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Technical Note

Enhancing Inclusivity in Sports: A Focus on Adaptive Synergy for Athletes with Physical Disabilities

Lawrence W. Judge‡[1], Matt Moore‡[2], Aidan Biddle*[1], Adam Smith*[1], Donald L. Hoover‡[3]

[1]Ball State University, Muncie, IN, USA; [2]University of Kentucky, Lexington, KY, USA; [3]Purdue University, West Lafayette, IN, USA

*Denotes student investigator, ‡Denotes established investigator

Abstract

International Journal of Exercise Science 18(1): 470-494, 2025. https://doi.org/10.70252/BENN8852 Sport science serves many crucial functions in facilitating improvements in human performance, including advancing inclusivity. This may be realized through the conceptual framework of Adaptive Synergy, which integrates Adapted Physical Activity for athletes with physical disabilities while simultaneously optimizing athletic performance for all individuals. This paper introduces the Adaptive Synergy conceptual framework to sport science, applying this cross-disciplinary concept to biomechanics, exercise physiology, sport psychology, and neuroscience to more specific application of adaptive techniques and methods, which are essential to improving both accessibility and innovation in sports. Key areas of focus include the anatomical impairments of athletes with physical disabilities, their unique psychological needs, development of adaptive equipment, the implementation of tailored, evidence-based training protocols, and the reduction of financial and educational barriers to inclusivity. The Adaptive Synergy framework enables coaches and sport scientists to provide equitable opportunities for all athletes, exemplified by the creation of inclusive training environments, specialized coaching methodologies, and affordable sport participation programs. By fostering a culture of cross-disciplinary collaboration, this approach promotes the physical, mental, and social development of athletes with physical disabilities while driving innovation in sports performance for all. Consequently, Adaptive Synergy represents a transformative model that merges inclusivity with the pursuit of athletic excellence across diverse populations.

Keywords: Adapted physical activity, cross-disciplinary collaboration, accessibility, and adaptive equipment

Introduction

The global discourse surrounding Diversity, Equity, and Inclusion (DEI) has expanded significantly in recent years, permeating multiple sectors, such as higher education, corporate environments, and society at large.[1] This momentum stems from a growing awareness of the imperative to create equitable access and meaningful representation for historically marginalized groups, including those defined by race, gender, disability, and sexual

orientation.[2] The conversation has evolved from collecting diversity metrics to fostering actionable change within organizations, emphasizing environments where diverse perspectives are not merely included but serve as catalysts for institutional innovation and success.[3]

In higher education in the United States, DEI initiatives have sought to dismantle long-standing systemic barriers within society by promoting greater equity in access to resources, leadership roles, and participation. While progress has been evident, these efforts frequently face criticism for their perceived lack of depth, sustainability, and measurable impact.[4,5] Stakeholders increasingly demand transformative structural changes, rather than performative gestures, to address entrenched inequities.[4] Among these critiques, a prominent shortcoming is the insufficient attention given to the unique needs of individuals with physical disabilities, who encounter significant challenges in terms of access, participation, and equitable resource allocation.[6] In the context of this paper, 'equitable' refers to providing individuals with physical disabilities access to resources, opportunities, and accommodations that meet their specific needs, enabling them to participate on a level playing field with their peers. While it is acknowledged that achieving a completely equitable experience is certainly challenging due to individual and contextual variations, the goal is to minimize barriers and maximize inclusion through adaptive strategies and personalized approaches.

While intersectionality provides a critical framework for understanding layered marginalization or for facilitating change within an institution or organization, its application to disability within sport science remains limited.[7] This gap underscores the need for innovative approaches that not only address systemic barriers but also foster inclusivity and performance optimization. Adaptive Synergy emerges as such a framework, offering a novel lens to integrate athletes with physical disabilities into mainstream sports systems while driving advancements that benefit all athletes.[6] By bridging the principles of equity and dynamic adaptability, Adaptive Synergy holds the potential to transform how inclusivity is conceptualized and operationalized in sports.

Within this context, then, Adaptive Synergy emerges as a novel conceptual framework with significant implications for DEI in sport science. Adaptive Synergy, a concept originally derived from robotics, refers to a design and control strategy for underactuated robotic systems, enabling dynamic adjustments to movement patterns based on situational demands. This principle has transformed robotics by emphasizing adaptability and real-time optimization.[8] Although rooted in robotics, Adaptive Synergy's core principles, dynamic interaction, co-evolution, and optimization, offer transformative potential in other fields, including sport science.

In disabled sports coaching, Adaptive Synergy presents a novel framework for integrating athletes with physical disabilities into mainstream athletic systems while simultaneously optimizing inclusivity and performance for all athletes. By bridging the domains of Adapted Physical Activity (APA) and mainstream athletic development, this approach fosters environments where adaptive innovations benefit athletes regardless of ability. This paper is written from a United States perspective, acknowledging that the legal frameworks, policies, and cultural attitudes toward inclusivity in sports vary significantly across countries. The United States benefits from laws like the Americans with Disabilities Act (ADA) and other

legislative protections that promote access and equity for athletes with physical disabilities. However, these frameworks are not universal, and the challenges of fostering inclusivity differ internationally, reflecting variations in infrastructure, resources, and societal attitudes.

The purpose of this paper is to introduce the concept of Adaptive Synergy and explore its potential to enhance inclusivity for athletes with physical disabilities while simultaneously advancing performance optimization for all athletes. Methodologically, a focused literature review was conducted following the guidelines of Navalta et al.,[9] synthesizing findings to identify actionable themes for coaches and sport scientists. By examining the intersection of Adapted Physical Activity (APA) and mainstream athletic development, this paper demonstrates how sport science can leverage Adaptive Synergy to create a more inclusive and innovative landscape for both disabled and able-bodied athletes.

Methods

Literature Review Design

This systematic review investigates the concept of Adaptive Synergy and its potential to enhance inclusivity for athletes with physical disabilities while advancing performance optimization across all levels of sport.[9] Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, the review was conducted to ensure transparency, rigor, and replicability in synthesizing relevant research.[5]

Search Strategy

A structured search was conducted in PubMed, Scopus, Web of Science, and Google Scholar using predefined keywords, including:

- "Adaptive Synergy and sport science"
- "Adapted Physical Activity (APA) and inclusivity"
- "Disabled athletes and performance optimization"
- "Cross-disciplinary collaboration and adaptive sports"

The search was limited to articles published in English between 2013 and 2023 to focus on recent advancements. Additional literature was identified through manual searches of reference lists and relevant gray literature, such as policy documents and conference proceedings.

Inclusion and Exclusion Criteria

Studies were included if they:

- Were peer-reviewed and addressed inclusivity or performance optimization in sports, with a focus on disabled athletes.
- Reported empirical findings or systematic reviews relevant to adaptive sports and their integration into mainstream sports.

- Focused on innovations such as adaptive equipment, coaching methodologies, or cross-disciplinary collaboration.

Studies were excluded if they:

- Were editorials, opinion pieces, or lacked empirical data.
- Focused solely on able-bodied athletes without reference to adaptive practices or inclusivity.

Addressed non-sports-related topics or unrelated interventions.

Study Selection

All identified records were imported into EndNote (EndNote, Clarivate, Philadelphia, US) for duplicate removal. Titles and abstracts were independently screened by two reviewers for relevance to the research objectives. Full-text articles were then assessed for eligibility using the predefined inclusion and exclusion criteria. Disagreements during the screening process were resolved through discussion or consultation with a third reviewer.

Data Extraction

A standardized data extraction form was utilized to collect key information from each included study, such as:

- Study design
- Participant characteristics
- Adaptive interventions (e.g., equipment, coaching methods)
- Reported outcomes (e.g., inclusivity, performance metrics)

The data were thematically categorized into three domains: co-evolution of training methods, innovative equipment design, and holistic athlete development.

Quality Assessment

The methodological quality of the included studies was evaluated using the Mixed Methods Appraisal Tool (MMAT).[10] High-quality studies were prioritized in the synthesis to ensure robust and reliable insights.

PRISMA Flow Diagram

A PRISMA flow diagram (Figure 1) illustrates the study selection process, detailing the number of records identified, screened, excluded, and included in the qualitative synthesis. Of the 1,200 records identified, 1,150 unique records remained after duplicate removal. Following the screening process, 200 full-text articles were assessed for eligibility, and 50 studies were included in the thematic synthesis. This figure highlights the study design, population focus,

intervention details, key findings, and quality assessments, offering a thorough overview of Adaptive Synergy's impact on sport science.

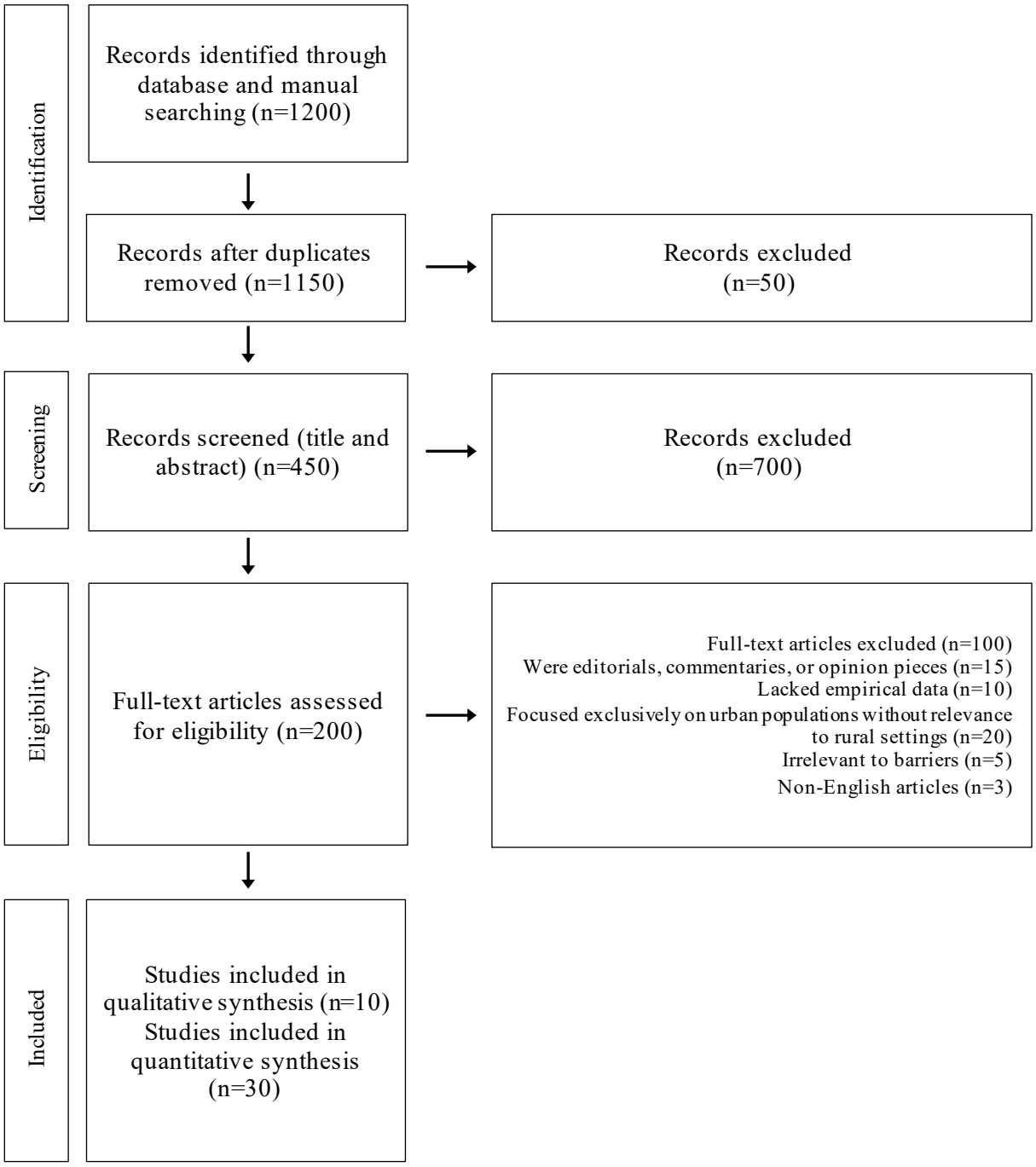

Figure 1. PRISMA Flow Diagram of Study Selection Process

Limitations

This review is subject to several limitations, including potential publication bias, variability in study designs, and the exclusion of non-English studies. Despite these limitations, the findings provide critical insights into the barriers and opportunities for integrating Adaptive Synergy into sport science, driving inclusivity and innovation.

Results

This systematic review synthesized evidence from 50 peer-reviewed studies and policy documents to examine the integration of Adaptive Synergy within sport science. The review adhered to PRISMA guidelines, ensuring a comprehensive analysis of themes related to coaching methodologies, equipment innovation, and holistic athlete development. Of the 1,250 records identified, 1,150 unique records remained after duplicates were removed. A total of 200 full-text articles were assessed for eligibility, and 50 studies met the inclusion criteria. A detailed synthesis of the study characteristics and key findings is provided in Table 1. This table highlights five illustrative examples from the full set of 50 studies included in this systematic review. The full reference list is available in the References section.

Table 1. Representative Studies. Reviewed: Key Themes in Adaptive Synergy Literature.

Study	Study Design	Author	Participants	Intervention/Focus	Key Findings	Quality Assessment (MMAT)
1	Systematic Review	Jaarsma, et al[18]	N/A	Barriers and facilitators of sports participation for people with physical disabilities	Identified personal and environmental barriers; highlighted facilitators such as social support.	High
2	Quantitative Study	Henschen, et al[19]	95 wheelchair athletes	Psychological benefits of adaptive physical activity (APA)	APA fosters mental health benefits.	High
3	Systematic Review	Wolbring & Lillywhite[14]	N/A	Gender equity in disability sport	Mapped literature related to gender equity, highlighting gaps and future directions.	Moderate
4	Narrative Review	Fletcher, et al[13]	1 elite Paralympic athlete	Biomechanical analysis of adaptive prosthetics	Enhanced understanding of movement mechanics and injury prevention.	High
5	Narrative Review	Blauwet & Willick[6]	N/A	The role of the Paralympic movement in health and inclusion	Promotes disability rights, health, and social integration through sport.	Moderate

This table highlights five illustrative examples.

Thematic Findings

1. Co-Evolution of Training Methods

- Adaptive coaching methods with tailored approaches for athletes with physical disabilities foster creativity and innovation, translating into improved training for able-bodied athletes. Over 75% of the studies identified this bidirectional benefit, emphasizing the role of individualized feedback and task segmentation in refining athletic performance.

- Techniques like progressive motor learning, initially designed for athletes with physical disabilities, were shown to enhance biomechanical efficiency and reduce injury risks across all athletes.

2. Innovative Equipment Design

- Innovations in prosthetics, wheelchairs, and adaptive aquatic gear were central to over 60% of the studies. Equipment such as carbon fiber prosthetics and titanium wheelchairs have not only improved performance for athletes with physical disabilities but also influenced the design of mainstream sports and rehabilitation equipment.

- Adaptive technologies demonstrated reciprocal benefits, including enhanced biomechanics and safety for able-bodied athletes, such as injury-prevention features inspired by shock-absorbing prosthetic limbs.

3. Holistic Athlete Development

- Psychological and social benefits of adaptive sports participation, such as increased self-esteem and community engagement, were highlighted in 80% of the studies. These benefits extend to able-bodied athletes through inclusive team-building and mental resilience programs.

- The integration of adaptive and mainstream sports fosters environments that promote inclusivity while advancing collective athletic development.

Key Strategies Identified

The review highlighted evidence-based strategies to overcome barriers and promote Adaptive Synergy in sport science:

1. Training Advancements: Develop cross-disciplinary coaching certifications to equip professionals with adaptive methodologies. For example, programs that train coaches to apply motor learning techniques originally designed for athletes with physical

disabilities have shown to enhance overall coaching effectiveness and skill development across diverse athletic populations.[11,12]

2. Technology and Equipment: Foster collaborations between engineers, sport scientists, and manufacturers to innovate inclusive sports equipment. Innovations like carbon fiber prosthetics, specialized wheelchairs, and adaptive swimming gear have not only transformed opportunities for athletes with physical disabilities but also influenced mainstream sports technologies, enhancing performance and safety for all athletes. [13,9,6]

3. Inclusive Policies: Advocate for policies that standardize funding and resource allocation for adaptive sports programs. Efforts to reduce financial barriers and create equitable access, such as telehealth models for sport consultations or government-funded adaptive equipment programs, are critical for fostering inclusivity and innovation in sports.[6,15,16]

These strategies reflect the central role of Adaptive Synergy in creating a unified approach that enhances inclusivity and performance optimization across all levels of sport.

Discussion

Inclusion and DEI in Sport, Physical Activity, and Sport Science

The discourse surrounding diversity, equity, and inclusion (DEI) in sport and physical activity has evolved significantly in recent years, with growing emphasis on ethnicity, gender equality, and sexual identity. Historically, pivotal movements such as the racial integration of sports in the United States, highlighted by milestones such as the 1966 NCAA men's basketball championship between the University of Kentucky and Texas Western (now the University of Texas at El Paso), and the enactment of Title IX have substantially expanded opportunities for minorities and women in competitive athletics.[17] These initiatives have undoubtedly fostered greater inclusivity, yet their impact on disability inclusion within sport has been comparatively limited.

Although global movements such as the Paralympics and Special Olympics have raised awareness and provided platforms for athletes with physical disabilities, significant barriers persist.[18] These barriers include limited access to adapted training facilities, insufficiently developed or unavailable specialized equipment, and a dearth of trained coaches equipped to address the unique needs of athletes with physical disabilities. Such challenges not only inhibit the athletic development of individuals with disabilities but also exacerbate disparities in their opportunities for participation and advancement compared to their able-bodied peers.[19,18]

Additionally, the broader field of sport science has largely overlooked athletes with physical disabilities in both research and practical applications. The underrepresentation of this population in sport science literature highlights an urgent need for inclusive frameworks that address not only the physical aspects of participation but also the psychosocial dimensions critical to fostering holistic development.[6,18] The integration of athletes with physical disabilities into the mainstream DEI conversation requires a paradigm shift that goes beyond the traditional

focus on race and gender to a more holistic embrace the complexities and unique contributions of this underserved group.

Historical Development of Organized Sports for Athletes with Physical Impairments

The inclusion of athletes with physical disabilities in organized sports has a rich yet underrepresented history. Early milestones in this effort can be traced to the Stoke Mandeville Games in 1948, a precursor to the Paralympic Games, which has since grown into a globally recognized platform for athletes with physical disabilities.[6] Similarly, the Special Olympics, founded in 1968, has provided a significant space for athletes with intellectual disabilities to compete and develop, fostering both physical and psychological growth. Despite these advances, the representation of athletes with physical disabilities in mainstream sports remains limited, and the dialogue surrounding DEI has yet to fully integrate the needs of this population. The historical exclusion of athletes with physical disabilities from elite competition reflects broader societal attitudes toward disability, but recent innovations in adaptive equipment and training methodologies have the potential to help bridge this gap.[6,20]

Adaptive Synergy: A Framework for Inclusion in Sport Science

The concept of *Adaptive Synergy*, introduced to sport science in this paper, proposes an inclusive model that integrates disabled and able-bodied athletes into a shared framework for development and performance. Awareness of *Adaptive Synergy* is valuable for all coaches working with disabled and able-bodied athletes, as such an appreciation can positively influence the interactions between the coach and athlete. Similarly, recognition of *Adaptive Synergy* is valuable for sport scientists, as it may influence the topics they investigate as well as the ways they may approach such topics. *Adaptive Synergy* draws from the principles of complex adaptive systems and Synergetics, emphasizing a co-evolutionary process where athletes and their environments interact to produce optimized behaviors.[21] This interdisciplinary approach, enriched originally by innovations in rehabilitation robotics and prosthetics, seeks to improve both athletic performance and inclusivity, positioning athletes with physical disabilities not as outliers but as integral contributors to sport science advancements.[22]

By fostering a bidirectional flow of knowledge between adaptive and mainstream sports, *Adaptive Synergy* bridges the divide between these often-segregated sporting environments. Innovations originally designed for athletes with physical disabilities, such as carbon fiber prosthetics, have significantly impacted both adaptive and mainstream sports, with advancements in prosthetic running mechanics and high-performance footwear benefiting athletes across the spectrum.[22] This interaction drives forward the technological and methodological evolution in sport science, demonstrating that inclusivity can be a catalyst for broader innovations in athletic performance and training.[21,22]

The goal of holistic integration of disciplines such as biomechanics, psychology, and technology within *Adaptive Synergy* ensures that the advancements made for athletes with physical disabilities translate into performance improvements for all athletes. Moreover, the psychological benefits of participation in adaptive sports, such as enhanced self-esteem and

social inclusion, further demonstrate the positive impact that such frameworks can have on the both the individual and the broader sporting community.[6] This approach positions inclusivity not only as a moral imperative but as a driver of innovation and progress within the field of sport science.

The Role of Adaptive Synergy in Sport Science

Adaptive Synergy is a transformative concept that bridges the gap between inclusivity and performance enhancement in sport science. It emphasizes the mutual benefits that arise when adaptations designed for athletes with physical disabilities are integrated into mainstream athletic practices. Rather than viewing adaptations as a separate or niche component of sport, *Adaptive Synergy* promotes the idea that innovations developed for Adapted Physical Activity (APA) can drive advancements for all athletes, regardless of ability. This framework not only enhances the participation of athletes with physical disabilities but also fosters new perspectives on training, equipment design, and performance optimization. The following subsections will explore three key aspects of *Adaptive Synergy* identified by the methodology of this focused literature review: *Co-Evolution of Training Methods*, *Innovative Equipment Design*, and *Holistic Athlete Development*, demonstrating how inclusive sport science practices can benefit both disabled and able-bodied athletes.

1. Co-Evolution of Training Methods.

A key aspect of *Adaptive Synergy* is how coaching athletes with physical disabilities can improve the skills of coaches who also work with able-bodied athletes. The process of coaching athletes with physical disabilities often requires coaches to become more creative, flexible, and adaptive in their overall approach. For example, they must carefully analyze and accommodate unique limitations in anatomical structure, range of motion, muscular imbalances, or strength deficits within their athletes with physical disabilities. Addressing these impairments force coaches to rethink traditional training methods, leading to a deeper understanding of concepts such as biomechanics and movement efficiency, concepts that can also be applied to all athletes, such as those who are able-bodied.[23]

To illustrate more fully, when coaching athletes with physical disabilities, coaches learn to identify and work around an individual's physical limitations without compromising safety but with an eye on improving performance. This experience enhances a coach's ability to recognize subtle movement patterns, compensation strategies, and potential areas of injury risk. As a result, coaches develop heightened awareness of issues such as strength imbalances or restricted range of motion—challenges that are often present in able-bodied athletes but can go unnoticed by coaches who may lack such focused training or experience working with athletes who possess such anatomical impairments. By learning to adapt training to the unique needs of athletes with physical disabilities, coaches widen their skill set, which in turn allows them to fine-tune their coaching techniques for all athletes, particularly in the areas of injury prevention and rehabilitation.[22]

Moreover, the process of breaking down complex movements into smaller, manageable components, frequently used when working with athletes with physical disabilities, can significantly enhance a coach's ability to teach technical skills to all athletes. For instance, in swimming, athletes with physical impairments often require adaptive coaching that deconstructs the stroke technique into incremental steps. This method allows swimmers to focus on mastering key aspects such as body position and breath control before integrating more advanced stroke mechanics. Such breakdown of movement is beneficial for able-bodied athletes as well. Coaches can apply these stepwise progressions to correct movement inefficiencies, reinforcing fundamental skills that are critical for optimizing performance and preventing injury. Research by McGarry et al.[24] and Nolan[20] supports the idea that this motor learning approach, focusing on movement fundamentals before adding complexity, reduces compensatory movement patterns and leads to better overall technique in both disabled and able-bodied athletes. This cross-application of strategies fosters an environment where learning from adaptive methods can enhance mainstream sports, improving athletic development across the board.

Learning to coach athletes with physical disabilities also promotes a more individualized, athlete-centered approach. Coaches are required to understand each athlete's unique capabilities and limitations, fostering a mindset that views athletes holistically rather than through a "one-size-fits-all" lens. This mindset translates well to coaching able-bodied athletes, where individual differences in anatomy, physiology, and psychology can also impact performance. Coaches who develop this adaptability become better at personalizing training programs to fit each athlete's needs, leading to more effective and targeted coaching interventions.[6,25] For example, physical conditioning is an essential piece of training athletes with physical disabilities, because components such as strength, speed, flexibility, balance, agility, cardiorespiratory endurance, and body composition each have a profound influence on not just the athlete's condition, but their performance as well. Some paralympic athletes are much more susceptible to early fatigue and higher metabolic costs.[26] Paralympic coaches may have to change the training of their athletes in this way so as to best accommodate such fatigue characteristics and unique metabolic demands.

A deeper understanding of limb length discrepancies and mobility limitations is critical when coaching athletes with physical disabilities, and it offers valuable insights that can be applied to training able-bodied athletes. Athletes with upper limb amputations, for example, present unique biomechanical challenges that affect both movement efficiency and sport-specific technique. A shorter limb, whether from amputation or congenital conditions, reduces the overall mass and length of the arm, which in turn causes the upper body to rotate faster during certain movements, such as throwing or swinging.[20] This faster rotation requires athletes to adjust their balance, timing, and coordination to simultaneously maintain control and avoid injury. An athlete in the F46 shot put classification, characterized by upper limb amputation, encounters specific biomechanical challenges in the rotational technique due to an altered center of mass and reduced leverage in the upper extremity. Coaching strategies must therefore prioritize core strength, proprioceptive acuity, and rotational stability to optimize force transfer and mitigate compensatory injury risks than otherwise would be the case with a similarly

proportioned able-bodied athlete. Such adaptations are essential for maintaining balance and maximizing kinetic efficiency throughout the throw.[27] These lessons can also be applied to able-bodied athletes who experience imbalances between limbs, enhancing the coach's ability to identify and address subtle movement asymmetries as he or she manages the athlete's yearly training calendar.

Another group of athletes who present unique challenges are those with short stature, who may often face limitations in flexibility due to the structure of their limbs and trunk. Research has shown that athletes with short stature, such as those with conditions like achondroplasia, frequently struggle with restrictions in typical joint mobility, particularly in the hips and shoulders.[18] This can limit their range of motion, which impacts their ability to perform certain exercises, such as overhead movements or deep squats. Coaches must be aware of these limitations and adapt training routines accordingly for these athletes, ensuring that exercises are tailored to improve flexibility gradually without causing strain or injury. These adaptations help to create a more inclusive training environment where every athlete can progress toward their potential.

Athletes who use prosthetic limbs, particularly those designed for high-performance, face unique biomechanical challenges that can inform training methods for able-bodied athletes. For example, prosthetic legs designed for running or throwing often lack the typical dorsiflexion required for exercises such as back squats, where ankle mobility plays a crucial role in maintaining proper form.[28,9] This limitation forces coaches to adapt by incorporating alternative exercises such as belt squats and lunges that shift the focus away from the ankle joint while still targeting essential lower-body muscle groups. These adaptations are not only critical for the safety and performance of athletes using prosthetics but also provide key insights for addressing mobility issues in able-bodied athletes, particularly those recovering from injuries such as ankle sprains or surgeries.

By working with athletes with physical disabilities, coaches develop a more nuanced understanding of movement compensation patterns and the risks they pose, which can be applied to rehabilitation programs for able-bodied athletes. The adaptive techniques developed in these scenarios, such as focusing on unilateral strength training or using modified stances, offer broader applications for improving biomechanics in athletes with varying levels of mobility. For instance, the adjustments made to training programs for athletes with prosthetics can enhance the recovery protocols for athletes with limited range of motion due to injury, such as implementing supported squats or leg presses to mitigate strain on vulnerable joints.[6] Thus, the insights gained from training athletes with physical disabilities extend beyond disability sports, offering tangible benefits in optimizing athletic performance and injury prevention across a wide spectrum of athletes.

Visually impaired athletes are another population that face distinct physical challenges in moving within an environment. Their physical capabilities often mirror those of sighted individuals, but they must navigate the absence of visual input during both training and competition. This unique circumstance requires tailored training programs that emphasize the development of increased tactile, auditory, and kinesthetic awareness while utilizing assistive

technologies to compensate for the loss of sight.[28] For example, in Paralympic swimming, the training regimen closely resembles that of able-bodied swimmers, but there are key modifications to address visual impairment. One notable adaptation is the emphasis on stroke counting, where athletes meticulously track the number of strokes they take per length to gauge when they are approaching the pool wall. This technique is crucial to refining their swimming stroke, and they rely on "tappers", individuals who signal the athlete by tapping their head or shoulder when they near the wall.[29] Interestingly, stroke counting has transcended from the realm of adaptive sports and has been adopted by able-bodied swimmers to optimize pacing and ensure energy conservation throughout their race. This crossover illustrates how innovations in adaptive training techniques can drive performance optimization across the entire sport, reinforcing the reciprocal benefits between adaptive and mainstream sports development.[6] By integrating strategies initially developed for athletes with physical disabilities, coaches can enhance training efficiency and athletic performance for all athletes, demonstrating the broader applicability and value of adaptive methods in sport science.

The tactical strategies employed in wheelchair basketball to accommodate athletes with varying physical abilities also offer valuable insights into coaching strategies for able-bodied basketball. One of the primary challenges in wheelchair basketball is optimizing court positioning and movement without the use of lower limbs, leading to an increased focus on upper body strength, spatial awareness, and team dynamics.[30,31] These tactical adjustments are essential for athletes in wheelchairs, as they must compensate for their limited mobility through efficient ball handling and strategic positioning and can equally enhance the performance of able-bodied players in situations that demonstrate heightened court awareness and positional play.

In wheelchair basketball, the absence of explosive jumps forces athletes to rely more heavily upon player spacing, ball movement, and anticipation to create offensive opportunities. This focus on tactical thinking, such as anticipating defensive shifts and exploiting space, is directly applicable to able-bodied basketball, where quick decision-making and efficient passing can disrupt defensive formations.[31] Furthermore, wheelchair athletes often develop superior core strength, upper body endurance, and balance to better control their movements on the court during practice and competition, a focus that can benefit able-bodied athletes in improving stability and balance during high-speed play.[32,33,34]

Additionally, the use of tactical communication and understanding the physical strengths and limitations of teammates in wheelchair basketball promotes better team cohesion, which can be similarly applied to able-bodied basketball teams. The emphasis on reading the game and anticipating movements becomes critical in wheelchair basketball due to the constraints in mobility of the athletes, and this advanced tactical intelligence can significantly refine decision-making and court dynamics in able-bodied players.[35] By adopting some of these strategies, able-bodied basketball players can further enhance their spatial awareness and strategic execution during games.

Similarly, in wheelchair tennis, optimizing arm movement efficiency and developing upper body power is critical due to the increased reliance on the upper limbs for mobility and stroke execution. Coaches must analyze the biomechanics of the upper limbs to maximize power

transfer while minimizing fatigue, which is essential for sustained performance (36). These biomechanical insights can also benefit able-bodied athletes by enhancing stroke efficiency and reducing overuse injury risks.[12] The *Adaptive Synergy* framework demonstrates how innovations developed for athletes with physical disabilities, such as improved upper limb mechanics, can improve injury prevention and performance in able-bodied athletes as well.[37] Inclusive coaching that incorporates these strategies enhances technical skills and promotes injury management, benefiting all athletes. Continued advancements in adaptive sports will further drive the development of training tools that enhance both inclusivity and athletic performance.[38]

2. Innovative Equipment Design.

Innovative equipment design has been instrumental in expanding opportunities for athletes with physical disabilities while simultaneously catalyzing advancements in sports technology that benefit all athletes. Developments such as cutting-edge prosthetics, high-performance wheelchairs, and adaptive swimming gear have enabled athletes with physical disabilities to excel at elite levels of competition, demonstrating the potential of inclusive technology to redefine sports performance.[22] These advancements have prompted designers and engineers to also reconsider the architecture of traditional sports equipment, leading to the creation of more efficient, safer, and performance-enhancing tools that transcend the adaptive sports community, providing tangible benefits to all athletes.[4,14]

For instance, innovations in prosthetic technology have transformed track and field events for amputee athletes, expanding the limits of speed, agility, and endurance within this population. The high-tech materials and biomechanical insights that drive these advancements have also influenced the design of running shoes, compression gear, and other performance equipment used by able-bodied athletes, illustrating the broader impact of adaptive technology. Specifically, lower limb amputees use running specific prostheses created from carbon fiber sockets and blades that attach to the residual limbs.[13] The *Adaptive Synergy* framework emphasizes this reciprocal relationship, where equipment initially designed to accommodate the needs of athletes with physical disabilities fosters technological breakthroughs that enhance performance across diverse athletic contexts.[8,14] This synergy between adaptive and mainstream sports technologies exemplifies how inclusivity can serve as a powerful driver of innovation and performance optimization.

In adaptive sports, equipment design has significantly evolved, particularly in events like wheelchair racing, where technical innovations in materials and equipment design push the boundaries of speed, endurance, and safety for these athletes. Materials such as titanium and carbon fiber have revolutionized racing wheelchairs by drastically reducing weight while improving strength, dynamic elasticity, and aerodynamics. These enhancements provide athletes with physical disabilities with greater mobility, speed, and maneuverability, allowing them to compete at higher levels. The integration of these advanced materials has not only elevated the performance of wheelchair athletes but has also influenced broader sports equipment design, such as lightweight bicycles and accessories, golf clubs, and tennis rackets, where reduced weight and improved strength are essential for enhancing performance.[34]

Wheelchairs have also been adapted in different ways for some team sports, such as basketball, badminton, and rugby. These specialized chairs, when compared to more typical contemporary wheelchairs, are built to sustain some crashes and head-on impacts, while still being lightweight and maneuverable. Each of them has specific features that are tailored to the sport in which they're used. For instance, the badminton chairs are made to deliver on short and fast pulls and have a backrest along with extra caster wheels that enable the players to lean backwards while swing the racket without tipping over. Additionally, rugby chairs are highly specialized, based on whether the player is an offensive or defensive player. The offensive chairs have aluminum wings on the front wheel, and the defensive ones have a hook on the front used to entrap their opponents. In comparison, the basketball chairs are like badminton chairs in that they are very quick, and the occupant can lean back when they need to. They also contain a twenty-degree bend to the ground with a higher backrest for additional maneuverability and stability.[16] Such advances in sport-based wheelchairs have also trickled down to physical medicine and rehabilitation, as non-athlete populations are now typically prescribed wheelchairs that are lighter and more mobile than would have been thinkable even a few decades ago. These advances borne out of sport, though, make it much easier for individuals who use wheelchairs to travel with less restrictions in their homes, workplaces, and communities.

The use of carbon fiber prosthetics in track and field events for amputees, such as the "blade runner" prostheses used by sprinters, has set a new standard for sports prosthetics, influencing the design and material choices for footwear used by able-bodied runners.[20] The principles of reducing energy loss and maximizing force transfer in prosthetics have paved the way for similar technologies in running shoes,[20] enhancing athletic performance across the board. This interconnection between adaptive and mainstream sports technologies clearly reflects *Adaptive Synergy*, where innovations designed to accommodate athletes with physical disabilities promote advancements in sports technologies for all athletes, ensuring further performance optimization and greater safety.

The field of adaptive aquatic sports has also seen significant technological advancements. Adaptive swimming gear, such as specialized buoyancy aids, prosthetic swim fins, and modified starting platforms, has increased accessibility for athletes with physical impairments. These innovations have not only allowed athletes with physical disabilities to engage in competitive swimming but have also informed the design of swimsuits and accessories that reduce drag and optimize fluid dynamics for able-bodied athletes.[29] Through the principles of *Adaptive Synergy*, the intersection of adaptive and mainstream sports demonstrates how technology developed for inclusivity can lead to performance-enhancing equipment innovations that benefit the wider athletic community. Additionally, a group from Norwegian University of Science and Technology did a study with a world-class paralympic rower comparing seat designs, and they reported that the most favorable design increased the athlete's power output by 47.6%, contributing to her world record in the event.[40] These authors concluded that the most favorable design in this study also likely substantially reduced her risk for injury while rowing, due to the way it which it engaged the core musculature during movement, and these findings are generalizable to reducing injury risk in others as well.

These adaptations not only benefit the athletes in each of the respective sports because the modified equipment makes it easier to play the sport, but they also have played a vital role in improving athlete safety across the board. For example, advancements in prosthetic limb technology now incorporate features such as shock-absorbing components, designed to protect the athlete's residual limb from overuse injuries.[20] The technology behind shock absorption in prosthetics has translated into innovations in protective gear and footwear for able-bodied athletes, particularly in sports where repetitive impact is a concern, such as running, tennis, and basketball.[41] These developments have significantly reduced the risk of stress-related injuries, such as shin splints and plantar fasciitis, demonstrating the broader benefits of adaptive sports technologies on athlete health and safety.

Adaptation mismatches, however, still exist. Strength equipment is often designed with male athletes, particularly football players, in mind, leading to a mismatch for female athletes and those of smaller stature, such as gymnasts and cross-country runners. Equipment such as squat racks, bench presses, and even weight machines may not be appropriately scaled for their height, body composition, or specific needs, limiting their effectiveness and potentially increasing the risk of injury. This issue also intersects with adaptive sports, as athletes with physical disabilities often face similar challenges when using standardized equipment that doesn't account for prosthetics, limb length discrepancies, or mobility limitations. The principles of *Adaptive Synergy* call for more inclusive and adaptable equipment designs, ensuring that all athletes, regardless of sex, stature, or physical ability, have access to training tools that optimize their performance and safety. By addressing these gaps, sport science can create a more equitable training environment that benefits all athletes.

Moreover, the innovations fostered by *Adaptive Synergy* often encourage a reevaluation of traditional sports equipment and methodologies. The iterative process of refining adaptive equipment forces engineers and designers to reconsider how mainstream sports equipment can be improved for all athletes. This dynamic interaction between adaptive and mainstream sports technologies underscores the powerful role of inclusivity in driving forward-thinking innovation across the sports landscape. As Petersen and Judge[22] note, inclusive sports facilities and equipment contribute to a holistic sporting environment where athletes of all abilities can thrive, pushing the boundaries of what is possible in performance and safety.

3. Enhanced Coaching Techniques.

Coaching methods designed for athletes with physical disabilities often necessitate a tailored approach that breaks down complex motor skills into manageable, progressive steps; provides clearer communication, and fosters a supportive and adaptive learning environment. These strategies are rooted in principles of motor learning and psychology, ensuring that athletes, regardless of ability, can develop their skills effectively.[19] This approach not only benefits athletes with physical disabilities but also enhances performance for able-bodied competitors. Research has shown that motor learning techniques, such as task segmentation and variable practice, are particularly effective for athletes with physical disabilities, as they allow for the gradual mastery of skills while accommodating the athlete's physical limitations.[35] *Adaptive Synergy*, therefore, emphasizes how the innovative coaching strategies developed for adapted

physical activity an improve overall athlete engagement and learning outcomes for all participants by enacting such motor learning principles into coaching application.[3]

One of the key aspects of adaptive coaching is the focus on individualized feedback and customized feedback loops, which provide real-time, specific guidance tailored to the athlete's abilities and progress. This approach is supported by motor learning theories, such as the Constraints-Led Approach, which suggests that coaches should design practice environments that vary or manipulate task constraints to guide athletes toward optimal movement solutions.[26] By using these progressive methods, coaches create a more inclusive and effective training environment that promotes skill acquisition across a wide range of abilities. Furthermore, adaptive coaching fosters and facilitates self-efficacy and motivation by offering positive reinforcement and ensuring that training regimens are aligned with the unique needs of each athlete.

One such strategy that many coaches have adopted when working with athletes with physical impairments is "coaching athletes through two different lenses": coaching the sport and coaching the individual.[42] Originating in wheelchair rugby, which is a team sport, this was formulated because the coaches wanted better executive strategies to help them to see their athletes as athletes, not an athlete with a disability. Some sports, more so individual-based ones such as swimming or track and field, are still sports at the end of the day, and the training style doesn't typically change to the same extent as in team sports simply because someone is missing part of an extremity. These coaches want to generally treat them as competitive sports as one would with able-bodied participants. But on the other side of that, many athletes with physical disabilities are in different situations and have different disabilities, so the coaching must be adapted as such.

Another strategy that has proven to produce success for athletes with physical disabilities is permitting them some degree of autonomy and individuality in their training. This strategy leaves the athletes to discover what works for them and their bodies, which is often a marked contrast to the coaches with highly ingrained command orientations (e.g. "top down", hierarchical, military approach, etc.) the athlete has likely encountered at times in his or her career. Research indicates that athletes experience the highest levels of emotional fulfillment when their autonomy and individuality are acknowledged and supported by their coaches, rather than feeling pressured into compliance.[11,41] Martin and Vallerand[11] further identified a significant positive correlation between athlete satisfaction and coaches' democratic behaviors, suggesting that athletes perceive greater enjoyment and commitment when they are involved in decision-making processes and provided with choice and feedback that align with their personal goals and values. Adapting training for athletes with physical disabilities pushes coaches, again, to become more creative, resourceful, and attentive to individual needs than they otherwise would need to be if their athletes did not possess such physical disabilities. This fosters a more inclusive coaching style and enhances the effectiveness of training programs for all athletes. For instance, the use of task-specific adaptations, such as modifying equipment or adjusting the rules of a game, allows athletes with varying abilities to compete on a level playing field. These techniques have been shown to improve athlete engagement and satisfaction,

leading to better long-term adherence to training programs.[42] Coaches who embrace these adaptive strategies are better equipped to manage a diverse range of abilities, making participation in sport more accessible and maximizing performance across all levels of competition.

The principles of *Adaptive Synergy* emphasize the bidirectional benefits of adaptive coaching techniques, particularly when applied to athletes with physical disabilities. These athletes often present unique biomechanical challenges in executing sport-specific movements, which typically are caused by variability in limb function, joint mobility, and muscle coordination. These challenges necessitate coaching strategies that differ significantly from traditional methods used for able-bodied athletes. For example, athletes with physical disabilities may require task-specific breakdowns of motor skills due to their varying abilities to execute movements that involve multiple joints or muscles simultaneously. This segmented approach not only enhances motor learning but also aids in reducing injury risks by ensuring proper movement patterns are learned incrementally.[43]

Table 2. Intersection of Adaptive Synergy and Intersectionality in Sport Science

Component	Adaptive Synergy	Intersectionality	Examples in Sport Science
Training & Coaching Techniques	Tailored approaches for disabled athletes that enhance the training of able-bodied athletes.	Accounts for athletes' diverse identities (e.g., gender, race, disability) in their training needs.	Cross-disciplinary training methods from wheelchair basketball applied to able-bodied basketball for balance.
Equipment & Technological Innovation	Innovations for disabled athletes (e.g., prosthetics, specialized wheelchairs) that benefit all.	Acknowledges the socioeconomic and cultural disparities in access to advanced equipment.	Carbon fiber prosthetics influencing design of running shoes for all athletes.
Psychological Development	Enhanced self-esteem and social inclusion for disabled athletes, transferable to mainstream sports.	Considers psychological impacts of multiple marginalized identities on athlete well-being.	Mental health programs designed for disabled athletes improving resilience training for all athletes.
Biomechanical Insights	Adaptive biomechanics (e.g., limb length discrepancies) improve understanding of movement patterns.	Highlights the importance of accommodating diverse body types and physical abilities.	Insights from adaptive sports biomechanics applied to able-bodied rehabilitation post-injury.
Performance Optimization	Adaptive methods lead to new performance thresholds across diverse athletic abilities.	Intersectionality ensures fair access to performance-enhancing opportunities for all identities.	Innovations in adaptive sports improving recovery protocols for all, enhancing performance across sports.

The implementation of immediate and precise feedback is another adaptive strategy that has proven effective for athletes with physical disabilities and offers significant benefits for able-bodied athletes as well. Studies show that athletes learn more efficiently when motor tasks are broken down into smaller, more manageable components, a technique often used in wheelchair basketball and tennis, where movement restrictions require more precision and coordination.[13,31] Moreover, these progressive learning methods help build a strong foundation of technique, essential for minimizing compensatory movements that could lead to injury over time if not addressed. By integrating these adaptive coaching strategies, there is potential for

significant advancement in training methodologies for all athletes, particularly in refining technical skills, improving movement efficiency, and enhancing long-term athletic development.

Table 2 illustrates how *Adaptive Synergy* facilitates the cross-pollination of training techniques, innovations, and performance strategies between disabled and able-bodied athletes, promoting a unified approach to optimizing athletic performance. At the same time, Intersectionality ensures that athletes with diverse identities, across race, gender, disability, and socioeconomic status, are considered in the design and application of these methods. This integration emphasizes the interconnectedness of inclusivity and innovation in sport science, fostering more equitable opportunities for all athletes.

The Significance of Adapted Physical Activity

APA plays a pivotal role in the *Adaptive Synergy* framework, serving as a critical tool for inclusivity in sports and physical activity. APA encompasses a range of sports and exercise activities that are modified to accommodate different abilities while maintaining the physical, psychological, and social benefits of traditional physical activity. This approach ensures that individuals with physical disabilities have equitable opportunities. While this approach aims to ensure equitable opportunities for individuals with disabilities, we recognize that significant challenges remain. As Martin (2018) notes in the *Handbook of Disability Sport and Exercise Psychology*, many athletes with physical disabilities are excluded from sports due to systemic, social, and structural barriers. Furthermore, attitudes toward inclusion often present obstacles to equitable participation. These challenges underscore the need for continuous effort and nuanced strategies to address the diverse variables at play in fostering genuinely inclusive environments. Participation in sports such as wheelchair basketball, hand-cycling, and adaptive swimming, thereby allowing participants to experience the same health benefits, such as improved cardiovascular fitness, muscle strength, and enhanced mental well-being, as their able-bodied counterparts.[44]

Historically, the roots of APA can be traced back to the early 20th century, when physical activity was first introduced as a therapeutic measure for soldiers injured in World War I and World War II. The physical rehabilitation programs designed for injured veterans laid the groundwork for the development of organized adapted sports, which later gained prominence in the 1960s with the establishment of the Paralympic Games. Since then, APA has evolved significantly, driven by advancements in sport science, biomechanics, and adaptive technologies, all of which have expanded the scope and accessibility of adapted sports.[45]

In the modern context, APA is not only about modifying physical activities to fit the needs of athletes with physical disabilities but also about driving innovation and inclusion in sport science. The practice fosters a deeper understanding of the interplay between physical limitations and performance, pushing researchers and practitioners to develop adaptive strategies that enhance not just accessibility but also the overall athletic potential of individuals with disabilities. For example, innovations such as carbon fiber prosthetics and high-

performance wheelchairs have revolutionized adapted sports, allowing athletes with physical disabilities to compete at levels previously deemed impossible.[20]

Furthermore, APA has been shown to provide substantial mental health benefits by fostering self-esteem, promoting psychological resilience, and encouraging the development of social connections among individuals with disabilities. Research indicates that participation in adapted sports can significantly reduce symptoms of anxiety and depression, while simultaneously improving overall life satisfaction.[6] These activities offer a sense of belonging and community, which is critical for mental well-being and social integration, particularly for individuals who may feel isolated particularly due to physical limitations. Through these comprehensive benefits, spanning mental, social, and physical health, APA not only enhances individual well-being but also serves as a foundational element of the *Adaptive Synergy* framework, demonstrating how sport science can be leveraged to create inclusive, empowering, and high-performance environments for all athletes.

Overcoming Barriers

The integration of *Adaptive Synergy* within sport science necessitates a comprehensive and multidisciplinary approach, engaging stakeholders from sport science, education, engineering, public policy, and healthcare. One of the critical barriers to inclusivity in sports is the lack of accessible and adaptive facilities. Aquatic centers, for example, often require significant retrofitting to meet the needs of athletes with physical disabilities. These facilities must be equipped with specialized tools such as adjustable pool floors, aquatic lifts, and ramps that facilitate ease of access and participation for individuals with mobility impairments. Research demonstrates that aquatic environments offer unique physical and therapeutic benefits, such as reducing joint strain and increasing freedom of movement, which are particularly valuable for athletes with physical disabilities.[1] To overcome this barrier, collaboration between engineers, architects, and sport scientists is essential. Cost-effective, inclusive design strategies must be developed, ensuring that adaptive aquatic and land-based sports facilities are widely available, not only in elite sports centers but also in community spaces, schools, and rehabilitation centers.

To effectively address the infrastructural challenges in implementing *Adaptive Synergy*, it is essential to expand research and professional training in APA. Currently, there remains a considerable gap between the growing demand for inclusive sports professionals and the availability of trained personnel.[3] While some undergraduate and graduate sport science programs have begun to incorporate APA principles, there is still much to be done to provide professionals with the specialized training needed to support athletes with physical disabilities. To address this gap, academic institutions must prioritize the development of comprehensive programs that offer certifications in adaptive sport methodologies and biomechanics, ensuring that graduates are prepared to meet the unique needs of athletes with physical disabilities.

Institutions such as the University of South Carolina and Texas Woman's University have developed APA certification programs that cover topics such as adaptive equipment design, biomechanics, and inclusive coaching strategies.[18] These certifications focus on providing professionals with hands-on experience and evidence-based strategies to work with athletes

with physical disabilities. In addition, continuing education opportunities offered by organizations such as the National Strength and Conditioning Association (NSCA) ensure that coaches and healthcare professionals stay up to date on adaptive training advancements.[6] By promoting APA certifications and professional development courses, sport science can better equip professionals to address the specific needs of athletes with physical disabilities, thereby fostering inclusivity and innovation in the field. Gender and disability barriers have proven to be a very determining factor that has very much inhibited the performance of a lot of paralympic athletes. In the past, women with disabilities have struggled to gain the same access and training as their male counterparts. However, they are becoming increasingly prevalent in amateur and elite paralympic sports.[26]

Historical and ongoing challenges for athletes with physical disabilities include pervasive public perceptions shaped by stereotypes that can limit their access to and engagement in physical activity. Such stereotypes contribute to feelings of humiliation, discreditation, and devaluation, stemming from societal norms that define physical capability in narrow terms.[18] However, recent strides toward inclusivity signal progress, with society moving closer to upholding athletes with physical disabilities' rights to dignity, equal opportunity, non-discrimination, and full societal integration.[26]

Economic limitations are another major barrier preventing paralympic sport from thriving. A glaring lack of sponsorship with paralympic events leaves athletes fending for themselves, trying to pay for most, if not all, of their expenses when practicing, traveling, and competing.[26] These sports and the regional, national, and international nature of events can be incredibly expensive, having to pay for everything ranging from plane tickets, sometimes across the globe, to practice equipment, to apparel, to practice space such as a gym or pool. These are all things that even some amateur level able-bodied athletes can get reimbursed for depending on where they come from, and this is notwithstanding the additional expenses that come along with impairment-related factors. The media plays a major role in this, because paralympic athletes don't receive nearly the amount of recognition as able bodied athletes do. Such media recognition may be the biggest step in increasing revenue for paralympic athletics, so that they can receive the same financial benefits as able-bodied athletes.[46]

Overcoming these barriers will require collaboration between academia, government agencies, and private organizations to fund and implement APA programs. The establishment of public-private partnerships can facilitate the development of adaptive sports facilities and provide ongoing funding for research into APA. In Canada, for instance, government-led initiatives have underscored the importance of embedding DEI principles into research and public policy, driving investments in inclusive sports and physical education programs.[15] Promoting similar collaborative efforts globally will help to ensure that APA becomes a standard part of physical education curricula and community-based sports initiatives. These efforts will create a more equitable landscape for athletes of all abilities, reinforcing that inclusivity and performance optimization are not mutually exclusive but, rather, interconnected goals that drive innovation informed by sport science.

Integrating the insights gained from adaptive sports into mainstream athletic training highlights the mutual benefits of a truly inclusive approach informed by sport science. The *Adaptive Synergy* framework facilitates this by blending advancements in equipment, technology, and coaching methods across different athletic communities. For example, innovations like specialized wheelchairs designed for adaptive sports, such as basketball and rugby, have driven material science and ergonomic improvements that enhance both durability and performance efficiency for all athletes.[30] These adaptations enrich able-bodied sports by introducing more effective tools and methodologies.

This knowledge exchange is not unidirectional. Research and developments from able-bodied sports can also refine training techniques and create new opportunities for athletes with physical disabilities. Coaching methods developed to address the specific biomechanical challenges of athletes with physical disabilities, such as breaking down complex movements into simpler components, have been widely adopted in able-bodied training to create more tailored and effective strategies.[35] In turn, an appreciation of these factors at play can positively impact what and how sport scientists elect to generate new knowledge through creative studies.

Moreover, recognizing this reciprocal relationship fosters a more comprehensive approach to sport science, where advancements in adaptive and mainstream sports are interwoven, creating a unified strategy that optimizes performance across all levels of ability. This approach aligns with intersectional principles, like those proposed by Crenshaw[7], which emphasize the importance of addressing overlapping identities and capabilities. Just as intersectionality in social sciences seeks to consider the layered effects of race, gender, and class, the *Adaptive Synergy* model promotes a framework that considers the diverse needs of all athletes, integrating inputs from biomechanics, psychology, and engineering to ensure that innovations uplift participants across the widest possible spectrum of physical abilities. By advancing this collaborative model, the *Adaptive Synergy* framework sets a new standard for inclusivity in sport science. It not only respects the contributions of athletes with physical disabilities but also harnesses these insights to elevate the entire field, ensuring that every athlete can reach their full potential. This vision promotes a future in which sport science evolves into a truly equitable discipline, driving innovation through inclusivity and shared progress.

References

1. Zallio M, Clarkson PJ. Inclusion, diversity, equity and accessibility in the built environment: A study of architectural design practice. *Build Environ.* 2021;206:108352. https://doi.org/10.1016/j.buildenv.2021.108352

2. Vanlandewijck YC, Evaggelinou C, Daly DJ. Proportionality in wheelchair basketball classification: The impact of physical impairments on the field performance. *Scand J Med Sci Sports.* 2001;11(2), 87-98.

3. Mullin AE, Coe IR, Gooden EA, Tunde-Byass M, Wiley RE. Inclusion, diversity, equity, and accessibility: From organizational responsibility to leadership competency. *Health Manag Forum.* 2021;34(5):311-315. https://doi.org/10.1177/08404704211038232

4. Ahmed S. *On Being Included: Racism and Diversity in Institutional Life.* Durham, NC: Duke University Press; 2012. https://doi.org/10.1515/9780822395324

5. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Med.* 2009;6(7):e1000097. https://doi.org/10.1371/journal.pmed.1000097

6. Blauwet C, Willick SE. The Paralympic movement: Using sports to promote health, disability rights, and social integration for athletes with disabilities. *PM&R.* 2012;4(11):851-856. https://doi.org/10.1016/j.pmrj.2012.08.015

7. Crenshaw K. Demarginalizing the intersection of race and sex: A Black feminist critique of antidiscrimination doctrine, feminist theory, and antiracist politics. *Univ Chic Legal Forum*. 1989(1); 139-167.

8. Haken H. *Synergetics: An Introduction.* Springer-Verlag; 1983. https://doi.org/10.1007/978-3-642-88338-5

9. Navalta JW, Stone WJ, Lyons S. Ethical issues relating to scientific discovery in exercise science. *Int J Exerc Sci*. 2019;12(1):1-8. https://doi.org/10.70252/EYCD6235

10. Hong QN, Pluye P, Fàbregues S, et al. Mixed Methods Appraisal Tool (MMAT), Version 2018: User Guide. Canadian Intellectual Property Office, Industry Canada; 2018. Accessed [November 15, 2024]. http://mixedmethodsappraisaltoolpublic.pbworks.com

11. Mageau GA, Vallerand RJ. The coach–athlete relationship: A motivational model. *J Sports Sci.* 2003;21(11):883-904. https://doi.org/10.1080/0264041031000140374

12. Reid M, Elliott B, Alderson J. Shoulder joint loading in the high-performance flat and kick tennis serves. *Br J Sports Med*, 2010;44(12):793-798.

13. Fletcher JR, Gallinger T, Prince F. How can biomechanics improve physical preparation and performance in Paralympic athletes? A narrative review. *Sports (Basel).* 2021;9(7):89. https://doi.org/10.3390/sports9070089

14. Wolbring G, Lillywhite A. Equity/equality, diversity, and inclusion (EDI) in universities: The case of disabled people. *Societies.* 2021;11(2):49. https://doi.org/10.3390/soc11020049

15. Best practices in equity, diversity and inclusion in research. October 10, 2024. Accessed October 25, 2024. https://www.sshrc-crsh.gc.ca/funding-financement/nfrf-fnfr/edi-eng.aspx.

16. International Paralympic Committee. Cutting-edge technology behind Para Sports. *Paralympic.org.* 2021. https://www.paralympic.org/feature/cutting-edge-technology-behind-para-sports.

17. Suggs W, Walton T. A place on the team: The triumph and Tragedy of Title IX. *Women Sport Phys Act J.* 2007;16(1):56-58. https://doi.org/10.1123/wspaj.16.1.56

18. Jaarsma EA, Dijkstra PU, Geertzen JHB, Dekker R. Barriers to sports participation for people with a physical disability: A review. *Scand J Med Sci Sports.* 2014;24(6):871-881. https://doi.org/10.1111/sms.12218

19. Henschen K, Horvat M, French R. A visual comparison of psychological profiles between able-bodied and wheelchair athletes. *Adapt Phys Act Q*. 1984;1(2):118-124. https://doi.org/10.1123/apaq.1.2.118

20. Nolan L. Carbon fibre prostheses and running in amputees: A review. *Foot Ankle Surg.* 2008;14(3):125-129. https://doi.org/10.1016/j.fas.2008.03.002

21. Davids K, Button C, Bennett S. *Dynamics of Skill Acquisition: A Constraints-Led Approach.* Human Kinetics; 2008.

22. Petersen J, Judge LW. Sport facilities planning, design, operation, and management trends: An introduction to the special issue. *J Appl Sport Manag.* 2023;15(4). https://doi.org/10.7290/jasm-2023-V15-I4-LoT7

23. Judge LW, Hoover DL, Bellar DM. Balancing the imbalance: The training of a Paralympic F44 discus thrower. *NSCA Coach.* 2018;5(3):40-48.

24. Martin JJ. *Handbook of Disability Sport and Exercise Psychology*. New York, NY: Oxford University Press; 2018. https://doi.org/10.1093/oso/9780190638054.001.0001

25. Liu J, Yu H, Bleakney A, Jan Y-K. Factors influencing the relationship between coaches and athletes with disabilities: A systematic review. *Front Sports Act Living.* 2024;6(1461512). https://doi.org/10.3389/fspor.2024.1461512

26. Rodríguez Macías M, Giménez Fuentes-Guerra FJ, Abad Robles MT. The sport training process of para-athletes: A systematic review. *Int J Environ Res Public Health.* 2022;19(12):7242. https://doi.org/10.3390/ijerph19127242

27. Judge LW, Cinnamo, J, Craig, BW. Designing a resistance training program for Paralympic throwers. *NSCA Coach.* 2023;10(4):10-15.

28. Ponchillia PE, Armbruster J, Wiebold J. The National Sports Education Camps Project for Athletes With Visual Impairments: A Final Report. *J Vis Impair Blind*. 2005;99(5):323-334. https://doi.org/10.1177/0145482X0509901107

29. Gaetano R, Melaranci P, Di Filippo F, Fratini A, Schena F. The role of the tapper in Paralympic swimming: Kinematic insights from a case study. Eur *J Sport Sci*. 2021;39(16):1914-1919.

30. Goosey-Tolfrey VL, Leicht CA. Field-based physiological testing of wheelchair athletes. *Sport Med*. 2013;3(2):77-91. https://doi.org/10.1007/s40279-012-0009-6

31. Hindawi OS, Orabi S, Al Arjan J, Judge LW, Cottingham M, Bellar DM. Offensive tactical thinking level of wheelchair basketball players in Arab countries. *Eur J Sport Sci* 2013; 13.(6): 622-629. https://doi.org/10.1080/17461391.2013.771383

32. Cavedon V, Zancanaro C, Milanese C. Body composition assessment in athletes with physical impairment who have been practicing a wheelchair sport regularly and for a prolonged period. *Disabil Health J.* 2020;13(4):100933. https://doi.org/10.1016/j.dhjo.2020.100933

33. Coutts A, Vicky C. Training loads and injury risk in wheelchair athletes: A review. *Int J Sports Sci Coach*. 2014;9(3):627-638.

34. Goosey-Tolfrey V, Butterworth D, Morriss C. Strength training for wheelchair athletes. *J Sport Sci*. 2002;20(8):595-600.

35. Tweedy SM, Vanlandewijck YC. Rehabilitation of sports injuries in athletes with a disability: A clinical perspective. *J Sci Med Sport*. 2011;14(1):60-65.

36. de Groot S, Balvers IJ, Kouwenhoven SM, Janssen TW. Validity and reliability of tests determining performance-related components of wheelchair tennis. *J Sport Sci*. 2016;34(5):424-431.

37. Litchke, L. G., et al. (2008). Wheelchair tennis: Movement dynamics and peer-reviewed training methods. *Adapt Phys Activ Q*. 25(4), 336-355.

38. Vanlandewijck Y, Daly D, Theisen D. Field test evaluation of wheelchair propulsion efficiency. *Br J Sports Med*. 2001;35(4), 244-248.

39. Chen P, Yu H, Lin CF, Guo J, Elliott J, Bleakney A, et al. Effect of adaptive sports on quality of life in individuals with disabilities who use wheelchairs: A mixed-methods systematic review. *Disabil Rehabil Assist Technol.* 2024;1-17. https://doi.org/10.1080/17483107.2024.2313110

40. Eikevag SW, Erichsen JF, Steinert M. Sports equipment design impact on athlete performance: The PR1 Paralympic women's indoor rowing world record. *Eng Sport.* 2022. https://doi.org/10.5703/1288284317474

41. Ross SA, et al. Advances in rehabilitation robotics and their application to sports performance. *J Biomech.* 2019;52:99-104.

42. Martin Ginis KA, Ma JK, Latimer-Cheung AE, Rimmer JH. A systematic review of review articles addressing physical activity participation among persons with disabilities. *Health Psychol Rev.* 2017;10(4):456-477. https://doi.org/10.1080/17437199.2016.1198240

43. Scholz JP, Schöner G, Latash ML. Motor control: Insights from motor learning and neurorehabilitation. *Compr Physiol.* 2017;7(2):397–435. https://doi.org/10.1002/cphy.c160046

44. Arora K, Wolbring G. Kinesiology, physical activity, physical education, and sports through an equity/equality, diversity, and inclusion (EDI) lens: A scoping review. *Sports (Basel).* 2022;10(4):55. https://doi.org/10.3390/sports10040055

45. DePauw KP, Gavron SJ. *Disability Sport.* Human Kinetics; 2005. https://doi.org/10.5040/9781492596226

46. Araújo D, Davids K. Team synergies in sport: Theory and measures. *Front Psychol.* 2016;7:1449. https://doi.org/10.3389/fpsyg.2016.01449