STRN Sports Tech Research Network

WHITE PAPER

Quality Framework for Sports Technologies

A standardized, evidence-based decision-making framework for evaluating the value, usability, and quality of sports technology

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Executive Summary

Identifying and applying tools to **effectively and efficiently evaluate technologies** is an area of increasing need for many sports stakeholders. A more robust and comprehensive process to evaluate technology would help to reduce negative effects due to adoption of poor-quality technology, such as low return on investment, technology misuse, or data breach.

This white paper introduces a **standardized, evidence-based framework** which can be adopted by sports technology stakeholders to assess the value, usability, and quality of technology. Developed **in collaboration with 48 experts** across the sports industry by means of a Delphi study design, the Sports Technology Quality Framework consists of **25 measurable features grouped under five quality "pillars"**: Quality Assurance & Measurement, Established Benefit, Ethics & Security, User Experience, and Data Management.

This framework can be used to help **design and refine** sports technology in order to optimize quality and maintain industry standards, as well as guide purchasing decisions by organizations. It also will serve to create a **common language** for organizations, manufacturers, investors, and consumers to improve the efficiency of their decision making on sports technology.

The Global Challenge of Evaluating Sports Technology

Technology use is accelerating everywhere, and sports are no exception. The last 20 years have seen exponential growth in the development and use of technology to identify, monitor, train, recover, and rehabilitate athletes [1], [2]. Although these technologies were once confined to elite sport, the **rapid democratization of technology and data** has created an explosion of opportunities at the amateur and general consumer level as well [3], [4]. Furthermore, the increased commercialization of sport has broadened the notion of sports technology beyond athlete performance. Digital technologies and investable enterprises have emerged across a range of sport-related applications, including fan engagement, stadium experience, venue operations, and entertainment and content creation [5]-[7].

Key stakeholders face numerous challenges when evaluating the **value, usability, and quality** of products in the rapidly-evolving sports technology marketplace (**Figure 1**). High-performance staff, leagues, and governing bodies are inundated with more tech proposals in one week than they could reasonably review in a year. Coaches attempting a simple online search are met with a daunting list of tech options but have limited resources to **distinguish hype from substance**. Tech start-ups receive considerable mentoring on how to develop a viable business but minimal direction on how to establish the quality of their product. Likewise, investors may look deep into financial projections for a company while only gaining superficial insight into the technology's technical suitability. Last but certainly not least, in a race for competitive advantage, it is the players that often have a limited voice in how sports technology is used to monitor and intervene on their training and performance.

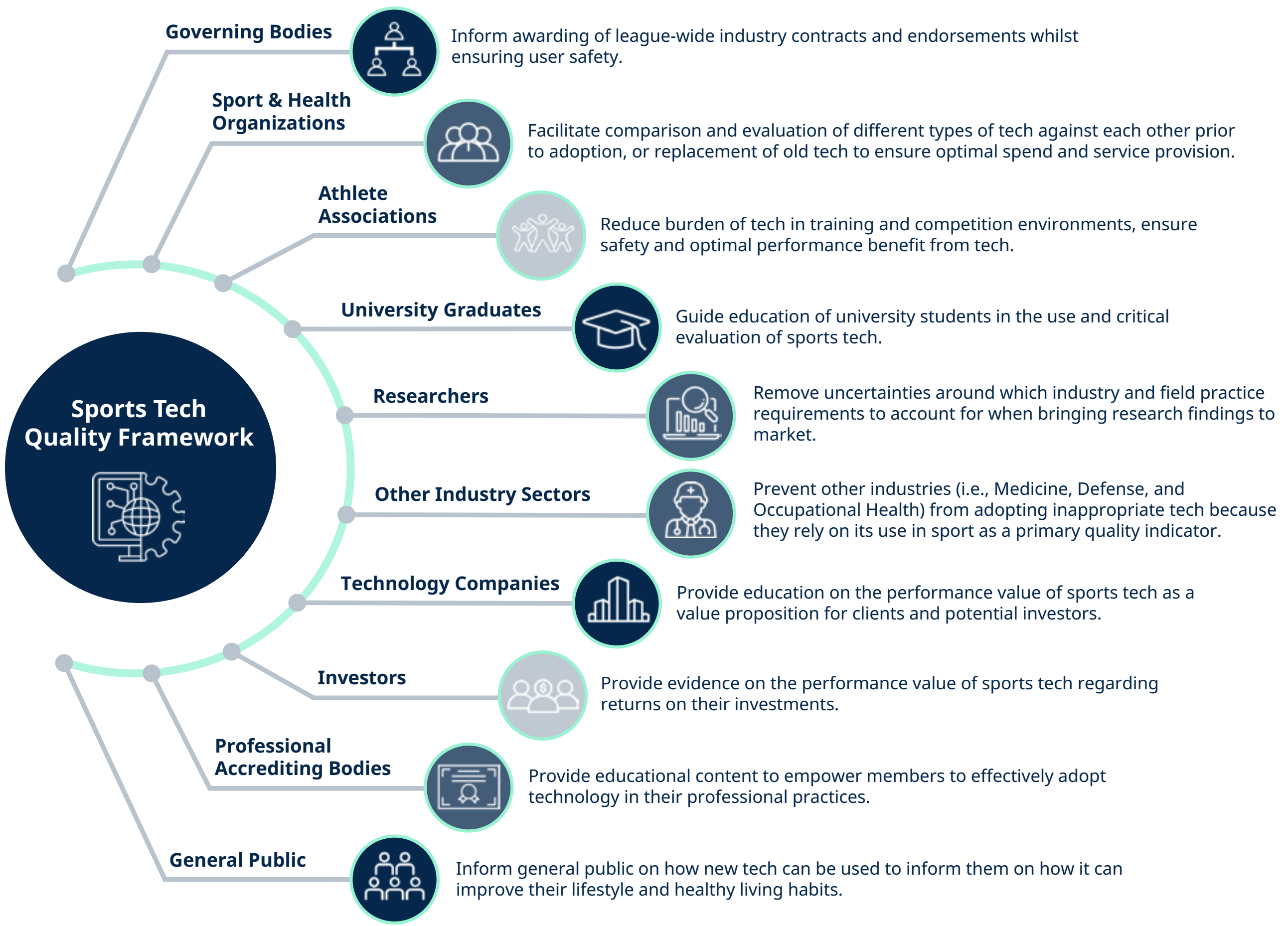


Figure 1. Benefits of a Sports Tech Quality Framework for Key Stakeholders

Identifying tools and processes to effectively and efficiently evaluate technologies is an area of increasing need for many sports stakeholders. Access to resources and training in this area would reduce the negative effects of adopting ineffective, unusable, burdensome, or unsafe technologies–including poor return on investment, wasted time and resources, unsatisfied consumers, or adverse events. **As sports technology continues to outpace user expertise, there is a critical need to implement better education, policies, and processes for evaluating the quality of a given sports technology.**

The Need for a Sports Technology Quality Framework

The **regulatory environment** for sports technology is not well defined. Unlike many other industries, the majority of sports technologies are not required to comply with statutory or regulatory requirements. At best, a patchwork of regulations and policies exist which are largely contingent on the relevant sport, competition level, and geographic region. Additionally, regulations may be present for **certain aspects of technology** (e.g., physical safety, data privacy) but not others (e.g., accuracy, efficacy, or usability). However, consumers are often unaware of this and generally assume that the product has met some level of technical quality before becoming commercially available.

In many instances, the **responsibility** to confirm the technical quality of a product ultimately rests with the manufacturer. However, this is also a challenge for manufacturers, who cannot point to a unified standard against which to design and test their product. Also, given competitive and financial concerns, manufacturers rarely disclose technical information on the product, including how it has been evaluated and how it compares to competitor products. On the academic research side, independent evaluation of a product may take years to conduct. Meanwhile, the technology of interest often has evolved its algorithms, firmware, and even hardware in the intervening period, rendering the research results obsolete as soon as they are published.

Sports governing bodies are marking important strides on assessing the safety and validity of sport technologies [8]-[10]. For example in 2017, the National Basketball Association (NBA) and NBA Players Association created a first of its kind joint Wearables Committee to review requests by NBA teams, the NBA, or the NBPA to approve a wearable device for use by players – clearly indicating the high priority for a standardized process for assessing sports technology [9]. In parallel, voluntary standards groups have begun rolling out test methods and evaluation criteria for specific health and fitness technology measures [11]-[16]. The sports science and research communities likewise have put forth several thoughtful approaches for decision-making around technology, aimed at various stakeholders [2], [17]-[19]. **Despite current advances toward more rigorous evaluation of sports and related technology, a unified global framework for evaluating sports technologies remains sorely needed.**

Development of the Sports Technology Quality Framework

Recognizing the aforementioned needs, the Sports Technology Research Network (STRN) convened a working group to develop a standardized, evidence-based, publicly-available framework intended to help sports technology stakeholders evaluate the **value, usability, and quality** of technology. It was envisioned that this framework would be used to:

1. Help **design and refine** sports technology in order to optimize quality and maintain industry standards,
2. Guide **purchasing decisions** by facilitating comparison of certain technologies that perform the same function with one another (i.e., optical tracking vs GPS), or certain providers of the same tech with one another (i.e., Sleep watch #1 vs Sleep watch #2),

3. Create a **common language** for organizations, manufacturers, investors, and consumers to improve the ease and transparency of discussing sports technology evaluation.

The working group consisted of 11 members from four countries (Australia, United States, Belgium & Germany). From February to August 2022, the group conducted a review of standards, research, and consensus statements on technology assessment in sports as well as adjacent industries, including digital health, psychology, software engineering, security and defense, and e-commerce, and developed a first draft of the framework (**Figure 2**).

The Framework Development Process

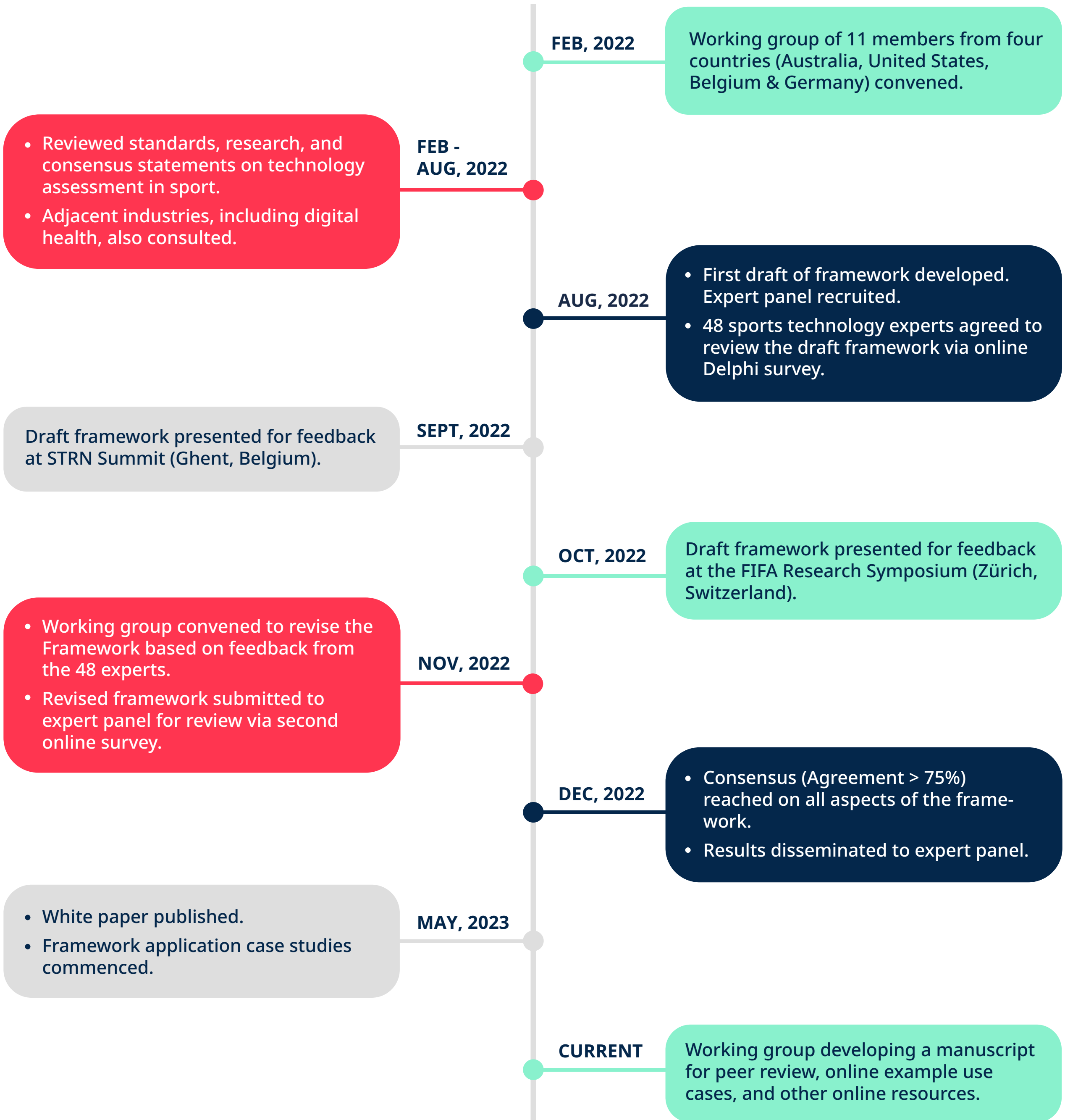


Figure 2. Development process of the sports technology quality framework

Formal review of the framework was undertaken in the form of a **Delphi approach** [20]. The working group contacted 110 experts in the sport technology field to review and comment on the draft framework, of which 48 experts participated. This expert panel was selected to **represent key stakeholder groups**, including: sports governing bodies and leagues, teams, practitioners, athletes, manufacturers, investors, educators, researchers, and consultants. Members of the working group also presented the draft framework at the Sports Tech Research & Innovation Summit (STRN, Ghent, Belgium, September 2022) and the Federation Internationale de Football Association (FIFA) Research Symposium (Zurich, Switzerland, October 2022). Following the first round of expert feedback, the working group convened to revise the framework. The revised framework was then submitted to the expert panel again for review until **consensus** (Agreement > 75%) was reached **on all aspects** of the framework [21].

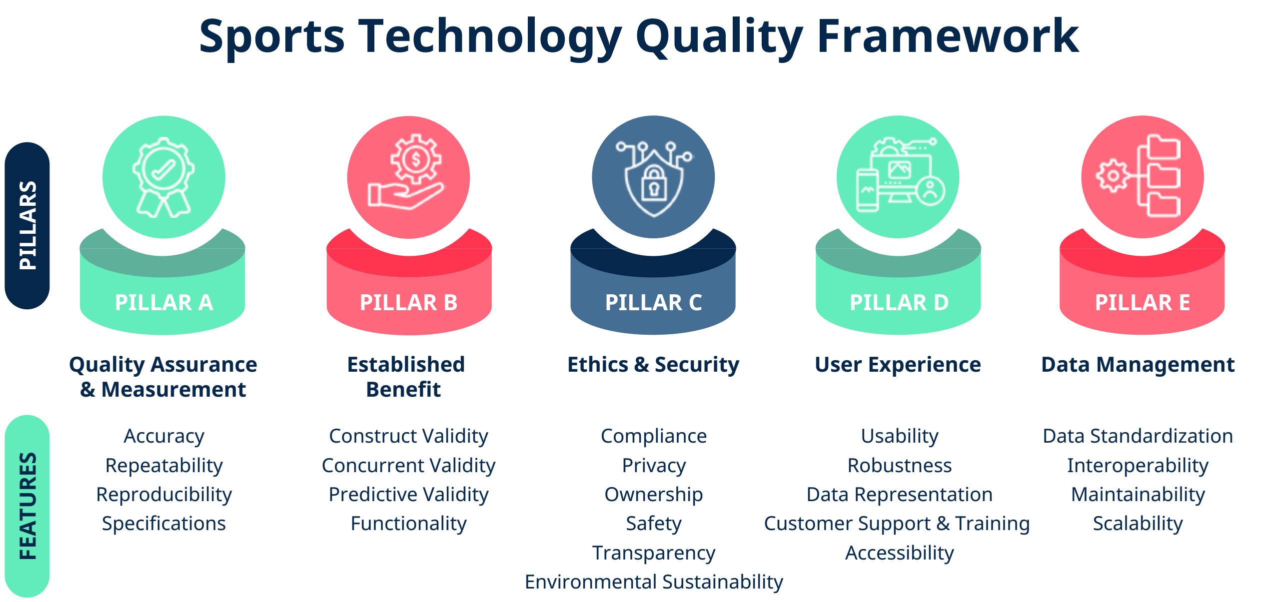


Figure 3. The Sports Technology Quality Framework

The framework is structured in two levels:

1. **Pillars:** Five high-level groupings of similar quality features
2. **Features:** Unique measurable aspects of quality of a sports technology

The following **tables** describe and define the features for each pillar, along with relevant practical examples.

Pillar A: Quality Assurance & Measurement

FEATURES	DEFINITION	PRACTICAL EXAMPLE #1 Athlete tracking (EPTS) in football	PRACTICAL EXAMPLE #2 Wrist-worn heart rate monitor in youth track and field (athletics)
#1 ACCURACY	The extent to which the tech's output relates to a current gold standard for similar measurement	Level of agreement for outputs such as velocity or position with passive optical marker-based motion capture (i.e., gold standard)	Mean absolute error between heart rate reported by tech and that measured with electrocardiogram (ECG)
#2 REPEATABILITY	The extent to which the tech's output remains the same under similar test conditions; including procedure, users, measuring system, operating conditions and location, and replicated on the same or similar objects over a short period of time	The ability of a person traveling on an identical path at a known velocity to be tracked by the system on repeated instances	The ability to measure heart rate with an accuracy similar to gold standard during a running trial at the same speed with the same individual, two days apart
#3 REPRODUCIBILITY	The extent to which the tech's outputs of the same measure remain the same when carried out under changed conditions of measurement. These conditions may include but are not limited to: user; device or device components; location; condition of use; and time. Inter-rater reliability (different users) and stability (extended time-period, such as multiple months or a season) are considered components of reproducibility	Differences in distance measurements calculated by a GPS system when operated by two different human users	Change in the output of heart rate on a smartwatch compared to gold standard when utilized by users of varying skin melanin content
#4 SPECIFICATIONS	Specifications of the tech such as its capacity, sample rate and dimensions are clearly available to the user	Global Positioning sampling and reporting rate of 10 HZ, accelerometer sampling rate of 1000 Hz and range of +/-16 g and reporting rate of 100 Hz, gyroscope sampling rate of 100 Hz and range of 2000 deg/s; and 6-hour battery life	Tech specifications indicate the watch dimensions, weight, water resistance, which types of optical sensors are used, heart rate reporting frequency and duration, whether it is reported in activity or resting or continuously, whether automatic or user-triggered, communication protocol, and battery life with and without heart rate tracking engaged

Pillar B: Established Benefit

FEATURES	DEFINITION	PRACTICAL EXAMPLE #1 Athlete tracking (EPTS) in football	PRACTICAL EXAMPLE #2 Wrist-worn heart rate monitor in youth track and field (athletics)
#5 CONSTRUCT VALIDITY	Ability of tech output to measure a specific area of interest, and/or differentiate between various groups or conditions	Data from the tech reveals that midfielders run further distance in a game of professional football comparative to strikers	Ability to differentiate illness status of athletes using tech's resting heart rate measure
#6 CONCURRENT VALIDITY	Extent to which the tech output relates to a previously validated measure administered at the same time	Velocity output from a GNSS-based system showing good agreement with an optical tracking system	Relationship between tech output (e.g., heart-rate based training impulse response/TRIMP) and athlete session rating of perceived exertion (RPE) measured at the same time is established
#7 PREDICTIVE VALIDITY	Output from the tech has been shown to predict outcome of a future state	High-speed running metric shown to predict creation of a scoring opportunity in team sport	A decrease in heart rate recovery time following standardized running intervals predicts faster 800 m time
#8 FUNCTIONALITY	The capability of the tech to provide functions which meet stated and implied needs, when the tech is used under specified conditions. Includes clear stating of intended limitations and delimitations	Information stating that a global positioning system should not be used with fewer than X satellites	Provider clearly states that wrist-based heart rate sensor should only be used to measure heart rate variability when at rest, and not during activity

Pillar C: Ethics & Security

FEATURES	DEFINITION	PRACTICAL EXAMPLE #1 Athlete tracking (EPTS) in football	PRACTICAL EXAMPLE #2 Wrist-worn heart rate monitor in youth track and field (athletics)
#9 COMPLIANCE	The extent to which the tech is aligned with relevant laws and regulation	The system complies with all relevant regulatory bodies from governments to leagues and clubs	Complies with World Athletics C2.1 6.4.4 if used during international competition
#10 PRIVACY	Extent to which the confidentiality of, and access to, certain information about the user is protected	Privacy statement is provided and readily available, along with a list of those with access to the data	Personal information stored in the cloud is subjected to security and privacy controls in line with applicable best practices
#11 OWNERSHIP	The ability to access, create, modify, package, derive benefit from, sell or remove outputs from the tech, as well as the right to assign these access privileges to others, is clearly defined	The tech provider clearly articulates customer vs. manufacturer's rights over the data	Users can grant or rescind access to all or parts of data to other stakeholders
#12 SAFETY	Freedom from conditions that can cause death, psychological or physical injury, occupational illness, damage to or loss of equipment or property, or damage to the environment	A global positioning system is assessed for its potential to cause injury during a fall	Watch is assessed for compatibility of its materials with human skin, potential to cause skin irritation, allergic reaction, burns or other injury or discomfort, when worn as instructed
#13 TRANSPARENCY	Recalls, transparent feature updates, honest and timely reporting available to users and governing bodies. Security vulnerabilities are reported, identified, assessed, logged, responded to, disclosed, and quickly and effectively resolved, where relevant with two-way feedback	Security breach at a professional match reported to clubs immediately	Manufacturer notifies users in a timely and clear manner of potential of a specific model of the product to cause skin burns and works with consumers to facilitate a replacement
#14 ENVIRONMENTAL SUSTAINABILITY	The ability of the tech to positively impact, or reduce negative impact to the environment through means of substitution (foster a shift from non-biodegradable and non-renewable to biodegradable and renewable), prevention (reduce or eliminate deterioration and contamination through its use or production), or efficiency (in terms of its demand on energy and resources)	Development of new hardware that uses available renewable materials and lengthens the life of the product	Watch uses improved battery technology that extends battery longevity and reduces environmental impact when disposed

Pillar D: User Experience

FEATURES	DEFINITION	PRACTICAL EXAMPLE #1 Athlete tracking (EPTS) in football	PRACTICAL EXAMPLE #2 Wrist-worn heart rate monitor in youth track and field (athletics)
#15 USABILITY	The extent to which a product can be learned and used by intended users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use	The tech's score on a scale assessing ease of use for deployment in community football	Clear instructions are provided for correct device placement and tightness, integration with mobile tablet, and subsequent data download for decision-making purposes and are understandable for both track and field coaches and youth track and field athletes
#16 ROBUSTNESS	The ability of the tech to operate correctly for its intended purpose across a wide range of operational conditions, and display a reasonable life expectancy	The ability of a global positioning-based system to function across various temperature and humidity levels	Watch performs equally across a range of workout intensities, temperature, and humidity levels. Bluetooth bandwidth and data storage permit athletes to use without carrying mobile device
#17 DATA REPRESENTATION	The interpretability, usefulness and attractiveness of methods used to represent information produced by the tech	The dashboard outputs provided by an EPTS company as rated by an end-user	Ability to represent and translate heart rate data in an efficient and succinct manner for decision-making by coaching staff
#18 CUSTOMER SUPPORT & TRAINING	The extent to which clear use guidelines are provided along with additional training and customer support	Provision of training and support information available online, along with responsive and adequately trained tech support team during live competition	Device includes 'Instructions for Use' document and 'Quick Start Guide' to enable efficient operation when used in the field. Customer service contact information is readily available and instructions online
#19 ACCESSIBILITY	The extent to which the tech is accessible and equitable to individuals from a range of different groups	Existence of a language option on the software interface that users can choose from	Tech provides indication of optimal placements for individuals with compromised upper limb function due to stroke or vascular impairments

Pillar E: Data Management

FEATURES	DEFINITION	PRACTICAL EXAMPLE #1 Athlete tracking (EPTS) in football	PRACTICAL EXAMPLE #2 Wrist-worn heart rate monitor in youth track and field (athletics)
#20 DATA STANDARDIZATION	Data is presented, available in and convertible to a standardized format(s) in line with conventions across a variety of contexts	Data is downloadable in various formats requested by end user and/or governing body	Data can be exported in a non-proprietary file type (e.g., .csv, .json)
#21 INTEROPERABILITY	Ability of the tech to physically connect to and logically communicate with another set of entities at foundational, structural, or semantic levels	Development of a high-quality and well-documented API	Ability for time-synchronous alignment of data from multiple devices and subsequent integration of said data with the user's athlete monitoring system
#22 MAINTAINABILITY	Extent to which the system's functionality remains stable with minimal disruption to the end-user whilst being upgraded, maintained, or serviced	EPTS company providing a back-up system to end user during periods of servicing	Ability for firmware/software upgrades to occur without data loss or other hindrances that may derail athlete training programs
#23 SCALABILITY	The measure of a tech's ability to increase in performance and cost in response to changes in application and system processing demands	Data output by the tech is stored on a cloud service with room for data storage and processing increases	Ability of system to analyze data from multiple training sessions uploaded from all team members' devices for efficient decision making

Recommended Use of The Quality Framework

Framework Specifications

The framework serves to provide users with an objective, systematic tool to assist their sport technology decisions. As such it is:

1. **Non-prescriptive:** The framework does not suggest that all features need to be assessed on a technology prior to use.
2. **Not defining good vs. bad:** A technology is not necessarily unsuitable for use if it does not reach a certain standard on some of the features.
3. **Inclusive:** Intentionally broad to address a wide-range of technologies and applications.
4. **Unweighted:** No pillar or feature is by default more important than another.
5. **Accessible:** Written in accessible rather than technically precise language, thereby facilitating broad use.

Feature Evaluation

Ideally, each feature should be evaluated against some criterion to determine whether it is sufficiently achieved. However, to **keep the framework broad, inclusive, and non-prescriptive**, evaluation criteria ("standards") have been excluded. Realistically, an acceptable performance for a given feature is dependent on the type of technology, the intended application, and the goals of the user (**Figure 4**). We encourage the user to consider the following sources of input within the context of their specific purpose:

1. **Relevant test standards**
2. **Practical knowledge**
3. **Relevant scientific literature**
4. **Known practical requirements**

Planning has begun on future work to support the development of evaluation standards and also to establish a repository of online resources.

Customizing Strategies for Implementation

We encourage users to **begin with the entire framework and adapt** it to their specific purpose. For example, all features of Pillar A: Quality Assurance & Measurement may be of critical importance for in-shoe pressure sensors, but low applicability to an athlete management system. Likewise, the degree of construct validity that is meaningful will likely differ between a professional football club and an Under 14 developmental squad.

Framework Application Example

			Tech #1	Tech #2	Tech #3	Tech #4
A	Quality Assurance & Measurement	#1 Accuracy	✓	✓	✓	✓
		#2 Repeatability	✓	✓	✗	✗
		#3 Reproducibility	✓	✗	✓	✗
		#4 Specifications	✗	✓	✗	✓
B	Established Benefit	#5 Construct Validity	✓	✓	✓	✓
		#6 Concurrent Validity	✓	✗	✓	✗
		#7 Predictive Validity	✓	✓	✗	✗
		#8 Functionality	✓	✓	✓	✓
C	Ethics & Security	#9 Compliance	✓	✓	✓	✓
		#10 Privacy	✓	✓	✓	✓
		#11 Ownership	✗	✗	✓	✓
		#12 Safety	✓	✓	✓	✓
		#13 Transparency	✓	✓	✗	✓
		#14 Environmental Sustainability	N/A	N/A	✓	✗
D	User Experience	#15 Usability	✓	✓	✓	✓
		#16 Robustness	✓	✗	✗	✗
		#17 Data Representation	✗	✓	✓	✓
		#18 Customer Service & Training	✓	✓	✓	✗
		#19 Accessibility	✓	N/A	✗	N/A
E	Data Management	#20 Data Standardization	✗	✗	N/A	✓
		#21 Interoperability	✗	✗	✓	✓
		#22 Maintainability	✓	✓	✗	✓
		#23 Scalability	✓	✓	✓	N/A

Figure 4. Benchmarking assessment of four different providers of a single technology. Some features are uniformly passed, some are uniformly failed, but most vary between passed or failed depending upon the application.

Overall, users should select the pillars and features most relevant to their needs. Other pillars and features can be ignored, assigned lower weight, or organized into a "gatekeeper" model, where they are not part of initial screening but may still block or qualify the extent of final implementation (**Figure 5**).

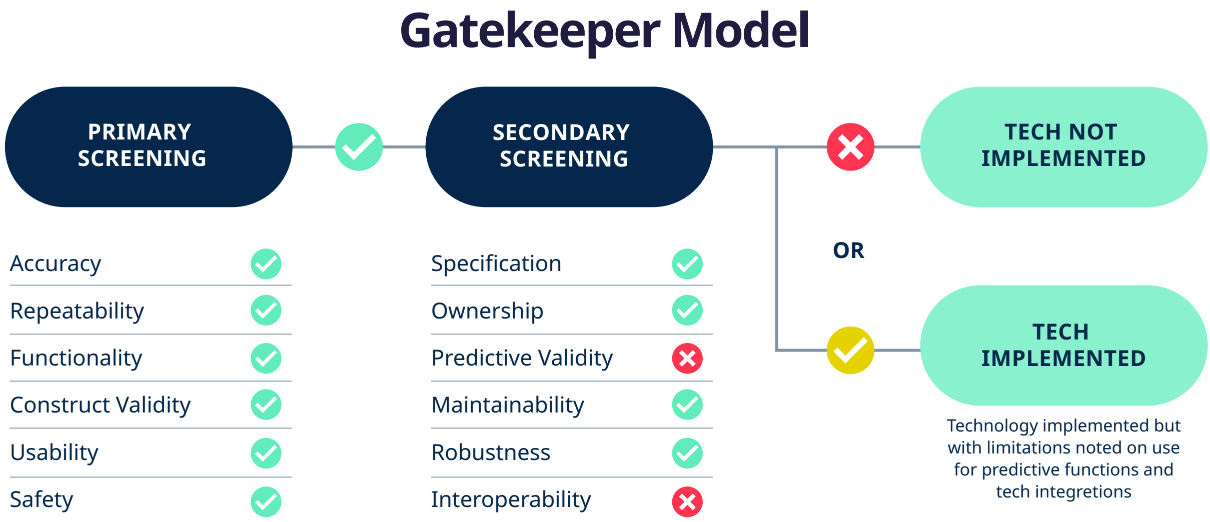


Figure 5. Example of gatekeeper model example applied to a sports tech device or metric where the user decides whether the technology is not implemented, or implemented with limitations on specific functionalities

Providing a Common Language

The framework will lay a foundation for a common language for organizations, manufacturers, investors and consumers to communicate and discuss the value of sports technology. The features described and defined in this framework can support unambiguous communication of the evidence and value of tech, for use cases ranging from a start-up company pitching to a sports league to a team looking to upgrade or purchase new technology. This communication flags which features exist and which are lacking, creating clear and mutual understanding between all parties including the end user, thus **supporting effective decision-making in the development and adoption** of fit-for-purpose sports technology.

Next Steps

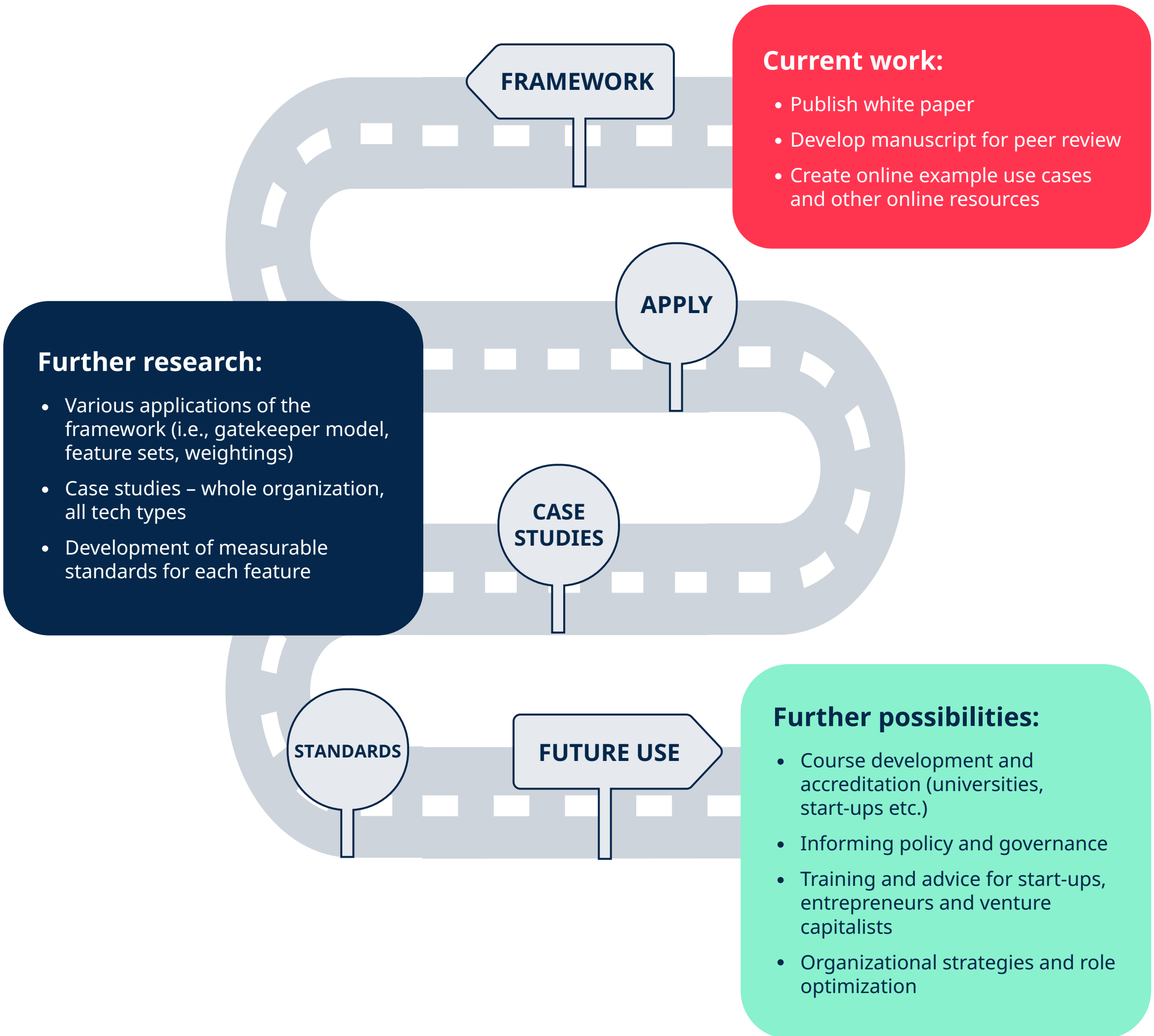
This framework represents an incremental, yet important step, toward improving the quality of sports technology. An accompanying scientific manuscript will shortly be submitted to a peer-reviewed journal. Furthermore, our next steps to improve and advance the framework over the coming year include:

1. **Case studies and framework validation**: To test the framework, it will be implemented for specific technology questions of selected partner organizations. These case studies will be published, and lessons learned will be used to validate and improve the framework.

2. **Implementation strategies**: Various implementation sequences such as the examples (see "Customizing Strategies for Implementation") will be explored and developed in the course of research and industry partnerships.

3. **Centering of standards**: While this framework is not intended to be prescriptive, it is expected many features will eventually accrue typical standards (e.g., minimum standards, gradings, pass/fail cutoffs) for specific technology types.

4. **Course development and accreditation**: The need for literacy in determining the quality of technology will continue to grow. Opportunities with governing bodies and tertiary institutions to offer formal education in this and related areas are being actively explored.
5. **Informing policy and governing bodies**: It is anticipated that governing bodies will use the framework to inform policy and technology adoption for specific leagues and competitions. The working group is available as partners to guide this process.
6. **Entrepreneur education:** Training materials and advising services are being considered to improve the technical support provided to start-ups, entrepreneurs, and venture capitalists.
7. **Organizational decision-making:** Organizations may improve their strategizing, such as optimizing the roles of their staff, by using the framework.



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Endnotes

[1] L. Torres-Ronda and X. Schelling, “Critical Process for the Implementation of Technology in Sport Organizations,” Strength Cond. J., vol. 39, no. 6, pp. 54–59, Dec. 2017, doi: 10.1519/SSC.0000000000000339.

[2] J. Windt, K. MacDonald, D. Taylor, B. D. Zumbo, B. C. Sporer, and D. T. Martin, “‘To Tech or Not to Tech?’ A Critical Decision-Making Framework for Implementing Technology in Sport,” J. Athl. Train., vol. 55, no. 9, pp. 902–910, Sep. 2020, doi: 10.4085/1062-6050-0540.19.

[3] G. I. Ash et al., “Establishing a Global Standard for Wearable Devices in Sport and Fitness: Perspectives from the New England Chapter of the American College of Sports Medicine Members,” Curr. Sports Med. Rep., vol. 19, no. 2, pp. 45–49, Feb. 2020, doi: 10.1249/JSR.0000000000000680.

[4] K. Trabelsi, A. S. BaHammam, H. Chtourou, H. Jahrami, and M. V. Vitiello, “The good, the bad, and the ugly of consumer sleep technologies use among athletes: A call for action,” J. Sport Health Sci., Mar. 2023, doi: 10.1016/j.jshs.2023.02.005.

[5] D. Patel, D. Shah, and M. Shah, “The Intertwine of Brain and Body: A Quantitative Analysis on How Big Data Influences the System of Sports,” Ann. Data Sci., vol. 7, pp. 1–16, Mar. 2020, doi: 10.1007/s40745-019-00239-y.

[6] B. T. Naik, M. F. Hashmi, and N. D. Bokde, “A Comprehensive Review of Computer Vision in Sports: Open Issues, Future Trends and Research Directions,” Appl. Sci., vol. 12, no. 9, p. 4429, Apr. 2022, doi: 10.3390/app12094429.

[7] J. Spitz, J. Wagemans, D. Memmert, A. M. Williams, and W. F. Helsen, “Video assistant referees (VAR): The impact of technology on decision making in association football referees,” J. Sports Sci., vol. 39, no. 2, pp. 147–153, Jan. 2021, doi: 10.1080/02640414.2020.1809163.

[8] FIFA, “Standards.” 2023. Accessed: Apr. 27, 2023. [Online]. Available: https://www.fifa.com/technical/football-technology/standards

[9] D. Leung, “NBA teams banned from using wearables data in contract negotiations, player transactions.” Sports Illustrated, Feb. 02, 2017. Accessed: Apr. 27, 2023. [Online]. Available: https://www.si.com/media/2017/02/02/nba-data-analytics-new-cba-wearable-device

[10] World Rugby, “Approved Devices.” 2023. Accessed: Apr. 27, 2023. [Online]. Available: https://www.world.rugby/the-game/facilities-equipment/equipment/devices

[11] ASTM International, “Standards Products.” 2023. Accessed: Apr. 27, 2023. [Online]. Available: https://www.astm.org/products-services/standards-and-publications/standards.html

[12] Consumer Technology Association, “Standards.” 2021. Accessed: Apr. 27, 2023. [Online]. Available: https://shop.cta.tech/collections/standards/health-and-fitness

[13] *Health software — Part 2: Health and wellness apps — Quality and reliability*, ISO/TS 82304-2:2021, Jul. 2021.

[14] State of Victoria, Australia, Department of Health, “Digital health capability framework for allied health professionals.” Victorian Government, Dec. 2021. Accessed: May 01, 2023. [Online]. Available: https://www.health.vic.gov.au/sites/default/files/2021-12/digital-health-capability-framework-for-allied-health-professionals.pdf

[15] The Digital Medicine Society (DiMe), "The Playbook - Digital Clinical Measures." 2023. Accessed: Apr. 28, 2023. [Online]. Available: https://playbook.dimesociety.org

[16] J. M. Mühlen et al., "Recommendations for determining the validity of consumer wearable heart rate devices: expert statement and checklist of the INTERLIVE Network," Br. J. Sports Med., vol. 55, no. 14, pp. 767–779, Jul. 2021, doi: 10.1136/bjsports-2020-103148.

[17] C. J. Ringuet-Riot, A. Hahn, and D. A. James, "A structured approach for technology innovation in sport," Sports Technol., vol. 6, no. 3, pp. 137–149, Aug. 2013, doi: 10.1080/19346182.2013.868468.

[18] S. Robertson, A. F. Burnett, and J. Cochrane, "Tests Examining Skill Outcomes in Sport: A Systematic Review of Measurement Properties and Feasibility," Sports Med., vol. 44, no. 4, pp. 501–518, Apr. 2014, doi: 10.1007/s40279-013-0131-0.

[19] G. I. Ash et al., "Establishing a Global Standard for Wearable Devices in Sport and Exercise Medicine: Perspectives from Academic and Industry Stakeholders," Sports Med., vol. 51, pp. 2237–2250, Nov. 2021, doi: 10.1007/s40279-021-01543-5.

[20] F. Hasson, S. Keeney, and H. McKenna, "Research guidelines for the Delphi survey technique: Delphi survey technique," J. Adv. Nurs., vol. 32, no. 4, pp. 1008–1015, Oct. 2000, doi: 10.1046/j.1365-2648.2000.t01-1-01567.x.

[21] I. R. Diamond et al., "Defining consensus: A systematic review recommends methodologic criteria for reporting of Delphi studies," J. Clin. Epidemiol., vol. 67, no. 4, pp. 401–409, Apr. 2014, doi: 10.1016/j.jclinepi.2013.12.002.

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