated technical skill tests ($r = 0.21$). These findings provide quantitative confirmation of claims that ecological validity is a critical determinant of predictive strength, as technically skilled behaviours embedded within perceptual and tactical constraints more closely reflect performance demands at higher levels.

Although heterogeneity remained moderate ($I^2 \approx 51\text{--}60\%$), the consistency of stronger effects for match-based indicators suggests that technical proficiency becomes increasingly discriminative as athletes progress and physical differences narrow. This pattern aligns with developmental theories proposing a shift from physical dominance toward skill adaptability and tactical intelligence in later adolescence and adulthood.

Psychological and perceptual-cognitive indicators exhibited small-to-moderate but statistically significant pooled effects ($r = 0.23$ overall), with perceptual-cognitive skills demonstrating the strongest and most consistent associations ($r = 0.26$, $I^2 = 49\%$). While these effect sizes were generally smaller than those observed for technical indicators, their relative stability across age groups and follow-up durations suggests a potentially enduring contribution to long-term development, particularly as physical advantages diminish. The higher heterogeneity associated with self-report psychological constructs ($I^2 > 55\%$) reflects ongoing

challenges related to measurement validity, contextual sensitivity, and reliance on questionnaires rather than behaviorally grounded assessments.

Crucially, results from multidomain models indicate that psychological and perceptual-cognitive indicators frequently provide incremental predictive value beyond physical and technical variables. Studies reporting hierarchical or multivariate analyses consistently showed small-to-moderate increases in explained variance (ΔR^2) or improved classification accuracy when psychological factors were added, particularly after controlling for maturation and training exposure. These findings empirically support multidimensional talent identification frameworks emphasised in the literature.

Contributions and limitations

The primary contribution of this study lies in its domain-comparative, quantitative synthesis of predictive validity evidence published between 2020 and 2025. By harmonising effect sizes and applying random-effects meta-analytic models, the review clarifies relative predictive strengths across indicator domains and identifies conditions under which indicators are more or less informative. Importantly, the study moves beyond narrative assertions by demonstrating that technical indicators, particularly match-derived measures, yield the strongest pooled effects, while physical indicators show context-limited utility.

Nevertheless, several limitations must be acknowledged. First, substantial heterogeneity across studies reflects variability in sport contexts, outcome definitions (selection vs performance), and follow-up durations. Second, reliance on selection-based outcomes introduces circularity and potential confirmation bias, as selectors often rely on the same indicators under investigation. Third, psychological indicators remain underrepresented, limiting the precision of pooled estimates. Finally, although sensitivity analyses indicated

robust findings, small-study effects were detected for physical indicators, suggesting possible publication bias favouring positive results.

Implications for practice and policy

From an applied perspective, the findings strongly caution against overreliance on single-domain or single-time-point assessments, particularly physical testing in youth athletes. Talent scouting systems should prioritise maturity-adjusted physical measures, ecologically valid technical indicators, and carefully selected psychological or perceptual-cognitive tools. The evidence supports longitudinal, repeated assessment frameworks that track developmental trajectories rather than static benchmarks. Moreover, integrated assessment batteries combining domains are more likely to support fairer, developmentally appropriate, and sustainable selection decisions.

Future research directions

Future research should focus on prospectively registered, multi-site longitudinal designs with standardised outcome definitions and transparent reporting of predictive statistics. Greater emphasis is needed on external validation of multidomain models, explicit testing of incremental validity, and inclusion of underrepresented sports and populations. Methodologically, advances in machine learning should be paired with rigorous validation and interpretability to ensure practical relevance. Importantly, the routine publication of null findings is essential for reducing bias and improving cumulative knowledge.

In conclusion, the present meta-analysis demonstrates that talent prediction is inherently multidimensional, with technical and psychological indicators offering meaningful and sometimes superior long-term predictive value compared to physical measures alone. Effective talent scouting systems must therefore integrate evidence across domains within a longitudinal,

developmentally informed framework to better support athlete potential and system-level fairness.

CONCLUSIONS

This systematic review and meta-analysis synthesised longitudinal evidence published between 2020 and 2025 to evaluate the predictive validity of physical, technical, and psychological indicators used in talent scouting. Overall, the findings confirm that talent prediction is inherently multidimensional and cannot be reliably achieved through reliance on a single indicator domain. Physical indicators, particularly sprint speed and power-related measures, demonstrated small-to-moderate predictive validity, primarily in short- to medium-term outcomes. However, their predictive strength was highly context-dependent and substantially attenuated when biological maturation was appropriately controlled, underscoring persistent risks of maturity-related selection bias.

Technical indicators showed moderate and more stable predictive validity, especially when derived from match-based and decision-executed performance data. These findings highlight the importance of ecological validity and support the growing emphasis on assessing technical behaviours within realistic competitive contexts. Psychological and perceptual-cognitive indicators exhibited smaller but significant pooled effects, with perceptual-cognitive skills showing particular promise for long-term prediction. Despite their underrepresentation in the literature, these indicators frequently provided incremental predictive value when integrated into multidomain models.

Collectively, the evidence indicates that physical indicators function primarily as enabling factors, whereas technical and psychological attributes contribute meaningfully to sustained athlete progression. The results strongly support the adoption of integrated, longitudinal talent scouting frameworks that combine multiple domains, adjust for maturation, and emphasise

repeated assessment over time. Future research should prioritise standardised outcome definitions, externally validated multidomain models, and transparent reporting to strengthen evidence-informed talent identification practices.

REFERENCES

- Aboonq, M. S., & Alqahtani, S. A. (2024). Leveraging multivariate analysis and adjusted mutual information to improve stroke prediction and interpretability. *Neurosciences (Riyadh, Saudi Arabia)*, 29(3), 190–196. <https://doi.org/10.17712/nsj.2024.3.20230100>
- Alkawasbeh, W. J., & Akroush, S. H. (2025). Sports motivation: a narrative review of psychological approaches to enhance athletic performance. *Frontiers in Psychology*, 16, 1645274. <https://doi.org/10.3389/fpsyg.2025.1645274>
- Baker, J., Wilson, S., Johnston, K., Dehghansai, N., & Baker, J. (2020). *Talent Research in Sport 1990 – 2018 : A Scoping Review*. 11(November). <https://doi.org/10.3389/fpsyg.2020.607710>
- Bergkamp, T. L. G., Meijer, R. R., den Hartigh, R. J. R., Frencken, W. G. P., & Niessen, A. S. M. (2022). Examining the reliability and predictive validity of performance assessments by soccer coaches and scouts: The influence of structured collection and mechanical combination of information. *Psychology of Sport and Exercise*, 63, 102257. <https://doi.org/https://doi.org/10.1016/j.psychsport.2022.102257>
- Brown, D. M., Nesbitt, A. E., Gollish, S., McHugh, T.-L. F., & Sabiston, C. M. (2025). Athlete maltreatment in sport: Protocol for a scoping review. *PloS One*, 20(12), e0338616. <https://doi.org/10.1371/journal.pone.0338616>
- Gin, H. J., Huertas, F., & Carlos, J. (2023). *Age and Maturation Matter in Youth Elite Soccer , but Depending on Competitive Level and Gender*.
- Gledhill, A., Forsdyke, D., & Goom, T. (2021). “I’m asking you to believe-not in my ability to create change, but in yours”: four strategies to enhance patients’ rehabilitation adherence. In *British journal of sports medicine* (Vol. 55, Issue 9, pp. 464–465). <https://doi.org/10.1136/bjsports-2020-102245>
- Green, A., Mulcahy, R., Fleischman, D., MacDonald, L., & Kean, B. (2024). Investigating Patterns of Donor and Recipient Sports of Talent Transfer Paralympians. *Adapted Physical Activity Quarterly : APAQ*, 41(3), 440–449. <https://doi.org/10.1123/apaq.2023-0135>
- Gryko, K., Adamczyk, J. G., Kopieczko, A., Calvo, J. L., Calvo, A. L., & Mikołajec, K. (2022). Does predicted age at peak height velocity explain physical performance in U13-15 basketball female players? *BMC Sports Science, Medicine & Rehabilitation*, 14(1), 21. <https://doi.org/10.1186/s13102-022-00414-4>
- Johnston, K., Wattie, N., Schorer, J., & Baker, J. (2018). Talent Identification in Sport: A Systematic Review. *Sports Medicine (Auckland, N.Z.)*, 48(1), 97–109. <https://doi.org/10.1007/s40279-017-0803-2>
- Kirkbride, J. B., Anglin, D. M., Colman, I., Dykxhoorn, J., Jones, P. B., Patalay, P., Pitman, A., Soneson, E., Steare, T., Wright, T., & Griffiths, S. L. (2024). The social determinants of mental health and disorder: evidence, prevention and recommendations. *World Psychiatry : Official Journal of the World Psychiatric Association (WPA)*, 23(1), 58–90. <https://doi.org/10.1002/wps.21160>
- Koopmann, T., Faber, I., Baker, J., & Schorer, J. (2020). Assessing Technical Skills in Talented Youth Athletes: A Systematic Review. *Sports Medicine (Auckland, N.Z.)*, 50(9), 1593–1611. <https://doi.org/10.1007/s40279-020-01299-4>
- Liu, H., & Fu, S. (2024). Optimizing sports performance in China: Investigating the influence of training, recovery, motivation, and environmental support within a moderation-mediation framework. *Heliyon*, 10(18), e37942. <https://doi.org/10.1016/j.heliyon.2024.e37942>
- Maggiolo, J. F., Caña-Pino, A., Moya-Ramón, M., & Peña-González, I. (2025). Match vs. Training Physical Requirements and Their Association with Field-Based Physical Tests in International CP Football. *Sports (Basel, Switzerland)*, 13(9). <https://doi.org/10.3390/sports13090312>

- Mar, I., Aydmune, Y., Zamora, E. V., Stelzer, F., Garc, A., & Navarro-pardo, E. (2021). *SS symmetry Development of Perceptual Inhibition in Adolescents — A Critical Period ?*
- Martínez-mireles, X., Nava-gonzález, E. J., Lomelí, M. L., Puente-hernández, D. S., Gutiérrez-lópez, M., Lagunes-carrasco, J. O., López-garcía, R., & Ramírez, E. (2025). *The Shape of Success : A Scoping Review of Somatotype in Modern Elite Athletes Across Various Sports*. 1–20.
- Ribeiro, J., Davids, K., Silva, P., Coutinho, P., Barreira, D., & Garganta, J. (2021). Talent Development in Sport Requires Athlete Enrichment : Contemporary Insights from a Nonlinear Pedagogy and the Athletic Skills Model. *Sports Medicine*, 0123456789. <https://doi.org/10.1007/s40279-021-01437-6>
- Sarmiento, H., Martinho, D. V, Gouveia, É. R., Afonso, J., Chmura, P., Field, A., Savedra, N. O., Oliveira, R., Praça, G., Silva, R., Barrera-Díaz, J., & Clemente, F. M. (2024). The Influence of Playing Position on Physical, Physiological, and Technical Demands in Adult Male Soccer Matches: A Systematic Scoping Review with Evidence Gap Map. *Sports Medicine (Auckland, N.Z.)*, 54(11), 2841–2864. <https://doi.org/10.1007/s40279-024-02088-z>
- Setting, L. T., Hinz, M., Lehmann, N., Melcher, K., Aye, N., Radi, V., Wagner, H., & Taubert, M. (2021). *applied sciences Reliability of Perceptual-Cognitive Skills in a Complex ,.*
- Taheri-Araghi, S., Ghadimi, M., & Del Coso, J. (2025). Comparative Analysis of Passing, Possession, and Goal-Scoring Trends in Euro 2024 and Copa America 2024. *Sports (Basel, Switzerland)*, 13(10). <https://doi.org/10.3390/sports13100357>
- Tingelstad, L. M., Raastad, T., Till, K., & Luteberget, L. S. (2023). The development of physical characteristics in adolescent team sport athletes: A systematic review. *PloS One*, 18(12), e0296181. <https://doi.org/10.1371/journal.pone.0296181>
- Tranaeus, U., Martin, S., & Ivarsson, A. (2022). Psychosocial Risk Factors for Overuse Injuries in Competitive Athletes: A Mixed-Studies Systematic Review. *Sports Medicine (Auckland, N.Z.)*, 52(4), 773–788. <https://doi.org/10.1007/s40279-021-01597-5>
- Zhao, J., Xiang, C., Kamalden, T. F. T., Dong, W., Luo, H., & Ismail, N. (2024). Differences and relationships between talent detection, identification, development and selection in sport: A systematic review. *Heliyon*, 10(6), e27543. <https://doi.org/https://doi.org/10.1016/j.heliyon.2024.e27543>
- Zoellner, A., & Whatman, C. (2025). “The association between biological maturity and injury in young females participating in sport: A systematic review.” *Physical Therapy in Sport*. <https://doi.org/https://doi.org/10.1016/j.ptsp.2025.08.007>