International Journal of Applied Sports Sciences
2025, Vol. 37, No. 2, 174-187.
https://doi.org/10.24985/ijass.2025.37.2.174

ISSN 2233-7946 (Online)
ISSN 1598-2939 (Print)

Conditioning Strategies to Enhance Performance for Wheelchair Athletes: A Systematic Review

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Abstract

This study aims to systematically organize previous research on conditioning management to assist wheelchair athletes perform at their best in international competitions. The systematic literature review examined the factors affecting the performance of wheelchair athletes both nationally and internationally, highlighting key considerations for creating conditioning strategies for these athletes. It investigated training methods in preparation for international competitions, as well as nutritional and hydration intake before, during, and after these events. The study briefly presented methods for nutritional intake tailored to the characteristics of various sports for athletes with disabilities. The results of the systematic review were grouped into factors influencing the performance of wheelchair athletes. This summary emphasizes the essential points to consider when developing conditioning strategies for wheelchair athletes, along with the characteristics and precautions that must be taken into account during training and competition participation. The main factors affecting the performance and conditioning of wheelchair athletes are identified as follows: performance-related factors, prevention and management of pressure ulcers, fall prevention, nutrition and hydration, sleep and rest, management of jet lag, and accessibility. The results of this study are expected to improve the performance of wheelchair athletes and reduce injuries by enhancing their conditioning in preparation for international competitions.

Key words: conditioning, performance, wheelchair athletes, systematic review

Introduction

The key factors influencing athletic performance include skills, physical fitness, psychological factors, and tactics (Yun et al., 2006). Additionally, the athlete, coach, and environment can have a significant impact on performance (Jung & Kim, 2004). Conditioning refers to a series of processes that integrate various performance components into an optimal state, maximizing an athlete's potential during competitions. It also involves maintaining the physiological and psychological conditions necessary to cope with the environment and perform exercises effectively (Song et al., 2012). Furthermore, conditioning encompasses not only systematic training to maintain peak performance but also recovery methods, such as adequate nutrition intake, sufficient sleep, and rest (Park et al., 2018).

The academic concept of sports conditioning is described as a structured training process aimed at enhancing physical fitness elements and neuromuscular control capabilities to improve athletic performance. Furthermore, wheelchair athletes display unique traits

Submitted : 16 June 2025
Revised : 4 August 2025
Accepted : 4 November 2025
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compared to non-disabled athletes in areas like immune response, nutrition management, and mental health, requiring focused scientific research and program development (İslamoğlu & Kenger, 2019). This shows that sports conditioning goes beyond just improving physical fitness, taking a whole-person approach that includes both physical and mental qualities. Exercise intensity, frequency, and recovery strategies lead to different physiological responses depending on whether athletes have impairments affecting condition management. However, there is a lack of comprehensive and systematic research on condition management for athletes with disabilities compared to athletes without disabilities (Puce et al., 2023; Sellami et al., 2023). Research on conditioning strategies for athletes with disabilities preparing for international competitions is limited. The types of disabilities among participating athletes vary and include physical disabilities (such as spinal cord injuries and amputations), visual impairments, brain injuries, and intellectual disabilities. Research on conditioning strategies for athletes with disabilities preparing for international competitions is limited. The types of disabilities among participating athletes vary and include physical disabilities (such as spinal cord injuries and amputations), visual impairments, brain injuries, and intellectual disabilities (Kim et al., 2020). The travel time required for participation in international competitions can be burdensome for most athletes, but it presents an even greater challenge for athletes with disabilities (Campbell & Jones, 2002). According to Bawden (2006), the biggest source of stress for athletes with disabilities was the long flight times for international competitions. Factors like boarding and disembarking from airplanes, transferring from wheelchairs to airplane seats, restroom accessibility, and personal care items during the flight all created challenges for these athletes. Traveling by vehicle within the country can also be challenging for athletes with disabilities. Moreover, venues that do not consider accessibility can impose restrictions on athletes with disabilities (Katz, 2007). In the Paralympics, due to the nature of disabled sports or the lack of accessibility at venues, events may take place in locations other than the host city. For instance, at the 2008 Beijing Paralympics, sailing events were held in Qingdao, and equestrian events took place in Hong Kong. In contrast, skiing events at the 2014 Sochi Paralympics were conducted 60 km away from the Paralympic Village in Sochi (Martin, 2015).

The climate of the host city is also a crucial factor. The heat produced during metabolism in athletes with disabilities can differ based on the type of disability, its severity, and location of the injury. Unlike athletes with spinal cord injuries, those with cerebral palsy and amputations may be considered at higher risk due to these conditions (Griggs et al., 2019). The 2020 Tokyo Paralympics took place from August to September, and concerns about athletes' performance dropping due to high temperatures and humidity arose even before the event. In response, Griggs et al. (2019) suggested strategies to improve performance at the 2020 Tokyo Paralympics, such as cooling techniques, equipment innovations, heat acclimation and acclimatization, and hydration and nutritional practices.

While there are differences depending on the type of disability, considerations for mobility and accessibility are crucial for wheelchair athletes. For athletes with spinal cord injuries and neurological impairments, strategies to manage climate conditions, such as temperature and humidity, must also be included. The performance of athletes with disabilities involves a complex process that requires a multifaceted and layered research approach to improve effectiveness (Bae et al., 2020). Therefore, conditioning strategies for athletes with disabilities in international competitions should not only include general conditioning methods suitable for able-bodied athletes but also account for the unique attributes of wheelchair athletes. This study aims to propose conditioning strategies that will allow wheelchair athletes competing in international competitions to compete under optimal conditions.

Methods

Systematic Review

A systematic review is a thorough research method used to find, assess, and combine all relevant studies

related to a specific research question, following a transparent and reproducible process. This approach begins with formulating a clear and focused question. Then, a thorough and systematic search is carried out across multiple databases, using predefined keywords and inclusion/exclusion criteria to ensure repeatability and reduce bias (Bero, 2017). The next stage involves independently screening and selecting studies based on these criteria, followed by a thorough assessment of each study's methodological quality and risk of bias. Afterward, data are extracted using standardized forms, and the findings are synthesized using either qualitative or quantitative techniques, such as meta-analysis when applicable. The final results are interpreted considering their strengths and limitations, following reporting standards such as the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency and completeness (Shamseer et al., 2015).

Data Collection Procedure

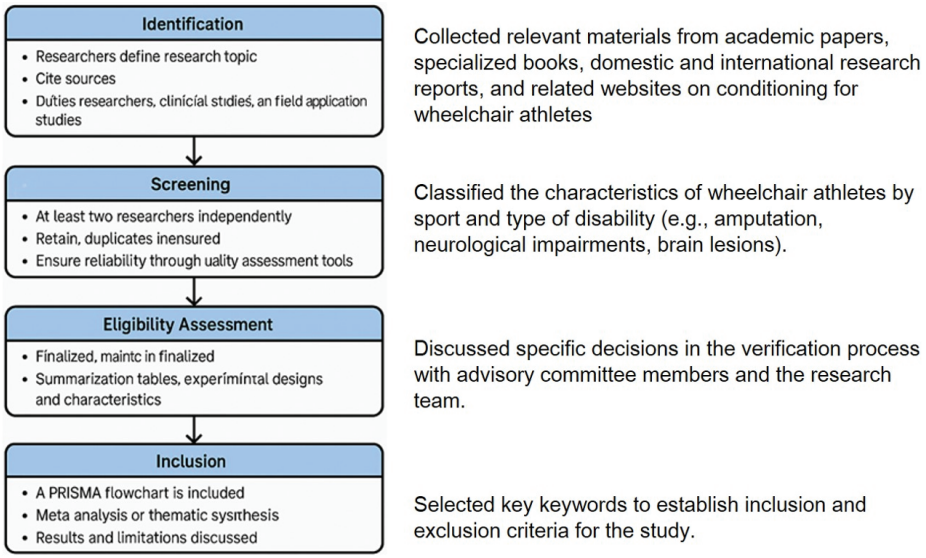
A systematic review was conducted to identify the characteristics of various sports for wheelchair athletes, and the types of disabilities involved, including amputations, neurological disorders, and brain injuries. The review aimed to determine key considerations for developing effective conditioning strategies. Relevant materials were gathered from academic papers, specialized books, domestic and international research reports, and related websites, with a focus on previous studies. For academic papers related to conditioning for athletes with disabilities, electronic databases were reviewed, and key search terms were identified. Inclusion and exclusion criteria were established to guide the selection of studies. Additionally, discussions were held with advisory committee members and researchers to address specific decisions in the verification process.

Furthermore, information about the climate, unique culture, security, and infectious diseases in regions that have recently hosted international competitions for athletes with disabilities, such as the Paralympics. This enabled for the calculation of travel time to the host city and the time difference relative to the scheduled arrival time in the host city. Consequently, comprehensive conditioning strategies were proposed before participation in international competitions. These strategies included adapting to different time zones, maintaining physical fitness, managing nutrition intake, regulating sleep, and addressing psychological factors. A systematic literature review using the PRISMA approach provides a comprehensive analysis of wheelchair athletes, highlighting the connection between specific impairments (e.g., spinal cord injury, amputation, neurological damage, and brain injury) and athletic participation.. Key studies confirm that wheelchair athletes face a wide range of physiological and functional demands, influenced by both the type of sport and the athlete's underlying disability. These systematic efforts promote an evidence-based understanding of how disability-related factors shape sports participation and athlete development in wheelchair athletics.

A review of wheelchair athletes, based on the PRISMA is systematically organized in a stepwise manner: (1) identification, (2) screening, (3) eligibility assessment, and (4) inclusion. In the first step, researchers define the scope of the research topic and comprehensively collect all relevant materials, including research papers, clinical studies, and field application studies. Next, two or more researchers independently screen and review the papers, retaining only those that are not duplicates and are relevant, while ensuring reliability through quality assessment tools. Once the dataset is finalized, the main indicators of the included papers, experimental designs, and characteristics of the target groups are summarized in tables, followed by a meta-analysis or thematic synthesis. Finally, a PRISMA flowchart is included in the paper to visualize the transparency of the data screening process, and the interpretation of results for various wheelchair sports and athlete groups, along with their limitations, is discussed in detail. The classification of previous studies related to wheelchair athletes is presented in Table 1 and Firgure 1.

Table 1. Types of disabilities for wheelchair athletes

	Classification		Subclassification
1	Brain injury disability	Severe	Classification by parasports
2		Mild	Able to stand with crutches or against a wall
3	Spinal cord injury		Unable to support upper body
4			Able to support upper body
5	Physical function disability		Polio, amputation, etc.



Figue 1. Systematic review of wheelchair athletes.

Results

Factors Affecting the Performance of Wheelchair Athletes

Perret (2017) suggested that training, recovery, and sleep, as well as psychological and physical factors, age and gender, talent, personal environment, coaching, mental factors, motivation, training possibilities, equipment, environment, form on the day, and experience all play a role.

Paulson & Goosey-Tolfrey (2017) reported that athlete profiles, physical capacity, equipment, and competition environments are factors affecting performance in wheelchair court sports such as Wheelchair basketball, Wheelchair rugby, and others. They also suggested training prescriptions and monitoring, equipment innovations, cardiovascular hemodynamics, cooling strategies, and nutritional practices as intervention methods to improve performance.

Sports equipment significantly affects performance in various sports. In para sports, it is also a major factor influencing performance and is sometimes considered an extension of the body (Kim, 2019). Previous studies have also indicated that equipment is a crucial factor influencing performance (Perret, 2017; Paulson & Goosey-Tolfrey, 2017). These sports equipment allow athletes with disabilities to participate in the same sports as athletes without disabilities, but they are used differently depending on the sport and the individual athlete's characteristics. In the case of wheelchairs, which are primarily used in sports by athletes with physical disabilities, they vary in design even within

Figue 2. Factors affecting the performance of wheelchair athletes.

the same track and field sport. They are custom-made to match the individual athlete's characteristics by integrating engineering elements. Since the development of equipment has a positive impact on the performance of athletes with disabilities, ongoing research should be conducted in this area.

According to a study examining a total of 21 studies on factors affecting the performance of athletes with disabilities, training programs for them primarily focus on immediate intervention and training, with long-term training programs lacking (Dehghansai et al., 2017). Additionally, an analysis of 26 studies focused on enhancing the performance of athletes with disabilities confirmed that intervention programs were categorized into factors such as physical strength, technical training, coaching, environment, equipment, psychology, and recovery. Specifically, the focus was on physical strength, technical training, and psychological factors (Bae et al., 2020).

Prevention and Management of Pressure Ulcers

Pressure ulcers (PUs) are conditions in which skin tissue dies due to impaired blood circulation in specific areas of the body. It can occur for various reasons, including damage to nerve tissue, degeneration of sensory organs from aging, individuals with disabilities who spend prolonged periods sitting or lying down, the elderly, those who are immobile before and after surgery, and people with chronic conditions such as diabetes (Shaw, 1998). In the case of wheelchair users, most of the body weight is concentrated on the buttocks (hips), leading to excessive pressure concentration, asymmetry between the left and right buttocks, and excessive pressure gradients that contribute to the development of PUs (Kang et al., 2010). In particular, individuals with spinal cord injuries, especially cervical cord injuries, may face various complications, including PUs, as well as functional limitations such as trunk control (Bond & McKerracher, 2014; Grossman et al., 2012).

The causes of PUs are primarily categorized into external factors (pressure, responsiveness, friction, etc.) and internal factors (nutritional deficiency, old age, decreased tissue perfusion, etc.). It is advisable to identify these causes in advance to prevent their occurrence. In particular, focus on factors such as pressure, responsiveness, friction, chemical irritants, and moisture, while also improving overall health and maintaining an appropriate nutritional state that includes adequate protein, vitamins, and water intake. It is recommended to change positions at least every two hours to minimize skin damage and to maintain cleanliness and sanitation. Previous studies indicate that various long-term factors can affect the occurrence of

PUs, including aging factors such as a decreased inflammatory response, reduced production of cytokines and growth factors, and an increase in senescent cells (Pittman, 2007); disability and health status factors such as obesity, diabetes, hypertension, peripheral vascular disease, fecal incontinence, and a history of pressure ulcers (Wound, Ostony, and Continence Nurses Society, 2003; Gray et al., 2007); and lifestyle factors like smoking, activity level, mobility, and stress (Park et al., 2005; Burns et al., 2003; Vileikyte, 2007). Among these, health status factors such as obesity, diabetes, and hypertension, along with lifestyle factors like smoking, activity level, and stress, can be managed by individuals, so it is essential to understand and prevent them clearly.

Preventing PUs is the top priority; however, if they do occur, appropriate treatment should be administered based on the priorities of PUs management. Specifically, wheelchair athletes with spinal cord injuries or chronic conditions like obesity, diabetes, and high blood pressure require extra attention.

Prevention of Falls

Falls refer to unintentional events that can cause injuries or sequelae such as fractures, soft tissue damage, and limitations in independent living. In addition to contact falls that occur during competition and training, wheelchair-using athletes with disabilities can also experience mainly non-contact falls while moving around in their wheelchairs. In particular, falls while using a wheelchair can lead to significant and minor injuries to the upper extremities (joints related to the wrist, arm, and shoulder), face, and head, and can result in skin damage due to abrasions (Curtis & Dillon, 1985). These injuries can affect the performance of disabled athletes and have serious negative effects on game outcomes (Curtis & Dillon, 1985; De Luigi, 2017). Additionally, repeated wheelchair falls can lead to psychological damage (trauma), which can negatively impact participation in and results of the game (Taylor & Williams, 1995). Therefore, it is essential to be aware of precautions to prevent falls when using a wheelchair during and before the competition.

Although there is limited scientific evidence and statistics on the causes of falls and injuries related to falls among wheelchair-using disabled athletes, it is understood that approximately 30-65% of individuals with spinal cord injuries who use wheelchairs in their daily lives have experienced at least one fall (Forslund et al., 2017). Additionally, it is known that the most frequent causes of falls among wheelchair-using disabled athletes occur during mobility, and falls often happen when the surface on which the wheelchair travels is poor or when attention or concentration is lacking during movement (Sung et al., 2019). Therefore, both assistants helping with wheelchair mobility and wheelchair athletes using wheelchairs should focus on looking ahead while moving and remain cautious about engaging in other activities (e.g., using a mobile phone or listening to music) to prevent falls during movement. Additionally, they should navigate through areas with better road conditions and less congestion, avoiding uneven or crowded spaces. If the wheelchair must be momentarily stopped, always ensure that the assistant or wheelchair athletes do not let go of the wheelchair if possible.

Nutrition and Hydration

Sedentary sports include activities for individuals with cerebral palsy and lower body disabilities who have limitations in standing. Low- to medium-intensity sedentary sports, which feature low exercise intensity, such as Boccia and Lawn bowls, encompass a broader range of disability types, including amputation and lower body disabilities as well as cerebral palsy. In this context, there is a greater reduction in muscle mass and sympathetic nervous system activity, along with lower energy demand, compared to both disabled and non-disabled athletes who can stand. This variation is attributed to the type of disability and the sport's specificity (Price, 2010). Additionally, prolonged sitting can lead to gastrointestinal disorders, resulting in physical issues such as nausea and vomiting (Graham-Paulson et al., 2015). Meanwhile, medium-intensity sedentary sports, such as archery and shooting, require

agility and coordination that focus on the upper body, primarily utilizing energy through the ATP-PC system (Sung, 2017).

According to a study by Wang et al. (2005), leptin levels in spinal cord injury patients were reported to be 32% higher than in non-disabled individuals. High leptin levels interfere with appetite control, leading to poor dietary intake patterns, particularly in the consumption of vitamins and minerals such as fruits and vegetables, which were found to be low (Eskici, 2016). Furthermore, since sedentary wheelchair athletes' exhibit lower physical activity levels compared to athletes in other sports, their calorie intake and requirements may decrease, potentially resulting in nutrient deficiencies, such as iron deficiency (Scaramella et al., 2018). Additionally, muscle mass may decline due to the influence of a limited metabolic rate, reduced energy expenditure, and decreased glycogen absorption. Prolonged sitting can lead to gastrointestinal and bowel disorders, necessitating a tailored nutritional intake appropriate for the sport and the athlete's specific condition. Consequently, the recommended daily carbohydrate intake for sedentary athletes includes complex carbohydrates, such as whole grains (e.g., multigrain rice), vegetables, and fruits. For low-intensity sports, an average of 3 to 5 g/kg per day is recommended, while for high-intensity sports, 8 to 12 g/kg is advised. Furthermore, to prevent muscle loss, a protein intake of 1.2 to 1.7 g/kg per day is necessary. Additionally, carbohydrate intake prior to training (1 to 4 hours before) can be suggested in the form of oatmeal, rye bread, and similar foods (Flueck, 2021).

In particular, wheelchair athletes with spinal cord injuries are more likely to experience heatstroke because their autonomic dysfunction decreases skin blood flow and impairs sweating control, both of which are essential for regulating body temperature. Therefore, managing heatstroke requires consistent water intake during and after the game, especially during training, with a recommended water intake of 500−1,000 mL to prevent a loss of more than 2% of body weight due to dehydration (Goosey-Tolfrey et al., 2016). After training, carbohydrate intake of 1−1.2 g/kg is necessary to replenish glycogen, while a water intake of 1.5 L per 1 kg of weight loss is suggested. Moreover, 20−25 g (or 0.3−0.5 g/kg) is recommended to support muscle synthesis (Flueck, 2021).

Sleep and Rest

Getting enough sleep is important because a lack of sleep or deprivation can negatively affect physical performance, mood, and psychological well-being, leading to issues such as depression, tension, fatigue, and anger, while also reducing vitality (Watson, 2017; Reilly & Edwards, 2007). Additionally, sleep is essential for recovery and adaptation to training and competition. Generally, it is recommended that healthy adults sleep for more than 7 hours each night and ideally maintain a sleep efficiency of greater than 85%.

In general, athletes experience sleep loss both before and after competition, which is known to significantly impact their performance and recovery (O'Donnell et al., 2018). In particular, para-athletes have been reported to have poorer sleep quality and increased daytime sleepiness compared to general athletes (Szabo & Kennedy, 2022).

As introduced in the study of sleep optimization guidelines for athletes by Vitale et al. (2019), several specific behavioral guidelines for achieving sufficient and appropriate sleep are recommended: 1) Do not go to bed until you feel sleepy; if you're not sleepy, get out of bed and do something else until you are. 2) Maintain a regular sleep and rest pattern; reading or taking a warm bath before bed can help. 3) Avoid napping as much as possible; if you must nap, limit it to less than one hour and refrain from doing so after 3 PM. 4) Use the bed only for sleep and intimacy; do not use it for other electronic devices such as TVs or smartphones. 5) Avoid caffeine if possible; if necessary, refrain from it after lunch. 6) Do not drink alcohol or smoke before sleep. 7) Avoid engaging in high-intensity physical activity right before bedtime. 8) The bedroom should be as quiet as possible, kept dark, slightly cool rather than warm, and maintained at an appropriate humidity level. 9) Avoid blue light from electronic devices at least two hours before going to bed; blue light is known to suppress melatonin

production, which is vital for sleep induction. 10) When you wake up, try to expose yourself to bright, natural light. 11) Avoid watching TV before bed; sleep studies indicate that doing so can lead to frequent awakenings at night and disrupt quality sleep. 12) Limit water intake just before bed to prevent early morning bathroom trips.

When resting, it is helpful to maintain a good condition by resting in a comfortable area (e.g., a bed or a cozy chair or sofa in private accommodation) away from the wheelchair (unless you must sit in it). Prolonged time in a wheelchair is known to cause pressure injuries (localized damage to tissue) due to shear force among wheelchair athletes and can adversely affect the body's recovery (Edsberg et al., 2016; Dutton, 2019). Additionally, since wheelchair athletes must move and train extensively using their upper extremities, they should minimize upper extremity movement as much as possible during rest and perform light static stretching of the upper extremities during this time to reduce body fatigue and prevent additional injuries (Dutton, 2019). Furthermore, because wheelchair-bound athletes have more difficulty regulating their body temperature than general athletes, it is recommended to prevent hyperthermia by exposing them to cool air during rest periods immediately after exercise training or competition, icing, and (if possible) full-body cold water baths (which are known to be more effective than icing or cold towel compresses (Forsyth et al., 2016), along with adequate hydration (Dutton, 2019).

Managing Jet Lag

The process of physical functions change over a 24-hour cycle is called circadian rhythm. Traveling abroad, especially to regions with a time difference of more than three hours, can disrupt circadian rhythms, which are closely linked to sleep, activity cycles, body temperature, meals, and hormone secretion (Klerman, 2005). Reduced sleep duration, poor sleep quality, and sudden alterations in circadian rhythms significantly affect athletic performance (e.g., reaction time, muscular endurance, anaerobic power, cognitive function, and running speed), regardless of the athlete's characteristics or sport, and can increase the risk of injury (Watson, 2017). According to a recent study on the effects of jet lag and sleep deprivation resulting from international competitions on the sleep and subjective fatigue of wheelchair basketball athletes, overall conditions were better during long-term travel (up to 30.2 hours) than during short-term international travel (up to 6.5 hours) (Thornton et al., 2018). This occurs because the greater the change in time zone at the travel destination and the longer the travel duration, the worse the circadian rhythm mismatch and the more significant the resulting sleep disturbance. Additionally, sleep deprivation and shifts in circadian rhythm can negatively affect psychological factors such as anxiety, stress, and compulsion, while also leading to a decline in physical performance (Watson, 2017).

The sleep and rest characteristics and strategies of wheelchair athletes participating in international competitions are not considered significantly different from those of non-disabled athletes competing in international events. However, considering the various obstacles and restrictions associated with wheelchair use (e.g., physical exhaustion due to inconveniences such as using flights and public transportation, moving to locations beyond transportation, and using restrooms), it is crucial to make efforts to minimize physical exhaustion compared to everyday life (Jaarsma et al., 2013; McLoughlin et al., 2016). Therefore, sports medicine professionals and coaching staff should thoroughly manage and assist athletes with appropriate schedules, travel protocols, time management, stress management, and sleep hygiene to enhance overall health and performance. However, considering the various obstacles and restrictions related to wheelchair use (e.g., physical exhaustion due to inconveniences such as navigating flights and public transportation, reaching locations beyond transportation access, and using restrooms), it is essential to strive to reduce physical fatigue compared to daily life (Jaarsma et al., 2013; McLoughlin et al., 2016). Therefore, sports medicine professionals and coaching staff should carefully manage and support athletes with suitable schedules, travel protocols, time management, stress management, and sleep hygiene to improve overall health and performance.

Accessibility

The entire process of moving to the stadium, training site, and accommodation during the competition period significantly impacts the performance of wheelchair athletes. Therefore, considering the time required for movement, transportation, the presence of obstacles, and facilities for the disabled, finding the optimal route should be regarded as a crucial element for the effective conditioning management of disabled athletes. Among the factors limiting wheelchair athletes' participation in sports, inadequate facilities and issues related to mobility and accessibility are often mentioned. This is because wheelchair athletes encounter various adverse conditions in the external environment, such as insufficient space, poor road conditions, stairs, and speed bumps. For disabled athletes, traveling to stadiums or other venues for sports participation often requires more time and money than necessary. They report experiencing physical and mental fatigue based on the availability of facilities for people with disabilities, such as elevators or ramps (Kim & Seo, 2015; Lee et al., 2016). Access to the stadium for wheelchair athletes directly influences their performance and forms the basis for conditioning these athletes. This includes identifying the best routes to the stadium or training ground while considering traffic congestion and time zones to prevent and address such issues (Jang et al., 2016). As a result, major events like the Olympics and Paralympics are driving the movement to create an inclusive environment for people with disabilities to participate in society. This involves installing convenient facilities to improve stadium accessibility and fostering an environment where anyone can easily take part in sports, regardless of disability (Sneep, 2020; Tomomi, 2009).

To enhance the performance of wheelchair athletes in international competitions, it is essential to proactively identify barrier-free environments, such as stadium accessibility, and utilize them effectively. Barrier-free is a movement aimed at addressing the challenges faced due to physical and mental limitations, such as improving the physical environment and addressing psychological disabilities, with a focus on socially disadvantaged individuals, including the disabled and the elderly. Barrier-free refers to the concept of 'no obstacles or barriers,' which is reflected in the design and planning of buildings and facilities. This approach ensures that individuals with disabilities can fully engage in society and achieve equality, allowing them to participate in daily life and social activities without inconvenience (Lee & Kim, 2023). Barrier-free and universal designs are expected to positively impact awareness of individuals with disabilities and promote a sense of community. These designs are closely linked to the participation of people with disabilities in sports. Accordingly, active measures are being taken to reduce the physical and psychological access gap between individuals with disabilities and those without, regarding facility use and viewing. These measures include installing ramps and wheelchair-accessible elevators next to stairs, creating parking spaces for vehicles used by individuals with disabilities, and providing restrooms with accessible facilities (Yun & Kang, 2019). Policies and systems that are barrier-free and inclusive of people with disabilities must be actively implemented and embraced by the systems of countries hosting international competitions.

Discussion

The objective is to develop a strategy aimed at reducing injuries by promoting parasports and enhancing performance as a conditioning approach for wheelchair athletes. The results of this study are discussed by categorizing them into the following results. Factors affecting the performance of wheelchair athletes' performance drivers among wheelchair athletes are multifactorial, including physical conditioning, aerobic and anaerobic capacities, wheelchair configuration, and skill proficiency. Prevention and management of PUs long-term seated activity exposes wheelchair athletes to an higher risk of pressure ulcers, particularly at the ischial tuberosities and sacral region. Falls frequently occur during transfers, rapid movement on court, or due to fatigue induced balance loss. Conditioning regimens should focus on core and upper limb strength to improve athlete stability, while

dedicated skills training can enhance transfer confidence and dynamic balance. Environmental adaptations, such as non-slip surfaces and accessible facility designs are essential.

Wheelchair athletes should prioritize hydration management, especially those with spinal cord injuries and impaired thermoregulation, as dehydration can decrease performance and increase the risk of pressure ulcers and urinary issues. Also, wheelchair athletes with physical impairments often experience greater sleep disruption due to pain, spasticity, or autonomic dysregulation. Tailored recovery protocols that schedule adequate rest between high-load sessions, optimize bedding, facilitate nocturnal comfort, and possibly incorporate cognitive behavioral approaches can significantly enhance sleep quantity and quality. Managing jet lag international competition schedules create circadian misalignment that impairs both physiological and cognitive performance. Successful management includes gradual shift of sleep wake cycles pre-travel, strategic exposure to natural light, hydration protocols, and, where appropriate, controlled use of melatonin or pharmacological aids. For athletes with compromised autonomic function, additional planning is necessary to minimize adverse post travel effects. Every aspect of conditioning and injury prevention is depending on access to facilities, equipment, medical care, and coaching expertise Equal access to these resources regardless of location or socioeconomic background is essential for safe participation and reducing injuries. Wheelchair athletes exhibit diverse physiological characteristics and responses depending on the type and severity of their impairments. Therefore, detailed monitoring and personalized conditioning programs are essential to optimize their performance. In addition to physiological factors, mental health and psychosocial elements also play a significant role in the performance and recovery of wheelchair athletes.

In summary, reducing injuries and improving performance in wheelchair athletes depends on a comprehensive approach that includes personalized physical and technical training, proactive skin and fall prevention, proper nutrition and hydration, sleep and recovery strategies, jet lag management, and ensuring universal accessibility. The integration of athlete-centered support, efficient equipment adjustments, and continuous evaluation build a strong foundation for advancing para-sport in both injury prevention and athletic achievement. The conditioning strategy outlined in this study for wheelchair athletes aims to enhance performance and reduce the risk of injuries during international competitions. Furthermore, this strategy is expected to gather vital data to support future sports science initiatives for wheelchair athletes. The conditioning strategy introduced in this study for wheelchair athletes aims to maximize performance and reduce injuries in international competitions. Additionally, it is expected to provide essential data for future sports science support for wheelchair athletes.

Acknowledgments

This study is a revised and supplemented version of the report titled “Conditioning Guidelines for Wheelchair Athletes in Preparation for International Competitions: Focusing on Summer Sports (KISS-202303-IF-024-01)” conducted by the Korea Institute of Sport Science in 2023.

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Conflict of Interest

The authors declare no conflict of interest.

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