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Research Article

Advancing Assessment Skills and Interventions for Para Athletes in Paraswimming and Other Sports: Integrating Technology and Novel Assistive Devices

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Abstract - *Para sports continue to evolve with increasing emphasis on evidence-based methods for athlete assessment and classification. Traditional techniques such as manual strength testing and qualitative movement analysis often lack objectivity and reliability, particularly in technically complex sports such as paraswimming. This paper presents a comprehensive evaluation of emerging technologies, including underwater motion capture, action-camera systems, instrumented strength and coordination tests, and inertial measurement units (IMUs) that offer enhanced accuracy, reproducibility, and sport-specific insight. A synthesis of sixteen studies spanning paraswimming, wheelchair sports, and para-football demonstrates clear improvement in measurement of impairment-based activity limitations. Despite this progress, barriers regarding methodological standardisation, accessibility, and cost remain. The review identifies future priorities including harmonised protocols, technological integration pathways, and frameworks that ensure fairness and global equity in classification.*

Keywords - *Assistive Devices, Biomechanics, Classification, IMUs, Parasports, Paraswimming, Technology Integration.*

I. INTRODUCTION

The Paralympic movement has grown rapidly over the past three decades, evolving into a highly professionalised sporting arena that continues to attract global attention and increasing participation. With this growth comes a pressing need for robust, fair, and evidence-based systems to evaluate and classify athletes with impairments. Assessment and classification lie at the heart of this endeavor, as they determine both athlete eligibility and competitive equity across parasports [1]. For para athletes, accurate assessment is not merely a matter of fairness, but also informs training, rehabilitation, and long-term performance development.

Despite significant progress, current classification and assessment approaches in parasports still have their limitations and continue to face challenges. Conventional assessment method such as manual strength testing, range of motion (ROM) batteries, and functional skill assessments have been widely adopted, yet they are often questioned from issues of subjectivity, questionable variability among classifiers, and limited validity [2]. These limitations become particularly apparent in sports such as swimming, where the interplay of neuromuscular function, coordination, and fluid mechanics creates complex demands that cannot be fully captured by land-based tests and observation alone.

Paraswimming provides a unique case study for examining the limitations of current methods due to its complexity in classification assessment. Athletes can present with a wide range of eligible impairments, including hypertonia, ataxia, athetosis, limb deficiency, and spinal cord injury [3]. Traditional field-based tests struggle to account for how these impairments interact with stroke mechanics, propulsion efficiency, and buoyancy in an aquatic environment, which are important elements in paraswimming. For instance, existing motor coordination tests used in paraswimming classification have been criticised for their subjectivity and lack of sensitivity in differentiating between levels of impairment [4]. As a result, classification decisions may vary and be inconsistent, which directly influences competitive fairness.

Advances in sports technology offer promising avenues to address these challenges. An example is inertial measurement units (IMUs), which are devices that combine accelerometers and gyroscopes to be used in sports for motion analysis, providing portable and relatively affordable tools for biomechanical assessment [5].

In paraswimming, IMUs attached to the limbs can capture stroke timing, velocity, and coordination, providing objective data that can complement or replace subjective observations. Similarly, optical motion capture systems, often regarded as the "gold standard" for biomechanical research, deliver high accuracy in quantifying movement but remain costly for widespread implementation in sport-specific contexts [6].

Recently, action cameras and computer vision–based tools have become more popular focuses and have been explored as possible alternatives. These approaches can track underwater stroke patterns and joint kinematics, potentially offering federations a cost-effective way to integrate technology into routine assessments in the long run [7].

Similarly, underwater 3D kinematics can provide a direct window into swimming biomechanics without any obstruction of view, allowing for detailed analysis of coordination and propulsion patterns that traditional land-based testing cannot reveal [8].

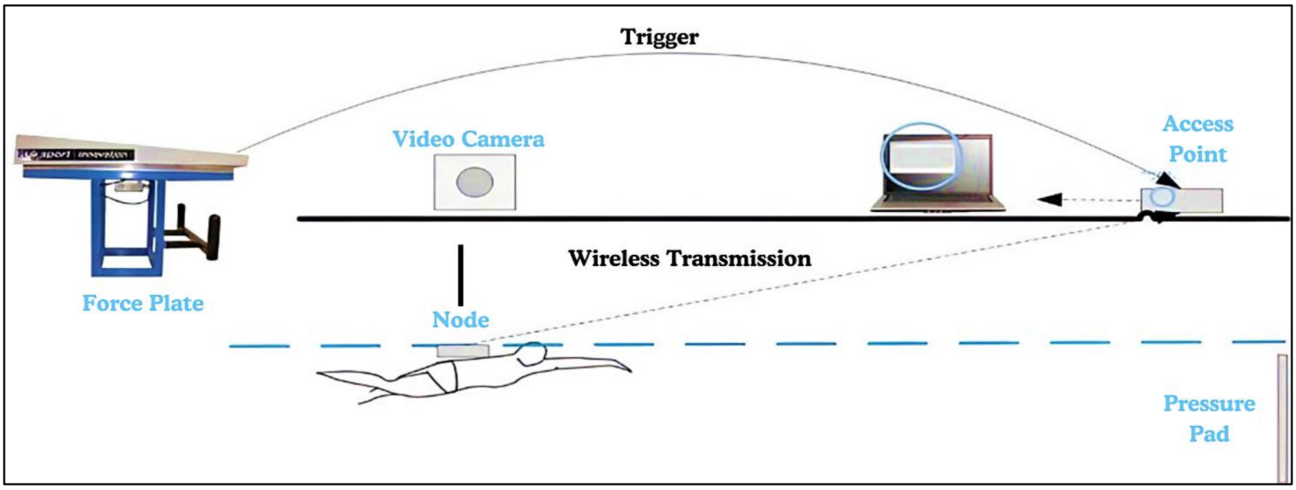

Figure 1: Synchronized System Utilising a High Speed Camera to Track Underwater Stroke Patterns [7]

In addition to methods for assessments, innovations in technology and assistive devices are increasingly shaping interventions for para-athletes. Adaptive resistance training equipment, wearable exoskeletons, and biofeedback systems are being applied in both rehabilitation and sports performance training [9].

These tools not only support strength and motor learning but may also improve movement efficiency. However, their use raises controversies around accessibility, cost, and the potential for unfair advantage if not carefully regulated within international classification frameworks [10].

The current International Paralympic Committee (IPC) calls for an "evidence-based classification", which emphasises the integration of scientific data into classification protocols [1]. While promising technologies exist, there remains a lack of consensus on how best to utilise, standardise, and implement them across different sports and impairment groups. Paraswimming exemplifies this tension as it stands to benefit greatly from objective, technology-supported assessments, yet practical and financial barriers limit immediate adoption of these technologies [11].

II. METHODOLOGY

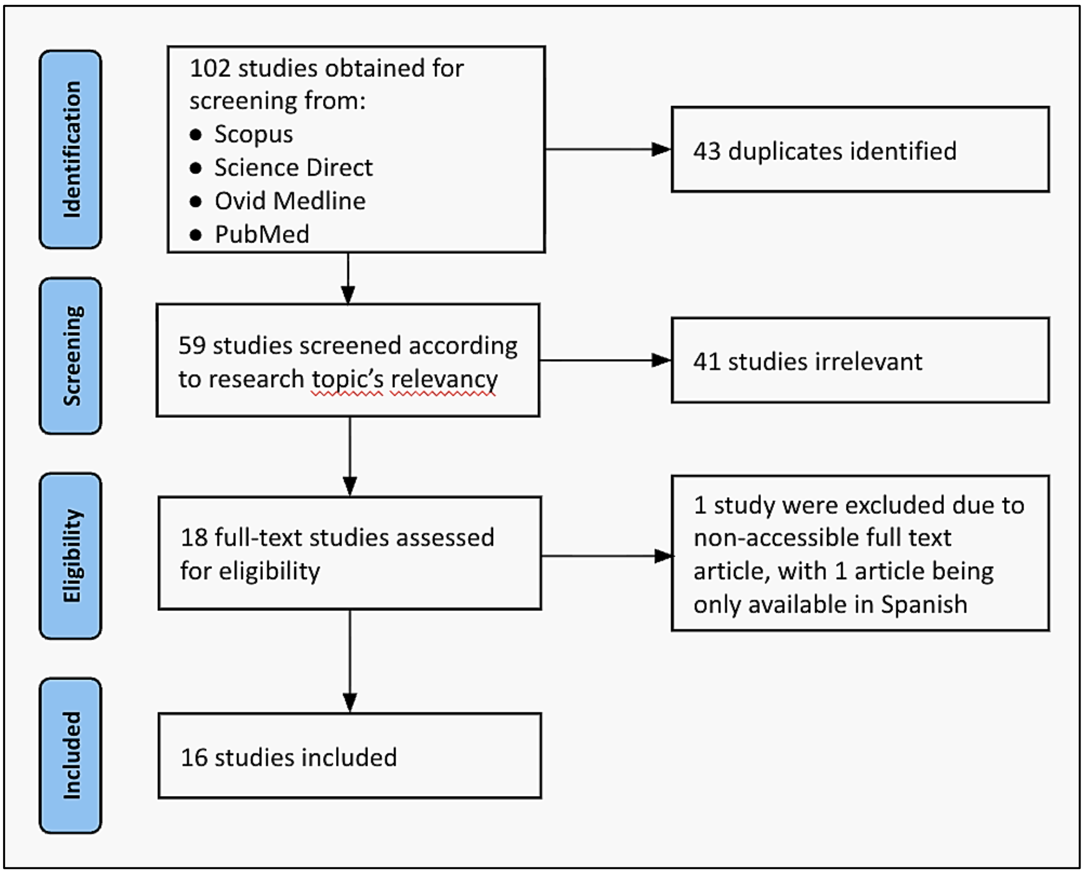

Figure 2: PRISMA Chart Illustrating the Selection Process of Relevant Articles for Review

A. Search Strategy

A comprehensive search on articles published between 2010 to 2025 on assessment tools, technological innovations, and assistive devices with a particular focus on paraswimming but also extending to other parasports was conducted across databases like Scopus, Science Direct, Ovid Medline and PubMed. Search terms were tailored to each database and combined using Boolean operators like "AND" and "OR". Keywords utilised in the search include "Parasports", "Para-athletes", "Paraswimming", "Classification Process", "Assessment", "Technology" and "Assistive Devices".

B. Inclusion Criteria

English-written articles involving technology or assistive devices in improving classification processes of para athletes in paraswimming or other sports were included. Additionally, studies proposing alternative objective assessment methods for improving the classification of para athletes were also included.

C. Exclusion Criteria

Studies that did not report measurable outcomes related to performance, assessment, classification, or intervention efficacy, or those lacking an English version were excluded.

D. Number of Articles Yielded

A total of 16 relevant articles were included and analysed in this study.

III. RESULTS

This review synthesised 16 studies and position stands spanning paraswimming, wheelchair sports, para-football, and vision impairment. Collectively, these studies illustrate advances in evidence-based classification through sport-specific assessment batteries, motion analysis, wearable sensor technologies, and systematic frameworks. The findings are organised and summarised as below.

Table 1. Summary of Results of Reviewed Articles

Study Title	Proposed Intervention and Research Outcomes	Author
A Battery of Strength Tests for Evidence-Based Classification in Para-swimming	Developed an objective isometric strength-testing battery using load cells to support evidence-based classification in paraswimming, Demonstrated high reliability and strong ability to differentiate impairment levels, with strength measures correlating to swimming velocity.	Hogarth et al. [2018]
Establishing the Reliability of a Novel Bettery of Range of Motion Tests to Enable Evidence-based Classification in Para Swimming	Created a swimming-specific active ROM test battery targeting key stroke-related joints. Tests showed good intra- and inter-rated reliability and helped distinguish movement limitations relevant to paraswimming classification.	Nicholson et al. [2018]
Using Underwater 3D Kinematics to Improve the Paralympic Swimming Classification System	Used underwated 3D motion capture to analyse stroke symmetry and propulsion in a para swimmer with hemiplegia. Identified impairment-related asymmetries, demonstrating the value of biomechanical assessment for classification.	Burkett et al. [2018]
Simultaneous In-Air and Underwater 3D Kinematic Analysis of Swimmers: Feasibility and Reliability of Action Sport Cameras	Evaluated a synchronized above and underwated action-camera system for 3D kinematic analysis. Found the low-cost setup to be feasible and reliable for field-based assessment of swimming technique and asymmetry.	Bernadina et al. [2024]
Improving the Objectivity of the Current World Para Swimming Motor Coordination Test for Swimmers with Hypertonia, Ataxia and Athetosis using Measures of Movement Smoothness, Rhythm and Accuracy	Improved the World Para Swimming motor coordination test by using accelerometers and video-derived measures of smoothness, rhythm, and accuracy. These objective metrics reliably distinguished swimmers with hypertonia from controls.	Maia et al. [2021]
Establishing the Reliability of Instrumented Trunk Impairment Assessment Methods to Enable Evidence-Based Classification in Para Swimming	Tested the reliability of instrumented trunk-function assessments using load cells and dynamometers. ROM and strength measures were reliable, though trunk coordination showed lower consistency.	Smith et al. [2021)
Error Assessment of a Three-Dimensional Underwater Motioncapture Methodology	Validated an IMU for wheelchair-racing propulsion analysis, showing strong agreement with a Lidar reference system. IMU metrics reliably captured propulsion characteristics and distinguished athletes of different ability levels.	Thompson et al. [2025)
Validity and Reliability of Inertial Motion Unit-Based Performance Metrics During Wheelchair Racing Propulsion	Used IMUs to measure propulsion patterns in wheelchair badminton players. Temporal and kinematic differences between WH1 and WH2 classes suggested that current classification groups may be too broad.	Ouellet et al. [2025]
Trying to Use Temporal and Kinematic Parameters for the Classification in Wheelchair Badminton	Collected real-world mobility data using wheelchair-mounted IMUs. Demonstrated that IMUs accurately measured distance, velocity, turning, and slope, supporting their use for ecological assessment and classification.	Alberca et al. [2025]
Real-Life Wheelchair Mobility Metrics from IMUs	Developed a method to estimate wheelchair frame rotation using a single wheel-mounted IMU. Produced highly accurate results compared to a frame-mounted reference sensor, offering a practical, low-cost field solution.	de Vries et al. [2023]

A Simple and Valid Method to Calculate Wheelchair Frame Rotation Using One Wheel-Mounted IMU	Systematic review of wheelchair-sport classification tools. Found moderate support for isometric strength tests and emerging evidence for IMU-based and biomechanical measures, but highlighted inconsistency across studies.	Klimstra et al. [2023]
Evidence-Based Classification in Wheelchair Sports: A Systematic Review	Validated a dribbling-based change-of-direction test battery for para-footballers with cerebral palsy. Tests showed excellent reliability and discriminated effectively between impairment groups.	Sá et al. [2023]
Validity and Reliability of a Test Battery to Assess Change of Directions with Ball Dribbling in Para-footballers with Cerebral Palsy	Systematic review of impairment-performance relationships across parasports. Identified strength and coordination tests as consistently meaningful measures but emphasized the need for more reliable, sport-specific tools.	Daniel et al. [2021]
Guiding Evidence-Based Classification in Para Sporting Populations: A Systematic Review of Impairment Measures and Activity Limitations	Outlined a framework for evidence-based classification and reviewed 19 empirical studies. Highlighted progress toward data-driven systems but noted persistent gaps in reliability, validity, and standardisation.	Wileman et al. [2025]
Classifying the Evidence for Evidence-Based Classification in Paralympic Sport	IPC/IBSA position stand on vision-impairment classification. Recommended sport-specific visual-function tests beyond acuity/field measures and emphasised performance-linked eligibility criteria.	Mann et al. [2021]
International Paralympic Committee (IPC) and International Blind Sports Federation (IBSA) Joint Position Stand on the Sport-Specific Classification of Athletes with Vision Impairment	Provided a comprehensive overview of evidence quality supporting classification across parasports. Found uneven strength of evidence and called for more rigorous, performance-based validation.	Mann et al. [2018]

A. Strength and Range of Motion (ROM) Batteries

Manual strength and ROM testing remains a pillar to classification in many parasports. They are considered to be highly feasible, low cost, and has minimal equipment requirements, which make them accessible across contexts [1,2]. However, these tests are inherently subjective, heavily relies on assessor judgment, and demonstrate limited sensitivity to impairment-related performance constraints, particularly in dynamic aquatic environments [3].

B. Motor Coordination Tests

In paraswimming, motor coordination assessments are particularly relevant for athletes with neurological impairments such as hypertonia, ataxia, or athetosis. The World Para Swimming motor coordination test is a foundational tool, however, it has been criticised for its variability and lack of objectivity[4]. Recent work has proposed quantitative measures such as movement smoothness, rhythm, and accuracy using biomechanical parameters to strengthen test reliability [4].

C. Functional Classification Frameworks

Functional classification remains widely used across parasports, with assessments designed to determine how an impairment affects performance in specific sport tasks [2,5]. While this contextual approach is aligned with the principles of evidence-based classification, functional tests continue to be affected by inter-rater variability, limited ecological validity, and challenges in distinguishing between minimal impairment categories [6].

D. Assessment Batteries in Paraswimming

Research in paraswimming has focused on developing valid and reliable impairment measures that can reflect function in-water. Hogarth et al. [12] introduced a battery of strength tests, demonstrating their utility in differentiating impairment levels and supporting evidence-based classification. Nicholson et al. [13] extended this work by establishing the reliability of a novel range of motion (ROM) battery, which provided more consistent outcomes compared with manual goniometry.

Motor coordination, particularly in athletes with hypertonia, ataxia, or athetosis, has been a classification challenge. Maia et al. [14] addressed this by incorporating quantitative metrics such as movement smoothness, rhythm, and accuracy into coordination tests, offering greater objectivity. Complementing these measures, Smith et al. [15] developed instrumented trunk impairment assessments, which demonstrated improved reliability compared with visual observation alone. Together, these studies highlight the progress toward more robust and standardised impairment assessments in paraswimming.

E. Motion Capture and Kinematic Approaches

High-resolution biomechanical analysis has been increasingly applied to paraswimming. Burkett et al. [16] showed that underwater 3D kinematics could identify impairment-related stroke characteristics, offering direct links between impairment and activity limitation. Bernadina et al. [17] tested the feasibility of combining in-air and underwater 3D kinematics using action sport cameras, achieving acceptable reliability at lower costs compared with laboratory systems.

Technical validation remains critical. Thompson et al. [18] assessed the error in a 3D underwater motion capture methodology, identifying sources of inaccuracy such as refraction and marker occlusion. These findings underline the potential of kinematic systems for classification, while highlighting the need for standardised protocols and improved calibration to ensure widespread applicability.

F. Wearable Technologies in Wheelchair Sports

Wearable inertial measurement units (IMUs) have emerged as portable tools for impairment assessment across parasports. Ouellet et al. [19] confirmed the validity and reliability of IMU-derived metrics during wheelchair racing propulsion, demonstrating strong correlations with performance. Similarly, Alberca et al. [20] explored temporal and kinematic IMU parameters in wheelchair badminton, showing their feasibility for classification but noting the need for further validation in competition settings.

Expanding to real-world monitoring, de Vries et al. [21] applied IMUs to quantify wheelchair mobility metrics in daily environments, supporting ecological validity. Klimstra et al. [22] advanced this by proposing a simple method to calculate wheelchair frame rotation using a single wheel-mounted IMU, offering an efficient, low-cost approach to functional assessment.

These findings collectively support the integration of IMUs into classification protocols, while emphasising the importance of data standardisation and translation of sensor-derived outputs into impairment–performance relationships.

G. Evidence from Systematic Reviews and Position Stand

Several reviews and position statements provide the broader conceptual foundation for evidence-based classification. Sá et al. [23] conducted a systematic review of wheelchair sports, finding strong support for IMU-based approaches but highlighting gaps in standardisation. In para-football, Daniel et al. [24] validated a test battery assessing change of direction and ball dribbling in athletes with cerebral palsy, showing that sport-specific tasks can align with impairment-related performance limitations.

At a broader level, Wileman et al. [25] systematically reviewed impairment measures and activity limitations across parasports, concluding that while tools are emerging, methodological inconsistencies remain a barrier. Mann et al. [26] reinforced this in their review, classifying the evidence for evidence-based classification as uneven across sports and impairments.

The IPC and International Blind Sports Federation (IBSA) joint position stand written by Mann et al. [27] further emphasised the importance of tailoring classification frameworks to the functional demands of specific sports, particularly for vision impairment.

H. Cross-Sport Comparisons

Taken together, the included studies illustrate both progress and challenges. In paraswimming, strength, ROM, coordination, trunk function, and kinematic analyses provide increasingly objective measures but remain resource-intensive and, in some cases, limited to laboratory contexts [12,13,14,15,16,17,18]. Wheelchair sports research demonstrates that IMUs can offer valid, scalable alternatives, with potential transferability to aquatic sports if waterproofed or adapted [19,20,21,22]. Systematic reviews and position stands stress the need for harmonization, cross-validation, and sport-specific frameworks [23,24,25,26,27].

I. Summary of Findings

The evidence base across these 16 studies demonstrates a shift toward more objective, technology-enabled approaches to classification. In paraswimming, validated strength, ROM, coordination, and trunk assessments are increasingly complemented by advanced biomechanical analyses [12,13,14,15,16,17,18]. Wheelchair sport research illustrates the practical application of wearable IMUs, offering real-world monitoring and scalable assessment [19,20,21,22]. Broader reviews and position statements underscore the necessity of harmonization, sport-specificity, and fairness [23,25,26,27]. Despite this progress, methodological inconsistencies, cost barriers, and limited cross-sport validation remain pressing challenges to fully realizing evidence-based classification.

IV. DISCUSSION

This review synthesises evidence across paraswimming, wheelchair sports, para-football, and vision impairment, situating the findings within broader sport science and parasport research. The collective body of work demonstrates a progressive shift from observational and subjective classification methods toward objective, technology-supported approaches. However, significant challenges remain, particularly in terms of methodological consistency, ecological validity, and equitable access to technology.

Paraswimming has emerged as a leader in evidence-based classification innovation. Multiple validated test batteries have been developed to quantify impairment in terms of strength, range of motion (ROM), motor coordination, and trunk impairment [12,13,16,17]. These studies demonstrate good reliability, marking a departure from traditional systems reliant on subjective visual inspection. Importantly, such batteries provide metrics that can be linked directly to performance outcomes, aligning classification with the International Paralympic Committee's (IPC) requirement for sport-specific, evidence-based systems [16,18].

Biomechanical technologies complement these batteries. Three-dimensional (3D) underwater motion capture has been applied to link impairment with stroke mechanics [14,18], while action sport cameras have enabled simultaneous in-air and underwater kinematic analysis [15]. These tools provide fine-grained insights into propulsion and stroke timing, enhancing the ecological validity of classification. Yet, studies also highlight methodological issues, such as calibration, refraction correction, and error variability that complicate implementation [18]. This reflects broader biomechanical concerns raised by Preatoni et al. [28] and Camomilla et al. [29] regarding the trade-offs between precision and field applicability.

Together, these paraswimming studies illustrate the feasibility of combining strength and coordination tests with biomechanical assessments, creating a multidimensional classification framework. However, resource intensity and expertise requirements present barriers to global implementation. Research in wheelchair sports demonstrates how portable, wearable technologies can support classification in field settings. Inertial measurement units (IMUs) have been validated across a variety of applications, including racing propulsion, temporal and kinematic analysis in badminton, ecological mobility metrics, and frame rotation measurement [19,20,21,22]. These devices are lightweight, cost-effective, and capable of capturing performance-relevant data in real time.

Systematic reviews confirm that IMUs are both reliable and valid for assessing impairment-related limitations [23], echoing findings from mainstream sport and rehabilitation research [30,31]. The portability of IMUs positions them as strong candidates for integration into classification systems, especially in contrast to resource-heavy motion capture setups [8]. However, Sá et al. [23] caution that inconsistencies in methodology and data processing limit comparability across studies, a concern mirrored in the broader wearable technology literature [29,31].

Para-football research provides another example of sport-specific validation. Daniel et al. [24] demonstrated that a test battery for players with cerebral palsy reliably linked impairments to performance in change of direction and dribbling tasks. This reinforces the necessity of sport-specific systems and aligns with principles articulated in the IPC position stand [2].

The International Blind Sports Federation (IBSA) and IPC joint position stand [27] established a framework for evidence-based classification in vision impairment, emphasising sport-specific functional measures. Ravensbergen et al. [32] further advanced this by using Delphi methods to achieve expert consensus on assessment priorities. Together, these works highlight the balance required between clinical measures such as visual acuity and performance-oriented tests like glare sensitivity in competition conditions. These insights are transferable to other impairment categories, stressing the principle that classification systems must reflect real-world sporting demands.

Systematic reviews provide an important reality check. Wileman et al. [25] and Mann et al. [26] concluded that although progress has been made, evidence quality remains inconsistent across sports, with small sample sizes and heterogeneous outcomes undermining generalisability. Similar conclusions were drawn by Mutlu et al. [33], who called for integrating impairment measures with activity limitation and sport performance outcomes.

These challenges mirror broader concerns in parasport biomechanics. Rajan et al. [35] noted that while advances in measurement technology can enhance performance analysis, they also risk fragmenting research efforts when studies are conducted in isolation. Goosey-Tolfrey and Leicht [34] similarly emphasised the need for harmonised protocols in wheelchair athlete testing. Without cross-sport validation, the risk remains that classification systems will evolve in silos, limiting transferability and comparability.

Despite technological promise, practical and ethical challenges must be addressed. Motion capture systems, while precise, require expensive infrastructure and expertise [14,15,18], making them impractical for many federations. IMUs offer more feasible alternatives, but require standardisation in data collection and analysis to avoid inconsistent outcomes. [19,20,21,22,23]

Ethically, the integration of technology must align with principles of fairness. Howe and Jones [36] argued that classification can either empower or disempower athletes depending on how systems are implemented. Wealthier federations with access to cutting-edge technology may gain advantages if standardisation and accessibility are not enforced. The IPC/IBSA position stand [27] provides a framework for mitigating this risk, but implementation will require ongoing vigilance.

There is also a potential ethical dilemma around training and assistive technologies. For example, exoskeletons or robotic aids used in rehabilitation could theoretically alter impairment profiles, raising questions about how to ensure fair classification if impairments are modified by intervention. While not yet addressed in the reviewed studies, this is an emerging area requiring attention.

V. FUTURE DIRECTION AND SUGGESTIONS

From this synthesis there are three priorities to be addressed. The first is the standaridisation of protocols. For instance, the harmonisation of IMU calibration, motion capture methodologies, and test batteries is essential for comparability across studies and sports [23,25,26]. The next focus is to establish accessible integration of technology. Building on the feasibility of IMUs, classification should prioritise tools that balance accuracy with affordability and portability [19,20,21,22].

Lessons from wearable sports science show that simple metrics can often yield valid outcomes when protocols are standardized [29,31]. Lastly, policies must ensure that technology enhances rather than undermines the integrity of parasport and to ensure equity and fairness. Following principles articulated by Howe and Jones [36], classification frameworks should include guidelines for equitable access and implementation.

VI. CONCLUSION

This report has examined current evidence on advancing assessment skills and interventions for para athletes, with a primary focus on paraswimming and complementary insights from other sports. The findings highlight a clear trajectory toward evidence-based classification systems that move beyond subjective observation to embrace objective, reliable, and sport-specific measures.

In paraswimming, validated test batteries for strength, range of motion, motor coordination, and trunk control provide robust foundations for linking impairment to performance. Complementary biomechanical approaches, such as 3D underwater kinematics and action-camera analysis, add detailed insights into propulsion and stroke mechanics. Wheelchair sports research illustrates how inertial measurement units (IMUs) can deliver portable, field-ready data on propulsion, kinematics, and mobility, while para-football demonstrates the feasibility of sport-specific functional test batteries. Vision impairment classification, guided by IPC and IBSA consensus statements, reinforces the principle that ecological validity and fairness must underpin all classification systems.

Despite these advances, challenges remain. Evidence quality is uneven across sports, with small samples and heterogeneous outcomes limiting generalisability. Resource-intensive methods such as motion capture, while precise, are impractical for global adoption, whereas IMUs and other wearable technologies, though promising, require methodological standardisation. Ethical considerations, particularly the equitable distribution of technology and avoidance of systemic bias, are critical for safeguarding fairness.

Moving forward, priorities should include cross-sport standardisation, integration of accessible technologies, and multicentre collaborations to strengthen evidence bases. Equally important is embedding fairness and inclusivity in policy, ensuring that advances in technology benefit athletes across diverse contexts. By addressing these challenges, the Paralympic movement can deliver classification systems that are not only scientifically robust but also equitable, transparent, and aligned with the values of para sport.

Conflicts of Interest

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests.

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VII. REFERENCES

1. International Paralympic Committee, “IPC Position Stand Background and Scientific Principles of Classification in Paralympic Sport,” *British Journal of Sports Medicine*, vol. 49, no. 6, pp. 319–324, 2015. Google Scholar | Publisher Link
2. Sean M. Tweedy, and Yves C. Vanlandewijck, “International Paralympic Committee Position Stand—Background and Scientific Principles of Classification in Paralympic Sport,” *British Journal of Sports Medicine*, vol. 45, no. 4, pp. 259–269, 2011. Google Scholar | Publisher Link
3. Floortje Morriën, Matthew J. D. Taylor, and Florentina J. Hettinga, “Biomechanics in Paralympics: Implications for Performance,” *International Journal of Sports Physiology and Performance*, vol. 12, no. 5, pp. 578–589, 2017. Google Scholar | Publisher Link
4. Luke Hogarth et al., “Classifying Motor Coordination Impairment in Para Swimmers With Brain Injury,” *Journal of Science and Medicine in Sport*, vol. 22, no. 5, pp. 526–531, 2019. Google Scholar | Publisher Link
5. Leandro Vieira et al., “Swimming Velocity Analysis Using Wearable Inertial Sensors and Speedometer: A Comparative Study,” *Bioengineering*, vol. 11, no. 8, p. 757, 2024. Google Scholar | Publisher Link
6. Julien Pansiot, Benny Lo, and Guang-Zhong Yang, “Swimming Stroke Kinematic Analysis With Body-Worn Inertial Sensors,” *IEEE Transactions on Human-Machine Systems*, vol. 48, no. 5, pp. 482–493, 2018. Google Scholar | Publisher Link
7. Tanya Le Sage et al., “Development of a Real-Time System for Monitoring of Swimming Performance,” *Procedia Engineering*, vol. 2, no. 2, pp. 2707–2712, 2010. Google Scholar | Publisher Link

8. Santiago Veiga et al., "Kinematic Analysis of the Underwater Undulatory Swimming Cycle: A Systematic and Synthetic Review," *International Journal of Environmental Research and Public Health*, vol. 19, no. 19, p. 12196, 2022. Google Scholar | Publisher Link
9. Franco Molteni et al., "Exoskeleton and End-Effector Robots for Upper and Lower Limb Rehabilitation: Narrative Review," *PM&R*, vol. 12, no. 9, pp. 932–939, 2020. Google Scholar | Publisher Link
10. Mike McNamee, Richard Parnell, and Yves Vanlandewijck, "Fairness, Technology and the Ethics of Paralympic Sport Classification," *European Journal of Sport Science*, vol. 21, no. 11, pp. 1510–1517, 2021. Google Scholar | Publisher Link
11. Sean M. Tweedy, Emma M. Beckman, and Mark J. Connick, "Paralympic Classification: Conceptual Basis, Current Methods, and Research Update," *PM&R*, vol. 8, no. S8, pp. S11–S17, 2016. Google Scholar | Publisher Link
12. Luke Hogarth et al., "A Battery of Strength Tests for Evidence-Based Classification in Para-Swimming," *British Journal of Sports Medicine*, vol. 51, no. 6, pp. 419–425, 2018. Google Scholar | Publisher Link
13. Vaughan P. Nicholson et al., "Establishing the Reliability of a Novel Battery of Range of Motion Tests to Enable Evidence-Based Classification in Para Swimming," *Physical Therapy in Sport*, vol. 32, pp. 34–41, 2018. Google Scholar | Publisher Link
14. Ana Carolina Maia et al., "Improving the Objectivity of the Current World Para Swimming Motor Coordination Test Using Measures of Smoothness, Rhythm, and Accuracy," *British Journal of Sports Medicine*, vol. 54, no. 23, pp. 1380–1386, 2021. Google Scholar | Publisher Link
15. Rachel Smith et al., "Establishing the Reliability of Instrumented Trunk Impairment Assessment Methods to Enable Evidence-Based Classification in Para Swimming," *Frontiers in Sports and Active Living*, vol. 3, p. 642951, 2021. Google Scholar | Publisher Link
16. Brendan Burkett et al., "Using Underwater 3D Kinematics to Improve the Paralympic Swimming Classification System," *Journal of Sports Sciences*, vol. 40, no. 5, pp. 575–583, 2022. Google Scholar | Publisher Link
17. Gustavo Ramos Dalla et al., "Simultaneous In-Air and Underwater 3D Kinematic Analysis of Swimmers: Feasibility and Reliability of Action Sport Cameras," *Journal of Biomechanics*, vol. 119, p. 110330, 2024. Google Scholar | Publisher Link
18. Isobel Thompson et al., "Error Assessment of a Three-Dimensional Underwater Motion Capture Methodology," *Journal of Sports Sciences*, vol. 37, no. 17, pp. 2003–2010, 2025. Google Scholar | Publisher Link
19. Raphael Ouellet et al., "Validity and Reliability of Inertial Motion Unit-Based Performance Metrics During Wheelchair Racing Propulsion," *Sports Engineering*, vol. 23, no. 1, p. 6, 2025. Google Scholar | Publisher Link
20. Llona Alberca et al., "Temporal and Kinematic Parameters for Classification in Wheelchair Badminton," *Journal of Sports Sciences*, vol. 39, no. 18, pp. 2081–2088, 2025.
21. Wiebe H. K. de Vries et al., "Real-Life Wheelchair Mobility Metrics From IMUs," *Sports Technology*, vol. 12, no. 3–4, pp. 101–108, 2023. Google Scholar | Publisher Link
22. Marc Klimstra et al., "A Simple and Valid Method to Calculate Wheelchair Frame Rotation Using One Wheel-Mounted IMU," *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 26, no. 6, pp. 1243–1250, 2023. Google Scholar | Publisher Link
23. Karina Sá et al., "Evidence-Based Classification in Wheelchair Sports: A Systematic Review," *Sports Medicine*, vol. 48, no. 8, pp. 1829–1854, 2023. Google Scholar | Publisher Link
24. Lucas Felippe Daniel et al., "Validity and Reliability of a Test Battery to Assess Change of Directions With Ball Dribbling in Para-Footballers With Cerebral Palsy," *Journal of Sports Sciences*, vol. 35, no. 23, pp. 2374–2381, 2021. Google Scholar | Publisher Link
25. Taylor M Wileman et al., "Guiding Evidence-Based Classification in Para Sporting Populations: A Systematic Review of Impairment Measures and Activity Limitations," *Sports Medicine*, vol. 47, no. 7, pp. 1337–1349, 2025. Google Scholar | Publisher Link
26. David L Mann et al., "Classifying the Evidence for Evidence-Based Classification in Paralympic Sport," *Sports Medicine*, vol. 44, no. 9, pp. 1229–1239, 2021. Google Scholar | Publisher Link
27. David L Mann DL, and HJ C Ravensbergen, "IPC and IBSA Joint Position Stand on the Sport-Specific Classification of Athletes With Vision Impairment," *British Journal of Sports Medicine*, vol. 52, no. 1, pp. 3–13, 2021. Google Scholar | Publisher Link
28. Ezio Preatoni et al., "Movement Variability and Skills Monitoring in Sports," *Sports Biomechanics*, vol. 12, no. 2, pp. 69–92, 2012. Google Scholar | Publisher Link
29. Valentina Camomilla et al., "Trends Supporting the In-Field Use of Wearable Inertial Sensors for Sport Performance Evaluation: A Systematic Review," *Sensors*, vol. 18, no. 3, p. 873, 2018. Google Scholar | Publisher Link
30. Justin J Kavanagh and Hylton B Menz, "Accelerometry: A Technique for Quantifying Movement Patterns During Walking," *Gait & Posture*, vol. 28, no. 1, pp. 1–15, 2008. Google Scholar | Publisher Link

31. Pietro Picerno, "25 Years of Lower Limb Joint Kinematics Using Inertial and Magnetic Sensors: A Review," *Gait & Posture*, vol. 51, pp. 239–246, 2017. Google Scholar | Publisher Link
32. H. J. C. Ravensbergen, "Expert Consensus Statement to Guide the Evidence-Based Classification of Paralympic Athletes With Vision Impairment: A Delphi Study," *British Journal of Sports Medicine*, vol. 50, no. 7, pp. 386–391, 2016. Google Scholar | Publisher Link
33. Akmer Mutlu, Sema Büğüşan, and Özgün K Kara, "Impairments, Activity Limitations, and Participation Restrictions in Ambulatory Cerebral Palsy: ICF Model Application," *Saudi Medical Journal*, vol. 38, no. 2, pp. 176–185, 2017. Google Scholar | Publisher Link
34. Rajan Kumar V K et al., "The Value of Novel Technologies in Performance Measurement and Management: A Systematic Review," *Data and Information Management*, vol. 8, no. 1, p. 100054, 2023. Google Scholar | Publisher Link
35. Victoria L. Goosey-Tolfrey and Christof A. Leicht, "Field-Based Physiological Testing of Wheelchair Athletes," *Sports Medicine*, vol. 43, no. 2, pp. 77–91, 2013. Google Scholar | Publisher Link
36. David P. Howe and Carwyn Jones, "Classification of Disabled Athletes: (Dis)Empowering the Paralympic Practice Community," *Sociology of Sport Journal*, vol. 23, no. 1, pp. 29–46, 2006. Google Scholar | Publisher Link