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# From Pool to Play: Designing a Game-Based Screening Tool for Early Swimming Talent Detection in Youth Athletes

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## ABSTRACT

Early swimming talent detection in youth athletes remains challenging because commonly used approaches are resource-heavy, technique judgments are often subjective, and prediction models may not generalize well across clubs, pools, and populations. Although physiological testing can explain swimming performance, many informative measures (e.g., laboratory $VO_2$max, controlled lactate profiling, repeated maximal protocols with advanced monitoring) are impractical for large-scale screening in community settings. Evidence from youth swimming indicates that performance is more consistently associated with strength/power and lean-mass–related traits than with body fat percentage, which shows weaker and more variable relationships. Longitudinal modeling studies further suggest that a compact set of feasible anthropometric and physiological indicators can provide meaningful predictive signal, and that explainable machine-learning methods can improve coach-facing transparency by clarifying which features drive model outputs. Technique remains central in a technique-dominant sport such as swimming; however, unstructured observation is vulnerable to rater bias and inconsistency. Standardized video-based tools such as Tec Pa demonstrate high inter-rater agreement, supporting the feasibility of structured technique checkpoints for early screening. Beyond physical and technical factors, talent-development scholarship highlights the risks of early exclusion and maturation bias, emphasizing that youth screening should be developmentally appropriate, repeatable over time, and fair. Psychological and cognitive indicators (e.g., motivation, self-regulation, goal orientation) may therefore be used as supportive signals to guide development rather than as strict selection thresholds. Building on this evidence, this short review proposes "From Pool to Play," a game-based screening concept that converts field-friendly physical proxies, structured technique checkpoints, and age-appropriate psychosocial measures into engaging, repeatable poolside and in-water "missions." The goal is to reduce assessment burden, enhance motivation and adherence, standardize data capture across contexts, and enable transparent, explainable profiling of early talent signals in youth swimmers.

**Keywords:** youth swimming; talent identification; game-based screening; technique assessment; Tec Pa; anthropometrics; machine learning; Random Forest.

## Introduction

Early swimming talent detection in youth athletes faces persistent hurdles because the methods used to infer "future potential" are often resource-heavy, subjective, and difficult to generalize across training contexts, clubs, or populations (1, 2). Physiological testing has clear value for performance explanation—especially for competitive swimming, where aerobic capacity, anaerobic power, and neuromuscular qualities contribute to race outcomes—but many of the most informative measurements (e.g., laboratory $VO_2$max protocols, repeated maximal efforts with sophisticated monitoring, controlled lactate profiling) are not feasible as routine screening tools for large youth cohorts in community pools. This practical barrier matters most at early ages, where coaches and programs want scalable ways to identify children who are likely to respond well to

training, yet the sport environment rarely supports frequent lab access, standardized testing conditions, or specialized staff. In addition, early selection carries ethical and developmental risks: talent is not fixed, maturation timing differs widely, and the consequences of premature exclusion can be substantial (missed opportunities, dropout, inequity) (3). A key implication is that effective early screening must prioritize field-friendly indicators that are (i) low burden, (ii) repeatable over time, (iii) interpretable for coaches and families, and (iv) robust to contextual differences (pool size, training culture, equipment availability) (3, 4). In swimming, this often means blending "what can be measured reliably poolside" with "what is meaningfully associated with later performance," while acknowledging that performance at young ages is shaped by growth, experience, technique exposure, and psychosocial factors rather than physiology alone (3, 4).

### *Key performance predictors and the shift to parsimonious measurement*

Evidence from large-scale youth swimming datasets suggests that a compact set of anthropometric and physiological variables can provide substantial predictive signal. Liu and colleagues developed predictive models using anthropometric and physiological phenotypes collected from a large adolescent swimmer cohort (ages 10–18) with a 3-year follow-up; Random Forest emerged as one of the strongest-performing algorithms, and explainable-AI outputs (SHAP) emphasized variables such as skinfold measures (e.g., abdominal and triceps), lung capacity, chest circumference, and shoulder width among highly influential predictors (2). Importantly, this type of result does not imply deterministic forecasting of elite status; rather, it shows that some readily measured attributes capture meaningful variance in longer-term outcomes and can inform screening that is less dependent on expensive testing (2). It also reinforces a practical point about body composition: lean mass proxies and strength/power-related traits tend to align more consistently with performance than body fat percentage alone, which can show weaker and more variable links when used as a standalone indicator (2). Work focused on predictive modeling in youth swimming similarly highlights the potential value of multi-domain profiling—including physiological and psychological attributes—to support more systematic identification and development decisions (1). Clarke's model-development paper frames talent identification in swimming as inherently multifactorial, motivating approaches that go beyond a single test or "trial day" and instead integrate information that can be gathered and updated over time (1). Together, these strands support a move away from "one-off" lab-driven screening toward portable models that can operate using a reduced set of measures collected under real-world constraints.

### *Technique assessment: essential but vulnerable to subjectivity*

While anthropometrics and physiology are informative, swimming is a technique-dominant sport: efficiency, coordination, and stroke mechanics shape performance and determine how effectively a young athlete can translate fitness into speed. Yet technique evaluation in practice often relies on non-standardized observation, making it vulnerable to coach-to-coach variation, halo effects, and context-specific expectations. Standardized tools can reduce this problem. Papadimitriou and colleagues introduced and evaluated Tec Pa, a video-based technique evaluation tool for young swimmers, where experienced coaches scored structured key points and demonstrated strong agreement—supporting the feasibility of more reliable technique screening than unstructured observation alone (5). Standardized technique checkpoints are particularly valuable for youth contexts because they can (i) make judgments explicit and auditable, (ii) guide targeted feedback, and (iii) enable consistent tracking as children progress through skill acquisition phases. However, technique scoring also brings implementation challenges: it requires coach training, time for observation (or video review), and agreement on what

constitutes "good technique" at different ages and maturation stages. A high-quality screening approach therefore needs to embed technique assessment in a way that is efficient and engaging, rather than adding an additional layer of testing burden.

### *Psychological and cognitive factors: avoiding "body-only" selection*

A major limitation of many talent identification systems is the over-weighting of current physical advantages that can reflect maturation rather than long-term potential. Talent development scholars emphasize that early identification should be approached cautiously, and that systems should prioritize developmentally appropriate processes that reduce premature exclusion and support long-term participation (3). In this broader view, psychological characteristics—such as motivation, resilience, goal orientation, and self-regulation—are not "extras," but plausible contributors to sustained engagement, training adherence, and progression through inevitable setbacks (3). Johnston and colleagues likewise stress practical considerations for athlete selection, including the need to clarify what "talent" means, recognize context effects, and minimize bias when making decisions that shape athlete trajectories (4). For early swimming screening, this implies that tools should not only ask "Who is fastest today?" but also "Who shows indicators associated with learning, persistence, and responsiveness to coaching?" While psychological profiling must be handled carefully (age-appropriate instruments, privacy, non-stigmatizing use), incorporating structured, transparent measures can help balance the tendency to select early maturers and instead emphasize a broader developmental picture (3, 4).

### *Advances in predictive modeling: explainability and portability as design requirements*

Machine learning can improve scalability, but its value depends on portability and interpretability. In Liu et al.'s longitudinal dataset, Random Forest offered strong predictive performance, and SHAP-based explanations provided an interpretable ranking of features—an important step toward coach-facing transparency (2). In talent contexts, "black-box" outputs are rarely acceptable for decision-making because they can hide bias and make it difficult to justify selections or guide training interventions. Explainable modeling can therefore be treated as a design requirement, not merely an analytical add-on: screening outputs should communicate why an athlete was flagged (e.g., a profile of strengths, not a single score) and what might be trainable (e.g., strength development, technical elements, breathing control) (2-4). Portability also matters: models trained in one region or talent pathway can fail elsewhere due to differences in coaching, selection practices, or baseline distributions of age and maturation. For this reason, model validation across independent contexts is essential if screening tools are intended for broad adoption (2).

### *Toward game-based screening: From Pool to Play*

These constraints and opportunities motivate the **From Pool to Play** concept: a game-based screening tool that translates validated, field-friendly predictors into short "missions" conducted poolside and in-water. The core idea is to standardize assessment without increasing burden by leveraging game design: clear rules, immediate feedback, progressive challenge, and repeatability. Such a system can unify (a) anthropometric/physiological proxies prioritized by evidence and feasibility (2), (b) structured technique checkpoints informed by standardized tools like Tec Pa (5), and (c) development- and equity-aware selection principles recommended in talent identification scholarship (3, 4). In practical terms, game missions can be designed to (i) elicit measurable movement and coordination patterns, (ii) incorporate technique prompts in an age-appropriate manner, (iii) reduce performance anxiety compared with formal testing, and (iv) produce data streams that support explainable scoring rather than opaque pass/fail judgments (2-4). In summary, early swimming talent detection requires methods that are scalable, transparent, developmentally appropriate, and less dependent on laboratory infrastructure.

The convergence of (i) evidence on compact predictive feature sets (2), (ii) structured technique assessment tools (5), and (iii) modern guidance on ethical and practical selection (3, 4) provides a strong rationale for a game-based screening framework.

## Methods

This brief review used a structured narrative (non-systematic) synthesis to summarize key empirical and conceptual evidence relevant to designing a field-feasible, game-based screening approach for early swimming talent detection in youth. The review question was framed using a Population–Concept–Context (PCC) structure: Population included youth swimmers and youth sport participants (approximately 5–12 years), with emphasis on early-to-middle childhood and adolescence; Concept covered practical talent identification/detection indicators (anthropometric/physical proxies, technique assessment, psychological/cognitive factors) and explainable predictive modeling; Context focused on community and club-based swimming environments where laboratory testing is not routinely available.

### *Search strategy and data sources*

A targeted search was conducted in PubMed/MEDLINE, Scopus, Web of Science, SPORTDiscus, and Google Scholar, supplemented by backward citation searching of included articles. Searches were performed up to the most recent available records at the time of manuscript preparation. Key terms (alone and in combination) included: swimming, youth, talent identification, talent detection, anthropometric, physiology, machine learning, Random Forest, explainable AI/SHAP, technique assessment, video rating, psychological profiling, motivation, and self-regulation. Evidence-mapping decisions were informed by methodological guidance for narrative synthesis in talent identification research (6) and by a swimming-focused narrative review of youth performance determinants to support domain classification (7).

*Eligibility criteria and screening*

Given the brief-review scope, studies were included if they (i) examined youth swimming predictors or (ii) provided transferable youth talent identification principles applicable to swimming, including methodological guidance and ethical considerations. Eligible evidence types included longitudinal or cohort studies, model-development papers, validated technique rating tools, and high-quality narrative/systematic syntheses. Studies were excluded if they were unrelated to sport, focused only on adults/elite populations without youth relevance, or lacked sufficient methodological clarity to interpret feasibility or measurement quality. Screening was performed in two stages (title/abstract followed by full-text review) to identify the most relevant sources.

*Data extraction, appraisal, and synthesis*

For each included source, key information was extracted on sample characteristics, measures/predictors, outcomes (e.g., progression, performance markers), analytic approach (including validation and explainability where applicable), and feasibility in field settings. As a brief narrative review, formal risk-of-bias scoring was not performed; instead, a pragmatic appraisal prioritized studies with clear sampling, defined measures, evidence of reliability/validity (e.g., inter-rater agreement for technique tools), and transparent modeling/validation practices (6). Findings were synthesized into four practical domains—physical/anthropometric, technical, psychological/cognitive, and implementation/ethics—to inform the design rationale for the *From Pool to Play* mission-based screening concept.

## Results

### *What predicts youth swimming potential with feasible field measures?*

Across included sources, scalable early screening prioritizes pool-compatible predictors over lab-dependent variables, with longitudinal modeling identifying key anthropometric/physiological signals that can support probabilistic inference about progression. Liu et al. demonstrated Random Forest models highlighting a compact set of features—including selected skinfolds and thoracic/upper-body dimensions alongside lung-capacity–related indicators—as influential predictors in youth cohorts (2). Complementary swimming-focused synthesis work emphasizes that anthropometrics, energetics, and efficiency-related factors interact, and that measuring feasible proxies consistently may be more useful than exhaustive lab batteries when the goal is wide implementation (7). A practical interpretation is that early screening can focus on simple anthropometrics (stature, mass, selected girths/breadths), limited composition proxies, and feasible aerobic/anaerobic field indicators—while avoiding reliance on any single metric.

### *Technique assessment is central, but requires standardization*

Technique and efficiency remain central determinants of youth swimming development; however, unstructured observation limits reliability and comparability across evaluators and time. The Tec Pa approach illustrates that structured video ratings with clear checkpoints can improve inter-rater consistency for young swimmers (5). Clarke's TI modeling perspective similarly underscores that technique should be integrated into systematic assessment rather than inferred solely from race outcomes, particularly when the goal is early detection and development support (1). Accordingly, technique assessment within a screening tool should be operationalized into observable subcomponents (e.g., alignment, coordination/timing, propulsion pattern, breathing integration) and captured via brief standardized clips or structured poolside checklists.

### *Psychological and cognitive factors support "developmental potential," not just current performance*

Talent systems must counter maturation and context bias by incorporating indicators of engagement, learning, and sustained participation. Broader TI guidance emphasizes that early selection decisions should remain development-focused and minimize premature exclusion (3, 4, 6). Recent mixed-methods evidence supports the relevance of psychological and environmental characteristics to talent development trajectories, reinforcing the value of including age-appropriate self-regulation and motivation signals in development-oriented screening frameworks (8). Synthesis for a game-based approach therefore prioritizes brief psychological indicators as supportive inputs (to tailor coaching and feedback), rather than as exclusion criteria.

### *Predictive modeling: explainability and portability are not optional*

Interpretable models validated across contexts are more likely to be adopted and ethically defensible. In Liu et al.'s study, explainable analysis (SHAP) clarified predictor importance, enabling more auditable and coach-facing interpretations of the model outputs (2). Clarke's work further emphasizes model portability and the need to integrate multiple domains when predicting or identifying youth swimming talent (1). This aligns with methodological TI reviews which caution against over-reliance on single tests and emphasize standardized procedures and longitudinal approaches (6). A practical synthesis is that screening outputs should be transparent profiles (strengths and development targets) with repeated measurement and tracking, rather than opaque rankings.

## Discussion

### *Why "From Pool to Play" fits the evidence base*

The core rationale for From Pool to Play is that early talent identification in youth swimming needs to be scalable, repeatable, and developmentally appropriate, while minimizing bias and avoiding over-reliance on laboratory infrastructure. Methodological reviews of talent identification emphasize that single-point testing and narrowly framed selection decisions can be distorted by maturation and contextual effects, and that better practice involves multi-domain, longitudinally minded approaches with standardized procedures that enhance reliability and fairness (6). Game-based "missions" provide a practical mechanism to operationalize these principles: they reduce dependence on laboratory testing by using feasible poolside/in-water proxies, reduce technique subjectivity by embedding structured checkpoints, and reduce maturation bias by enabling repeated monitoring of trajectories rather than one-off "trial day" judgments. These benefits align with broader TI guidance that prioritizes development-focused selection and reduction of premature exclusion risks (3, 6).

### *A design-based screening framework*

**Physical/Anthropometric domain.** Evidence from large youth swimming datasets suggests that a compact set of anthropometric and physiological phenotypes can provide meaningful predictive signal, especially when paired with explainable modeling (2). In this context, From Pool to Play prioritizes measures that are feasible in community settings (e.g., selected body dimensions and limited body-composition proxies) with clear protocols to improve measurement consistency across sites. Such parsimony is important because it supports adoption and repeat testing without creating high burden.

**Technical domain.** Swimming is technique-dominant, so screening must capture the quality of foundational movement patterns—not just race times. Clarke's model-development work reinforces that technique should be treated as a central construct in youth talent identification and integrated into systematic assessment, rather than inferred only from performance outcomes (1). From Pool to Play operationalizes technique through mission-embedded checkpoints (e.g., body alignment, timing/coordination, breathing integration), using structured observation or brief video capture to improve standardization and reduce coach-to-coach variability (5).

**Psychological/Cognitive domain.** Contemporary TI research recognizes that youth development is shaped by psychological and environmental characteristics that influence learning, persistence, and progression. Saward et al. highlight the contribution of psychological and environmental factors to talent development, supporting the inclusion of age-appropriate self-regulation and motivation signals as part of a holistic picture (8). From Pool to Play treats these variables as development supports rather than exclusion tools—helping coaches identify which athletes may benefit from different feedback styles, goal-setting scaffolds, or confidence-building interventions (3, 4).

**Implementation/Ethics domain.** Ethical and methodological guidance stresses the risks of premature labeling and the importance of transparent decision processes in youth selection (3, 4, 6). Explainable outputs—profiles that show why an athlete was flagged and what is trainable—are therefore essential. This aligns with explainable modeling approaches in youth swimming prediction research, where interpretability helps translate analytics into actionable coaching (2). In From Pool to Play, explainability also supports accountability: families and athletes can understand that screening results indicate current signals and developmental needs, not fixed destiny.

*Example "missions" (conceptual; to be validated)*

Because a game-based tool is only as good as its tasks, the missions must be aligned with swimming fundamentals and standardized scoring rules.

**Mission A: Streamline & glide (alignment/efficiency proxy).** A short, playful challenge that captures body position control and hydrodynamic alignment. This mission targets technique foundations prioritized in youth development models (1).

**Mission B: Kick rhythm (coordination/breathing integration).** A rhythm-and-control task designed to elicit bilateral coordination, timing stability, and breathing organization, addressing methodological calls for standardized, repeatable skill assessment rather than purely outcome-based selection (6).

**Mission C: Start/turn micro-skill (power + skill integration).** A constrained mission that combines safe execution and coordination under simple rules. It complements compact physical predictors (e.g., strength/power proxies and body dimensions) shown to be informative in predictive modeling (2).

**Mission D: Persistence loop (motivation/self-regulation signal).** A short repeated-round task with child-friendly self-report (e.g., perceived effort, confidence, willingness to repeat) to capture engagement and self-regulation signals supported by talent development research (8).

Together, these missions are designed to yield a multidimensional profile rather than a single rank. This approach is consistent with TI recommendations that emphasize triangulation and longitudinal tracking to mitigate maturation and context bias (3, 6).

## *Practical implications*

For coaches, From Pool to Play offers structured, engaging assessment that can be administered in routine sessions while generating comparable data across evaluators and timepoints. For researchers, mission-based screening enables standardized data capture and supports longitudinal modeling in real-world contexts, potentially improving external validity. For programs and governing bodies, the framework may reduce inequity by shifting emphasis from one-off selection to repeat assessment of developmental trajectories—an approach recommended across TI scholarship (3, 6).

## *Limitations of this review*

This paper is a short narrative review and therefore does not provide exhaustive coverage or PRISMA-level synthesis. The evidence base is heterogeneous (predictive modeling, technique assessment, psychological/environmental studies, and TI methodology), which limits direct quantitative integration. In addition, the mission set is conceptual and requires empirical validation to establish feasibility, reliability, sensitivity to change, and fairness across age, sex, and maturation profiles (3, 6, 8).

## *Future research directions*

1. Prototype and usability testing in 5–12-year-olds and early adolescents to optimize mission instructions, game mechanics, and burden (1).
2. Reliability studies (test–retest; inter-rater for technique checkpoints) to verify measurement quality in community settings (6).

3. Model development and external validation across clubs/regions/demographics, building on explainable modeling principles and compact predictor sets (2).
4. Longitudinal outcomes research linking mission profiles to progression, retention, and skill acquisition—beyond short-term performance (3, 6).
5. Ethical communication protocols that prevent deterministic labeling and emphasize developmental use of screening outputs (3, 4, 6).

## Conclusion

Evidence across youth swimming prediction research, TI methodology, and talent development scholarship supports a screening approach that is parsimonious, standardized, longitudinally oriented, and ethically grounded (2, 3, 6, 8). From Pool to Play synthesizes these principles into game-based missions that can reduce laboratory dependence, improve technique assessment reliability, and incorporate developmental psychological signals—producing transparent, coach-usable profiles that prioritize fair identification of early talent signals.

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## Authors' Contributions

All authors contributed equally to the conception and design of the review, literature searching and screening, data extraction and synthesis, drafting the manuscript, and revising the final version. All authors approved the final manuscript and agree to be accountable for all aspects of the work.

## Declaration of Interest

The authors of this article declared no conflict of interest.

## Ethical Considerations

This study is a narrative review and design-oriented synthesis based exclusively on published literature. It did not involve human participants, patient data, animal experimentation, or the collection of identifiable personal information. Therefore, institutional ethical approval and informed consent were not required.

## Transparency of Data

No new datasets were generated or analyzed in this study. All data supporting the conclusions of this review are available in the cited published literature. Any extraction tables or summary files produced during the review process can be provided by the corresponding author upon reasonable request.

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