South African Journal of Clinical Nutrition 2025; 38(4):197–205
https://doi.org/10.1080/16070658.2025.2558210

SAJCN
ISSN 1607-0658 EISSN 2221-1268

RESEARCH ARTICLE

Preliminary dietary recommendations for adult spinal cord-injured endurance hand cyclists

Reno Eron Gordon[a,b], **Sunita Potgieter**[c] and **Lize Havemann-Nel**[b]

[a]*Department of Human Nutrition and Dietetics, Sefako Makgatho Health Sciences University, Pretoria, South Africa*
[b]*Centre of Excellence for Nutrition (CEN), North-West University, Potchefstroom, South Africa*
[c]*Division of Human Nutrition, Stellenbosch University, Cape Town, South Africa*
**Correspondence: reno.gordon@smu.ac.za*

Sports nutrition recommendations for able-bodied athletes are well established. However, sports nutrition recommendations for para-athletes are still developing. Spinal cord-injured (SCI) hand cyclists face unique physiological and nutrition-related challenges compared with able-bodied athletes, complicating the extrapolation of recommendations. This paper aims to propose preliminary dietary recommendations for adult SCI endurance hand cyclists based on their unique challenges while considering existing sports nutrition recommendations for able-bodied and para-athletes. A two-phase approach was followed. Phase one involved a review of existing literature regarding the physiological and nutrition-related challenges experienced by SCI athletes, including their current dietary intake and body composition patterns, as well as existing sports nutrition recommendations. Phase two consisted of proposing dietary recommendations for SCI endurance hand cyclists, considering the information gathered during phase one. A total of 10 preliminary recommendations are proposed, focusing on general daily intake for carbohydrates, fibre, protein, fat, and micronutrients as well as exercise-specific guidelines covering carbohydrate, fluid, and protein intake before, during, and after exercise. These preliminary recommendations are based on current available literature but provide a starting point for developing dietary recommendations for SCI hand cyclists. Future research should rigorously test these recommendations and apply them to the broader paralympic community where applicable.

Keywords dietary recommendations, endurance exercise, spinal cord-injured hand cyclists

Introduction

Nutrition plays a critical role in the health and exercise performance of endurance able-bodied athletes, with established dietary recommendations for important nutrients such as carbohydrate, protein, and fluid.[1–3] Endurance able-bodied athletes are recommended to consume 6–10 g/kg/day of carbohydrates for exercise lasting 1–3 hours and 1–4 g/kg of carbohydrates 1–4 hours prior to an event.[4] A habitual protein intake of 1.2–2.0 g/kg(/day), and 0.3 g/kg immediately before and after exercise is recommended.[3,4] The challenges faced by able-bodied athletes, such as hyponatraemia, heat stroke, gastrointestinal problems, dehydration, and hypothermia, are well documented, along with practical recommendations to overcome these challenges.[5] However, less is known about the nutritional and physiological challenges faced by para-athletes, a growing group evidenced by the recent 2024 Summer Paralympic Games, where more than 4 400 athletes competed.[6] There is a lack of dietary recommendations for para-athletes, considering their unique physiological functions and challenges. Dietary recommendations for able-bodied athletes have been extrapolated to this population, but they may not always be appropriate based on the physiological challenges experienced by paralympic athletes.[7–11]

Hand cycling is a parasport with five different sports classes (H1–H5) accommodating SCI and lower limb amputee athletes. Lower categories in the five sports classes (H1 and H2) indicate more severe activity limitations. SCI hand cyclists compete in road races (men: 60–80 km, women: 50–80 km), time trials (men: 20–30 km, women: 20–30 km), and team relays. The average performance time for road races (56.8 km) in the 2024 Summer Paralympic Games was 101 minutes and 38 seconds (± 7 minutes and 53 seconds), with an average winning time of 97 minutes and 19 seconds (± 10 minutes and 11 seconds).[12] Therefore, SCI hand cyclists compete in road races generally lasting longer than 90 minutes and can be classified as endurance athletes.[13]

SCI athletes face various physiological challenges, including prolonged gastrointestinal transit time, impaired bladder control, limited hand function, and reduced bone mineral density.[14,15] The severity of these challenges varies depending on the level of spinal cord injury. For instance, athletes with higher-level spinal cord injuries may experience more significant limitations in hand function. These physiological challenges necessitate adjustments to the standard nutritional practices recommended for able-bodied athletes to better meet the unique needs of SCI athletes.

For example, it is important for SCI endurance athletes to ensure optimum carbohydrate and fluid intake during exercise to prevent dehydration, hypoglycaemia, and compromised performance.[7] However, the physiological challenges experienced by SCI endurance athletes, such as prolonged gastrointestinal tract transit time, can affect the timing of carbohydrate intake before and during endurance exercise.[16] To compensate for this prolonged gastrointestinal transit time and maintain blood glucose levels during endurance exercise, SCI endurance athletes must ingest carbohydrates earlier, in smaller amounts and more frequently compared with able-bodied athletes.[11]

Another example is that SCI athletes experience decreased sweat rates, so alternative cooling methods may be needed during endurance events in hot environments, such as using a spray bottle to keep the skin moist.[17]

The authors of the current paper attempted to propose preliminary dietary recommendations for SCI endurance hand cyclists based on their nutrition-related and physiological challenges, dietary intake, and existing sports nutrition recommendations for able-bodied and para-athletes. These preliminary dietary recommendations should be tested at a later stage among SCI endurance hand cyclists as well as other para-athletes facing similar challenges.

Methods

To propose preliminary dietary recommendations for SCI endurance hand cyclists based on their nutrition-related and physiological challenges and considering existing sports nutrition recommendations, a two-phase approach was followed. The first phase involved a narrative review of the literature to determine the nutritional status, nutrition-related and physiological challenges of SCI athletes. The review also considered the existing sports nutrition recommendations for able-bodied and para-athletes to determine whether they could be adapted for SCI endurance hand cyclists. The second phase encompassed proposing the preliminary recommendations for SCI endurance hand cyclists based on the information gathered in phase one.

Phase one: narrative review of the literature

The following databases were searched: Access Medicine, Access Surgery, Annual Reviews, CIHNAL Reviews, Clinical Key, Clinical Key Nursing, Cochrane, DynaMed, EBSCOHost, InCites Analysis, InCites Essential Science Indicators, InCites Journal Citation Reports, MEDLINE Ultimate, Nature, OVID, ProQuest, PubMed, SABINET African Journals, SAGE, Science Direct, Springer Nature, STM Source, Web of Sciences, Wiley Online Library, and Google Scholar. The following search terms were used: nutrition OR diet OR body composition AND spinal cord injury OR disability OR paraplegic OR tetraplegic OR wheelchair OR quadriplegic OR impairment AND athlete OR sport OR active individual OR player.

No time limit was placed on the year of publication, but only review articles, descriptive studies, and intervention studies published in English were considered. A total of 17 studies published between 1994 and 2024 met the eligibility criteria and were reviewed. The main findings of these studies are detailed in Table A1. The 17 included studies provided insight into the nutritional status, physiological and nutrition-related challenges of SCI athletes, forming the basis for the proposal of the preliminary dietary recommendations.

In addition to the 17 articles, eight position statements or sports nutrition recommendation articles for able-bodied and SCI athletes were reviewed.[2,4,7–11,17] These papers, published between 2018 and 2021, were analysed to determine whether their recommendations could be applied to SCI endurance hand cyclists, considering their nutritional status, physiological and nutrition-related challenges.

Results

Considerations for the development of dietary recommendations based on the narrative review (phase one)

Table 1 details the physiological and nutrition-related challenges reported by SCI athletes based on the findings of 17 reviewed studies. These challenges were mainly identified from the nutritional assessment findings of the 17 included studies. Table 1 also indicates the potential impact of the physiological and nutrition-related challenges on nutritional status, practices, and exercise performance of SCI athletes (column 2), and provides practical guidance (column 3) for each physiological and nutrition-related challenge. Some of the physiological challenges include low bone mineral density, which increases the risk of fragility fractures, and reduced muscle mass, leading to decreased muscle glycogen storage capacity. Among the nutrition-related challenges, inadequate daily carbohydrate intakes can result in fatigue. After identifying these challenges in phase one, the authors of the current paper proposed preliminary dietary recommendations for SCI endurance hand cyclists in phase two (Table 2).

Preliminary dietary recommendations (phase two)

In phase two, the physiological and nutrition-related challenges identified from the narrative review in phase one, with specific reference to those that affect nutritional status, practices, and exercise performance of SCI athletes (Table 1), were critically interpreted by the researchers and considered with the existing sports nutrition recommendations to formulate preliminary dietary recommendations specifically for adult SCI endurance hand cyclists (Table 2). The considerations for practical guidance for each challenge identified (Table 1) were systematically grouped together resulting in a total of 10 categories, of which six were relevant to general dietary intake, and four relevant to exercise intake. In line with the categories, 10 preliminary recommendations were formulated, with six recommendations focusing on daily macronutrient and micronutrient intake and four exercise-specific recommendations focusing on pre-, during, and post-exercise intake (Table 2). As two of the researchers are registered dietitians with expertise in sport nutrition, additional expert opinion was not sought for the formulation of the preliminary dietary recommendations to address the physiological and nutrition-related challenges detailed in phase one.

Discussion

The authors aimed to propose preliminary dietary recommendations with practical considerations for SCI endurance hand cyclists, considering their unique physiological and nutritional demands. Six general recommendations are proposed, covering daily carbohydrate (including fibre), protein, fat, and micronutrient intake. Specific micronutrients such as calcium, vitamin D, and iron were highlighted due to the special importance of these nutrients in this population. Additionally, four exercise-specific dietary recommendations are proposed, focusing on carbohydrate and fluid intake before and during exercise, as well as protein intake after exercise. While the preliminary dietary recommendations do not deviate much from the existing sports nutrition recommendations for para-athletes, they advocate for a lower daily carbohydrate intake (the upper range is lower), a higher daily protein intake, and an adjustment of race- or training-specific carbohydrate intake.

General recommendations

Daily carbohydrate intake

The first proposed recommendation, to consume 6–8 g/kg/bodyweight (BW) of carbohydrate per day, falls within the recommended range for para-athletes, which is 6–10 g/kg/BW daily.[7] However, it is suggested that SCI endurance hand cyclists, who typically train for 1–3 hours/day[21] aim for the lower end of this range due to their reduced muscle mass and subsequent reduced glycogen storage capacity compared

Table 1: Factors affecting nutritional status, practices, and exercise performance of SCI athletes

Factor	Impact on nutritional status, nutritional practices, and exercise capacity/performance	Considerations for practical guidance
Physiological challenges:		
Increased fat mass[18]	Decreased speed and endurance[19] Increased risk of chronic diseases of lifestyle[20]	Dietary energy intake should not exceed energy expenditure Limit fat intake to meet body composition goals
Low bone mineral density[15,18,21–24]	Increased fragility risk[25]	Optimise intake of protein, which improves calcium and phosphorus absorption in GIT[26] Increased intake of omega-3 fatty acid (especially PUFA)[27] Optimise intake of nutrients involved in bone health such as calcium, vitamin D, magnesium copper, zinc, manganese, vitamin K, vitamin A, vitamin C, vitamin B_{12} (cyanocobalamin), phosphorus, and potassium[28]
Decreased muscle mass[18]	Reduced muscle strength and muscle glycogen storage capacity[7] Lower peak power output	Optimise daily energy and macronutrient intake, as well as timing of nutrient intake before, during, and after exercise
Bowel dysfunction[14]	Compromised exercise performance due to delayed carbohydrate availability[29] Gastrointestinal discomfort[14] Restricting food intake to manage prolonged GI transit time[14]	Adjust timing of carbohydrate intake before exercise Optimise daily fibre intake
Pressure sores[14]	Compromised exercise performance[14] Inability to exercise due to discomfort[14]	Optimise protein, vitamin A, C, D, zinc, selenium, and iron intake[30]
Compromised bladder function[14]	Urinary tract infections[31] Restriction of fluid intake[14] Dehydration[14] Compromised exercise performance[14]	Optimise fluid intake daily and during exercise
Limited hand function[14]	Difficulty eating during exercise[14] Compromised exercise performance due to loss of momentum if cyclists use their hands to eat while on hand cycle[14]	Implement practical strategies to facilitate easier energy and nutrient intake during exercise
Decreased sweat rate and impaired thermoregulation[14,32,33]	Dehydration[34] Overheating[14] Muscle spasms[14] Cramping[34] Increased rate of perceived exertion[34] Heat illness / exhaustion[35] Increased risk of injury[36]	Implement cooling strategies Optimise fluid intake
Nutrition-related challenges:		
High fat intake[21,37]	May exacerbate gastrointestinal dysfunctions such as reduced gastric emptying,[38] increased fat mass[21]	Control fat intake to meet body composition and performance goals
Insufficient daily carbohydrate intake[21,37,39,40]	Fatigue[14] Increased risk of illness (especially URTI[41]) Hypoglycaemia[11] Compromised exercise endurance[11]	Optimise carbohydrate intake to meet daily carbohydrate requirements and meet training loads/exercise requirements
Timing and insufficient exercise-related carbohydrate intake[21]	Fatigue and decreased exercise performance and endurance[11] Increased risk of illness[42] Hypoglycaemia[43] Impaired exercise recovery[43]	Implement strategies to optimise carbohydrate intake before and after exercise
Low iron levels/anaemia[14,44]	Fatigue[14]	Implement strategies to optimise iron intake and/or absorption
Inadequate micronutrient intake [vitamin A, D, E, K, B_1 (thiamine), B_5 (pantothenic acid), B_9 (folate), B_{12} (cobalamin), B_6 (pyridoxine), magnesium, potassium, iron, calcium, zinc][21,37,39,40,45–47]	Fatigue[48] Increased rate of perceived exertion[48] Decreased aerobic capacity[48] High risk of fracture[49] Increased risk of illness[50]	Implement strategies to optimise micronutrient intake
Decreased appetite[14]	Macro- and micronutrient deficiencies[21] Fatigue Compromised exercise performance	Optimise carbohydrate and fluid intake during exercise
Restriction of fluid and food intake before and during exercise[14]	Insufficient carbohydrate and fluid intake before and during exercise[43] Fatigue[43] Hypoglycaemia[43] Dehydration[43] Compromised exercise duration and performance[43]	Implement strategies to encourage fluid and food intake before and during exercise

Table 2: Preliminary dietary recommendations and practical considerations for SCI endurance hand cyclists

Recommended intake	Practical considerations	Rationale for the recommendation
General recommendations		
Consume adequate CHO daily to match exercise loads (6–8 g/kg BW/day CHO for 1–3 hours of exercise/day and 8–10 g/kg BW/day when exercise exceeds 4 hours)	Eat regular meals and snacks and include a source of carbohydrate in each meal	To meet minimal carbohydrate energy requirements for training but account for the reduced glycogen storage capacity of SCI athletes compared with other athletes; the upper range for g/kg BM/day is lower for SCI athletes compared to the recommendation for other para-athletes and able-bodied athletes[7]
Consume adequate protein (1.25–2.0 g/kg BW of protein) every day	Eat a variety of protein sources such as red meat, fish, chicken, eggs, legumes, nuts, seeds and dairy products, and include a source of protein in a meal/snack throughout the day (every 3–4 hours)	To compensate for the additional protein required to promote healing and/or prevent pressure sores,[7–9] the protein recommendation for SCI endurance hand cyclists is slightly higher compared with the recommendations for para-athletes[8]
Limit fat intake to less than 30% of total energy intake	Focus on healthy fats such as unsaturated fats and include sources such as avocado, nuts (almonds, walnuts), and fatty fish (salmon and sardines)	Healthy fat intake is important for optimal health; in the absence of a fat intake guideline for para-athletes, a recommendation that does not exceed the accepted macronutrient distribution range (AMDR) and that will reduce the risk of excess energy intake from fat is recommended
Consume 25–30 g of dietary fibre per day	Focus on fibre-rich foods such as oats, carrots, green beans, berries, while avoiding gas-forming foods such as broccoli, beans, and carbonated beverages	This recommendation is necessary considering the bowel challenges of SCI athletes[14]
Ensure adequate micronutrient intake	Consume a variety of foods with focus on consuming five portions of vegetables and fruits every day	An optimal micronutrient status is important for health and performance
Ensure inclusion of sources high in calcium, iron, and vitamin D	For calcium and vitamin D, consume low-fat dairy foods, fish with soft bones, nuts, and soya beans; sun exposure (5–30 minutes/day, most days of the week, without sunscreen) can also assist in vitamin D synthesis; include foods rich in iron such as beef, fish, poultry, and eggs; vegetarian hand cyclists can consume spinach and fortified cereals, together with a source of vitamin C	This recommendation is important considering the poor bone health of SCI athletes, and a reported poor iron, calcium, and vitamin D intake[15,18,21–24]
Exercise-specific recommendations:		
Consume 1–4 g/kg BW of CHO 1.5–4 hours before exercise	Focus on low to medium GI carbohydrates (cooked oats, bananas, whole grain toast, and energy bars)	This recommendation differs slightly from the recommendation for able-bodied athletes; to account for the delayed gastric emptying in SCI athletes[16] they should ingest a pre-exercise meal at least 1.5 hours before exercise
Consume 30–60 g of carbohydrate per hour during exercise for exercise lasting 60–150 minutes and aim for the upper range if exercise exceeds 150 minutes	Carbohydrate-rich sources (carbohydrate-electrolyte beverage/energy drink, sports gel, pre-opened sports bar) that are practical for cyclists to handle	This recommendation is similar to existing recommendations for para-athletes and able-bodied athletes[11] and is necessary as SCI endurance hand cyclists have been found to restrict food and fluid intake during exercise[21]
Consume 100–125 ml of fluid every 10–15 minutes	Consume a cold sports drink through adaptive water bottles and hydration packs such as a hydropack to compensate for limited hand function	This recommendation is lower than the recommendation for able-bodied athletes[2] and accounts for the reduced sweat rate of SCI endurance athletes[51]
Consume a recovery meal (1.0–1.2 g/kg BW of carbohydrate in combination with 0.3–0.5 g/kg BW of protein) within 30–60 minutes after exercise	Examples of foods/meals that are carbohydrate-rich with added protein to consume after exercise include flavoured milk, cereal with milk, smoothies with milk and banana, toast with egg	This recommendation is similar to the recommendation for able-bodied athletes[7,9] and is important to replenish the glycogen stores of SCI endurance athletes that were already reduced owing to the reduced muscle mass when compared with able-bodied athletes[7]

BW = bodyweight; CHO = carbohydrate.

with able-bodied athletes and other para-athletes without SCI.[7] Foods consumed should not aggravate gastrointestinal tract issues, such as prolonged gastrointestinal tract transit time, which is common among SCI hand cyclists. Therefore, they should consume whole grain cereals and breads while limiting the intake of saturated fat, sugars, caffeine, carbonated beverages, and sweeteners. For para-athletes with a very high training load (exceeding 4–5 hours/day), the current recommendation is 8–12 g/kg/BW[4] of carbohydrates daily. It is again proposed that SCI endurance hand cyclists aim for the lower range of 8–10 g/kg/BW due to the above-mentioned challenges faced by these athletes. This recommendation will also ensure that SCI athletes meet their training energy needs.

Daily protein intake

In addition to carbohydrate, SCI endurance hand cyclists also need to consume adequate protein to meet the increased protein demands of exercise and aid in the healing of pressure sores,[8] a common challenge experienced by wheelchair users,[52] including South African SCI hand cyclists.[14] The preliminary recommendation of 1.25–2.0 g/kg BW protein per day is slightly higher than the standard recommendation for para-athletes (1.2–1.7 g/kg/BW)[8] to compensate for additional intake needed to assist in healing or prevention of pressure sores. The preliminary protein recommendation is also slighter higher than the recommendation for able-bodied athletes (1.2–2.0 g/kg/BW)[2] for building and maintaining muscle mass. However, SCI athletes often have reduced muscle mass compared with able-bodied athletes. Adequate protein intake will also help SCI hand cyclists maintain muscle mass, which is often reduced in this population due to activity limitation of certain limbs.[7] The focus should be on high-quality protein sources that include essential amino acids such as leucine and isoleucine. Protein-rich foods high in arginine, such as red meat, can also assist in the healing of pressure sores[53] and may assist in addressing the iron deficiency anaemia commonly experienced by female SCI hand cyclists.[14]

Fat intake

While fat is an essential component of a healthy diet, excessive fat intake can lead to increased body fat mass, health implications, and increased disease risk, and compromise exercise performance.[19,20] Recent articles on nutrition for para-athletes have not provided a general recommendation for fat intake.[7–9,11] The current paper proposes that SCI endurance hand cyclists limit their fat intake to 30% of their daily total energy intake, aligning with the recommendation for able-bodied athletes by Kerksick et al.[2] This recommendation will also reduce the risk of excess energy intake from fat previously reported in the SCI athlete population. A recent study on South African SCI hand cyclists reported a high fat intake in males and females (39.7% and 42.1%, respectively).[21] Fat intakes above the acceptable macronutrient distribution range (AMDR, 20–35%) have also being reported by male and female Canadian and American SCI wheelchair tennis, track, basketball, and rugby athletes[40] The emphasis should be on consuming healthy unsaturated fats to reduce the likelihood of increased fat mass and lower the risk of secondary complications of SCI, such as diabetes mellitus, and improving the blood lipid profile of hand cyclists.[54]

Daily fibre intake

Dietary fibre may help alleviate delayed gastric emptying experienced by SCI individuals by improving transit time[55] and potentially benefiting the gastrointestinal tract microbiome. Additionally, fibre can assist athletes in managing their bodyweight and fat mass due to the low energy content of fibre-rich foods.[56] SCI endurance hand cyclists are advised to consume 25–30 g of dietary fibre daily, including fibre-rich foods such as oats, carrots, and berries, while avoiding gas-forming foods (Table 2). This recommendation aligns with a previous recommendation regarding fibre intake for SCI athletes (25–30 g of dietary fibre per day).[11.]

Micronutrients

In addition to optimal macronutrient intake, micronutrients are also important for the overall health of SCI athletes. The preliminary recommendation to ensure adequate micronutrient intake, with a special emphasis on calcium, vitamin D, and iron, is based on evidence suggesting that SCI endurance hand cyclists are at risk of poor bone health[21] and anaemia, particularly among female athletes.[14] Further evidence indicates that South African SCI hand cyclists did not meet the RDA for calcium, vitamin D, folate, and potassium[21] and Canadian SCI athletes also reported intakes of calcium, vitamin D, magnesium, and folate among other micronutrients lower than the EAR.[46] Consuming a variety of foods, including five portions of fruit and vegetables daily, will assist para-athletes, including SCI athletes, to optimise their micronutrient intake and reduce the risk of illness by enhancing immunity.[9] While this recommendation regarding adequate micronutrient is not novel for able-bodied athletes, it is noteworthy that no specific practical consideration for fruit and vegetable intake was found in the literature for SCI athletes. Therefore, SCI endurance hand cyclists should focus on consuming a variety of foods, with an emphasis on five portions of fruit and vegetables daily. However, they should be cautious when consuming cruciferous vegetables, especially prior to exercise, as these can cause abdominal discomfort.

Vitamin D is important for calcium homeostasis and bone health, as well as enhancing the ability of muscles to make quick, explosive movements.[57] To ensure optimal vitamin D and calcium status, SCI hand cyclists should consume low-fat dairy foods, fish with soft bones, green leafy vegetables, nuts, and soya beans, and ensure adequate sun exposure (5–30 minutes per day, most days of the week, without sunscreen).[58]

Haematinics, such as iron, essential for exercise performance, as they help deliver oxygen to exercising muscles.[7] Athletes, including SCI endurance hand cyclists, need iron for increased haematopoiesis and greater turnover resulting from haemolysis, sweating, and gastrointestinal bleeding. SCI hand cyclists can increase their iron intake by choosing foods rich in iron such as beef, fish, poultry, and eggs. Vegetarian hand cyclists can consume spinach, fortified cereals, adding vitamin C, to ensure optimal absorption of the plant-based iron sources.[59] They should also limit the consumption of foods that impair iron absorption, such as tea, milk, and coffee during meals.[59]

Exercise-specific recommendations

Carbohydrate intake before exercise

In addition to general recommendations for daily intake, this article also proposes exercise-specific recommendations. Consuming carbohydrates before exercise will help SCI endurance hand cyclists boost their liver glycogen stores and spare their potential reduced muscle glycogen stores due to reduced muscle mass, especially during prolonged exercise. Flueck[9] recommended that para-athletes consume 1–4 g/kg/BW carbohydrate 1–4 hours before exercise. However, this recommendation may need to be adjusted for SCI athletes, as they may experience delayed gastric emptying,[16] which may delay carbohydrate absorption and its availability for oxidation.[60] Therefore, it is important to allow adequate time for digestion before exercise to ensure optimised endogenous glycogen stores and minimise the risk of gastrointestinal tract problems during exercise.[60] Fynne et al.[16] looked at the gastrointestinal tract transit time and gastric emptying of 19 SCI participants compared with 15 able-bodied individuals and found that the median gastrointestinal tract transit time of SCI individuals was more than 360 minutes (range: 258 to > 360) compared with 340 minutes (range: 224 to > 360) for able-bodied individuals ($p < 0.001$). This translates into a delay in gastrointestinal tract transit time of 34 minutes based on the difference in the minimum gastrointestinal tract transit time for SCI and able-bodied individuals.

Therefore, this paper proposes that SCI endurance hand cyclists should not wait until 1 hour before exercise to consume carbohydrates. Instead, they should consume 1–4 g/kg/BW of carbohydrates at least 1.5–4 hours before exercise. To avoid further delay in gastric emptying and reduce the risk of gastrointestinal issues such as bloating, small meals and liquid-consistency foods should be consumed.[7] Low-GI foods like cooked oats with berries can be beneficial as they provide a more sustained source of energy when carbohydrates cannot be consumed during exercise.[3] However, these should be consumed earlier than higher GI foods before exercise.

Carbohydrate intake during exercise

Reduced muscle mass and consequently lower glycogen storage capacity could lead to earlier glycogen depletion during exercise.[11] This increases the need for carbohydrate intake during exercise.[11] Both para-athletes and able-bodied athletes are advised to ingest 30–60 g of carbohydrate per hour from a higher GI carbohydrate source such as a 6–8% carbohydrate–electrolyte beverage, carbohydrate energy gels, energy bars, or other relevant carbohydrate-rich sources during endurance exercise lasting 60–150 minutes.[11] SCI athletes should aim for the upper range if exercise exceeds 150 minutes, although this remains controversial.[11] Hence, future research should assess the optimal amount of carbohydrate and timing of carbohydrate intake for SCI athletes.[11]

This recommendation for carbohydrate intake during exercise is similar to the current recommendation for para-athletes and able-bodied athletes.[7,9,11] Furthermore, it emphasises the consumption of beverages in a hydropack or food that tetraplegic endurance hand cyclists can consume with minimal use of their hands. Given the limited hand function of tetraplegic hand cyclists[10] and the necessity of using their hands to propel the hand cycle during exercise, extensive hand use for refuelling could result in loss of momentum. Therefore, foods and beverages consumed during exercise should not require cyclists to take their hands off the crank for extended periods.

Fluid intake during exercise

Fluid intake during exercise can help mitigate heat stress; however, SCI hand cyclists often restrict fluid intake due to bladder challenges.[14] This is concerning, as maintaining fluid intake and preventing dehydration during exercise are important for sustaining exercise capacity and endurance.[2] Regular intake of water and/or sports drinks during exercise can limit cardiovascular strain during endurance exercise.[2] It should also be recommended that SCI endurance hand cyclists not only consume fluids when they are thirsty, as this is a sign of dehydration,[44] but rather optimise their fluid intake during exercise.

Current fluid intake recommendations for SCI athletes are lacking. However, a recent publication from Hertig-Godeschalk and Perret[51] reported a sweat rate of 0.52 l/hour for elite endurance SCI athletes, suggesting an intake of approximately 500 ml (100–125 ml every 10–15 minutes) to replace sweat losses. This is slightly lower compared with the able-bodied recommendation of 175–350 ml every 10–15 minutes.[2] Considering that these athletes have a reduced sweat rate[33] they may need less fluid to replace sweat losses; however, they also experience thermoregulation challenges. Therefore, the authors of the current paper recommend a fluid intake of at least 500 ml/hour, particularly in hot environments.

Increased water intake during exercise and during the day will help address constipation, urinary tract infection, and thermoregulatory challenges, which are often experienced by SCI endurance hand cyclists.[14] However, it is known that tetraplegic athletes have lower sweat rates than paraplegic athletes and guidance on fluid intake should be tailored, based on disability, or even better on each hand cyclist's sweat rate, to prevent hyperhydration. In addition, tetraplegic athletes experience impaired thermoregulation compared with paraplegic athletes, so cooling strategies such as wearing an ice vest, cooling hats, or neck bands are important to mitigate heat stress.[61.]

Carbohydrate and protein intake after exercise

Adequate carbohydrate and protein intake after exercise can restore muscle glycogen levels, especially when recovery time between sessions is short.[7] Furthermore, consuming high biological value proteins that provide essential amino acids assists with muscle protein synthesis, maintenance of lean body mass, strength and power, and muscle repair, especially in relation to endurance exercise.[8] This is important considering the coupled effect of reduced muscle mass due to activity limitation.[8,62] On average, SCI endurance hand cyclists train five times a week with increased load closer to compeition.[21] It is recommended that SCI hand cyclists consume a recovery meal containing 1.0–1.2 g/kg/BW carbohydrate combined with 0.3–0.5 g/kg/BW protein within the 30–60 minutes post-exercise window, as also suggested by Flueck[9] and Scaramella et al.[7]

Strengths, limitations, and recommendations

The authors aimed to propose preliminary dietary recommendations for use by SCI endurance hand cyclists and other similar paralympic athletes, who face unique physiological and nutritional challenges that make application of general sports nutrition recommendations difficult. The recommendations suggested in this paper are based on a narrative review of the literature rather than a scoping or systematic review with a more rigorous methodological approach. Furthermore, testing and implementation of these recommendations is warranted to help establish clinical guidelines with practices tailored to the specific physiological and nutritional needs of paralympic athletes.

Conclusion

The unique physiological and nutritional challenges faced by SCI endurance hand cyclists and other paralympic athletes make the application of current sports nutrition recommendations difficult. Athletes, coaches, trainers, and dietitians can use these recommendations to improve exercise capacity and endurance in this group of athletes, with the potential to apply it to a wider group of paralympic athletes facing similar challenges. Optimising daily nutritional intake, as well as having clear, practical dietary recommendations for implementation before, during, and after exercise is critical to optimise the performance of these athletes and potentially a broader group of paralympic athletes.

Disclosure statement – No potential conflict of interest was reported by the authors.

Funding – This research was funded by the Research Development Grant (RDG: RE Gordon) administered by Sefako Makgatho Health Sciences University.

ORCID

Reno Eron Gordon http://orcid.org/0000-0002-1821-5937
Sunita Potgieter http://orcid.org/0009-0004-8683-9401
Lize Havemann-Nel http://orcid.org/0000-0002-9570-3280

References

1. Jäger R, Kerksick CM, Campbell BI, et al. International society of sports nutrition position stand: protein and exercise. J Int Soc Sports Nutr. 2017;14(1):20. https://doi.org/10.1186/s12970-017-0177-8
2. Kerksick CM, Wilborn CD, Roberts MD, et al. ISSN exercise & sports nutrition review update: research & recommendations. J Int Soc Sports Nutr. 2018;15(1):38. https://doi.org/10.1186/s12970-018-0242-y
3. Thomas DT, Erdman KA, Burke LM. Position of the academy of nutrition and dietetics, dietitians of Canada, and the American college of sports medicine: nutrition and athletic performance. J Acad Nutr Diet. 2016;116(3):501–528. https://doi.org/10.1016/j.jand.2015.12.006
4. Vitale K, Getzin A. Nutrition and supplement update for the endurance athlete: review and recommendations. Nutrients. 2019;11(6):1289. https://doi.org/10.3390/nu11061289
5. Martínez-Sanz JM, Fernández Nuñez A, Sospedra I, et al. Nutrition-Related adverse outcomes in endurance sports competitions: A review of incidence and practical recommendations. Int J Environ Res Public Health. 2020;17(11):4082. https://doi.org/10.3390/ijerph17114082
6. International Paralympic Committee Paris 2024 Paralympic Games Sports. https://www.paralympic.org/paris-2024/sports (accessed 11 September 2024).
7. Scaramella J, Kirihennedige N, Broad E. Key nutritional strategies to optimize performance in para athletes. Phys Med Rehabil Clin N Am. 2018;29(2):283–298. https://doi.org/10.1016/j.pmr.2018.01.005
8. Flueck JL, Parnell JA. Protein considerations for athletes With a spinal cord injury. Front Nutr. 2021;8:652441. https://doi.org/10.3389/fnut.2021.652441
9. Flueck JL. Nutritional considerations for para-cycling athletes: A narrative review. Sports. 2021;9(11):154. https://doi.org/10.3390/sports9110154
10. Bernardi M, Fedullo AL, Bernardi E, et al. Diet in neurogenic bowel management: A viewpoint on spinal cord injury. World J Gastroenterol. 2020;26(20):2479–2497. https://doi.org/10.3748/wjg.v26.i20.2479
11. Ruettimann B, Perret C, Parnell JA, et al. Carbohydrate considerations for athletes with a spinal cord injury. Nutrients. 2021;13(7):2177. https://doi.org/10.3390/nu13072177
12. International Paralympic Committee Para Cycling Road Schedule & Results. https://www.paralympic.org/en/paris-2024-paralympics/schedule/para-cycling-road (accessed 10 September 2024).
13. Saris WH, Antoine JM, Brouns F, et al. PASSCLAIM – physical performance and fitness. Eur J Nutr. 2003;42(Suppl 1):I50–95. https://doi.org/10.1007/s00394-003-1104-0
14. Gordon RE, Scrooby B, Havemann-Nel L. Physiological and nutrition-related challenges as perceived by spinal cord-injured endurance hand cyclists. Appl Physiol Nutr Metab. 2024;49(1):22–29. https://doi.org/10.1139/apnm-2023-0036
15. Miyahara K, Wang Dh, Mori K, et al. Effect of sports activity on bone mineral density in wheelchair athletes. J Bone Miner Metab. 2008;26:101–106. https://doi.org/10.1007/s00774-007-0789-1
16. Fynne L, Worsøe J, Gregersen T, et al. Gastric and small intestinal dysfunction in spinal cord injury patients. Acta Neurol Scand. 2012;125(2):123–128. https://doi.org/10.1111/j.1600-0404.2011.01508.x
17. McCubbin AJ, Allanson BA, Caldwell Odgers JN, et al. Sports dietitians Australia position statement: nutrition for exercise in Hot environments. Int J Sport Nutr Exerc Metab. 2020;30(1):83–98. https://doi.org/10.1123/ijsnem.2019-0300
18. Ribeiro S, Silva R, Castro I, et al. Assessment of nutritional status of active handicapped individuals. Nutr Res. 2005;25:239–249. https://doi.org/10.1016/j.nutres.2004.12.006
19. Genton L, Mareschal J, Karsegard VL, et al. An increase in Fat mass index predicts a deterioration of running speed. Nutrients. 2019;11(3):701. https://doi.org/10.3390/nu11030701
20. Ejigu BA, Tiruneh FN. The link between overweight/obesity and non-communicable diseases in Ethiopia: evidences from nationwide WHO STEPS survey 2015. Int J Hypertens. 2023;2023:2199853. https://doi.org/10.1155/2023/2199853
21. Gordon RE, Potgieter S, Havemann-Nel L. Nutritional practices and body composition of South African national-level spinal cord-injured endurance hand cyclists. Nutrients. 2022;14(23):4949. https://doi.org/10.3390/nu14234949
22. Brook EM, Tenforde AS, Broad EM, et al. Low energy availability, menstrual dysfunction, and impaired bone health: A survey of elite para athletes. Scand J Med Sci Sports. 2019;29(5):678–685. https://doi.org/10.1111/sms.13385
23. Cavedon V, Sandri M, Peluso I, et al. Body composition and bone mineral density in athletes with a physical impairment. PeerJ. 2021;9:e11296. https://doi.org/10.7717/peerj.11296
24. Flueck JL. Body composition in Swiss elite wheelchair athletes. Front Nutr. 2020;7:1. https://doi.org/10.3389/fnut.2020.00001
25. Denova-Gutiérrez E, Méndez-Sánchez L, Muñoz-Aguirre P, et al. Dietary patterns, bone mineral density, and risk of fractures: A systematic review and meta-analysis. Nutrients. 2018;10(12):1922. https://doi.org/10.3390/nu10121922
26. Kerstetter JE, Kenny AM, Insogna KL. Dietary protein and skeletal health: a review of recent human research. Curr Opin Lipidol. 2011;22(1):16–20. https://doi.org/10.1097/MOL.0b013e3283419441
27. Abou-Saleh H, Ouhtit A, Halade GV, et al. Bone benefits of fish Oil supplementation depend on its EPA and DHA content. Nutrients. 2019;11(11):2701. https://doi.org/10.3390/nu11112701
28. Karpouzos A, Diamantis E, Farmaki P, et al. Nutritional aspects of bone health and fracture healing. J Osteoporos. 2017;2017(1):4218472. https://doi.org/10.1155/2017/4218472
29. Mata F, Valenzuela PL, Gimenez J, et al. Carbohydrate availability and physical performance: physiological overview and practical recommendations. Nutrients. 2019;11(5):1084. https://doi.org/10.3390/nu11051084
30. Ghaly P, Iliopoulos J, Ahmad M. The role of nutrition in wound healing: an overview. Br J Nurs. 2021;30(5):S38–S42. https://doi.org/10.12968/bjon.2021.30.5.S38
31. Hertig-Godeschalk A, Perret C, Krebs J, et al. Urinary tract infections are common and have an impact on performance in elite wheelchair athletes: a cross-sectional study of self-reported data. Swiss Med Wkly. 2025;155:4113. https://doi.org/10.57187/s.4113
32. Dawson B, Bridle J, Lockwood RJ. Thermoregulation of paraplegic and able bodied men during prolonged exercise in hot and cool climates. Paraplegia. 1994;32(12):860–870.
33. Pritchett RC, Al-Nawaiseh AM, Pritchett KK, et al. Sweat gland density and response during high-intensity exercise in athletes with spinal cord injuries. Biol Sport. 2015;32(3):249–254. https://doi.org/10.5604/20831862.1163370
34. Périard JD, Eijsvogels TMH, Daanen HAM. Exercise under heat stress: thermoregulation, hydration, performance implications, and mitigation strategies. Physiol Rev. 2021;101(4):1873–979. https://doi.org/10.1152/physrev.00038.2020
35. Grossmann F, Flueck JL, Perret C, et al. The thermoregulatory and thermal responses of individuals With a spinal cord injury during exercise, acclimation and by using cooling strategies-A systematic review. Front Physiol. 2021;12:636997. https://doi.org/10.3389/fphys.2021.636997
36. Handrakis JP, Trbovich M, Hagen EM, et al. Thermodysregulation in persons with spinal cord injury: case series on use of the autonomic standards. Spinal Cord Ser Cases. 2017;3:17086. https://doi.org/10.1038/s41394-017-0026-7
37. Eskici G, Ersoy G. An evaluation of wheelchair basketball players' nutritional status and nutritional knowledge levels. J Sports Med Phys Fitness. 2016;56(3):259–268.
38. Gentilcore D, Chaikomin R, Jones KL, et al. Effects of fat on gastric emptying of and the glycemic, insulin, and incretin responses to a carbohydrate meal in type 2 diabetes. J Clin Endocrinol Metab. 2006;91(6):2062–2067. https://doi.org/10.1210/jc.2005-2644
39. Madden RF, Shearer J, Parnell JA. Evaluation of dietary intakes and supplement Use in paralympic athletes. Nutrients. 2017;9(11):1266. https://doi.org/10.3390/nu9111266
40. Gerrish HR, Broad E, Lacroix M, et al. Nutrient intake of elite Canadian and American athletes with spinal cord injury. Int J Exerc Sci. 2017;10(7):1018–1028. https://doi.org/10.70252/FQDQ5053
41. Cicchella A, Stefanelli C, Massaro M. Upper respiratory tract infections in sport and the immune system response. A review. Biology (Basel). 2021;10(5):362. https://doi.org/10.3390/biology10050362

42. Seidelmann SB, Claggett B, Cheng S, et al. Dietary carbohydrate intake and mortality: a prospective cohort study and meta-analysis. The Lancet Public Health. 2018;3(9):e419–e428. https://doi.org/10.1016/S2468-2667(18)30135-X
43. Jeukendrup AE. Carbohydrate intake during exercise and performance. Nutrition. 2004;20(7):669–677. https://doi.org/10.1016/j.nut.2004.04.017
44. Hertig-Godeschalk A, Ruettimann B, Valido E, et al. Energy availability and nutritional intake during different training phases of wheelchair athletes. Nutrients. 2023;15(11):2578. https://doi.org/10.3390/nu15112578
45. Shaw KA, Chilibeck PD, Warkentin TD, et al. Dietary quality and nutrient intakes of elite paracyclists. Nutrients. 2024;16(16):2712. https://doi.org/10.3390/nu16162712
46. Krempien JL, Barr SI. Risk of nutrient inadequacies in elite Canadian athletes with spinal cord injury. Int J Sport Nutr Exerc Metab. 2011;21(5):417–425. https://doi.org/10.1123/ijsnem.21.5.417
47. Grams L, Garrido G, Villacieros J, et al. Marginal micronutrient intake in high-performance male wheelchair basketball players: A dietary evaluation and the effects of nutritional advice. PLoS One. 2016;11(7):e0157931. https://doi.org/10.1371/journal.pone.0157931
48. Ghazzawi HA, Hussain MA, Raziq KM, et al. Exploring the relationship between micronutrients and athletic performance: A comprehensive scientific systematic review of the literature in sports medicine. Sports (Basel). 2023;11(6):109. https://doi.org/10.3390/sports11060109
49. Sale C, Elliott-Sale KJ. Nutrition and athlete bone health. Sports Med. 2019;49(Suppl 2):139–151. https://doi.org/10.1007/s40279-019-01161-2
50. Childs CE, Calder PC, Miles EA. Diet and immune function. Nutrients. 2019;11(8):1933. https://doi.org/10.3390/nu11081933
51. Hertig-Godeschalk A, Perret C. How elite athletes with a spinal cord injury sweat during exercise – An exploratory study. Sports. 2024;12(3):81. https://doi.org/10.3390/sports12030081
52. Alkhalifah A, Aljohani M, Almasaud W, et al. Skin problems among the wheelchair users: a prospective cross-sectional study. Ann Med Surg. 2023;85(4):655–658. https://doi.org/10.1097/MS9.0000000000000098
53. Brewer S, Desneves K, Pearce L, et al. Effect of an arginine-containing nutritional supplement on pressure ulcer healing in community spinal patients. J Wound Care. 2010;19(7):311–316. https://doi.org/10.12968/jowc.2010.19.7.48905
54. Kuksis A, Myher JJ, Geher K, et al. Effect of saturated and unsaturated fat diets on lipid profiles of plasma lipoproteins. Atherosclerosis. 1982;41(2):221–240. https://doi.org/10.1016/0021-9150(82)90187-3
55. Khalil RE, Gorgey AS, Janisko M, et al. The role of nutrition in health status after spinal cord injury. Aging Dis. 2013;4(1):14–22.
56. Mancin L, Burke LM, Rollo I. Fibre: The forgotten carbohydrate in sports nutrition recommendations. Sports Med. 2025;55(5):1067–1083. https://doi.org/10.1007/s40279-024-02167-1
57. Todd JJ, Pourshahidi LK, McSorley EM, et al. Vitamin D: recent advances and implications for athletes. Sports Med. 2015;45(2):213–229. https://doi.org/10.1007/s40279-014-0266-7
58. Srivastava SB. Vitamin D: Do We need more than sunshine? Am J Lifestyle Med. 2021;15(4):397–401. https://doi.org/10.1177/15598276211005689
59. Zijp IM, Korver O, Tijburg LBM. Effect of Tea and other dietary factors on iron absorption. Crit Rev Food Sci Nutr. 2000;40(5):371–398. https://doi.org/10.1080/10408690091189194
60. Broad E. *Sports nutrition for* paralympic athletes. second ed. Boca Raton (FL): CRC Press; 2019.
61. Griggs KE, Leicht CA, Price MJ, et al. Thermoregulation during intermittent exercise in athletes with a spinal-cord injury. Int J Sports Physiol Perform. 2015;10(4):469–475. https://doi.org/10.1123/ijspp.2014-0361
62. Figel K, Pritchett K, Pritchett R, et al. Energy and nutrient issues in athletes with spinal cord injury: Are they at risk for Low energy availability? Nutrients. 2018;10(8):1078. https://doi.org/10.3390/nu10081078
63. Pritchett K, DiFolco F, Glasgow S, et al. Risk of low energy availability in national and international level paralympic athletes: an exploratory investigation Nutrients. 2021;13(3):979. https://doi.org/10.3390/nu13030979

Appendix

Table A1: Studies reviewed documenting nutritional status, physiological and nutrition-related challenges of SCI athletes

Reference	Study title	Main findings
Gordon et al.[14]	Physiological and nutrition-related challenges as perceived by spinal cord-injured endurance hand cyclists	Bowel and bladder challenges, limited hand function, muscle spasms, thermoregulatory challenges, pressure sores, menstrual periods, and low iron levels/anaemia were perceived to impact food and fluid intake and compromise exercise capacity
Shaw et al.[45]	Dietary quality and nutrient intakes of elite paracyclists	Inadequate intakes of iodine, fibre, vitamin D, E.
Hertig-Godeschalk et al.[44]	Energy availability and nutritional intake during different training phases of wheelchair athletes	Low energy availability, iron-deficiency anaemia
Gordon et al.[21]	Nutritional practices and body composition of South African national-level spinal cord-injured endurance hand cyclists	Inadequate carbohydrate intake, high fat intake. Inadequate intake of B_9 (folic acid), vitamin D, calcium, potassium, B_5 (pantothenic acid), B_2 (riboflavin), B_1 (thiamine), vitamin B_6 (pyridoxine), iron, magnesium, selenium, and zinc
Cavedon et al.[23]	Body composition and bone mineral density in athletes with a physical impairment	Low BMD, osteopenia or osteoporosis
Pritchett et al.[63]	Risk of low energy availability in national and international level paralympic athletes: an exploratory investigation	Low BMD in the hip
Flueck[24]	Body composition in Swiss elite wheelchair athletes	Paracyclists had lowest fat mass compared with athletes from other sporting codes
Brook et al.[22]	Low energy availability, menstrual dysfunction, and impaired bone health: a survey of elite para-athletes	Low BMD among para-athletes
Madden et al.[39]	Evaluation of dietary intakes and supplement use in paralympic athletes	Para-athletes did not meet recommendations for vitamins A, D, E, B_5, B_9, magnesium, potassium, iron, and calcium
Gerrish et al.[40]	Nutrient intake of elite Canadian and American athletes with spinal cord injury	SCI athletes did not meet recommendations for vitamin B_6, B_9, B_{12}, C, calcium, iron, and zinc
Eskici and Ersoy[37]	An evaluation of wheelchair basketball players' nutritional status and nutritional knowledge levels	Athletes had low carbohydrate intake and high fat intake, and did not meet recommendations for vitamin B_1, B_9, magnesium, iron, and fibre
Grams et al.[47]	Marginal micronutrient intake in high-performance male wheelchair basketball players: a dietary evaluation and the effects of nutritional advice	Athletes did not meet recommendations for vitamin E and calcium
Pritchett et al.[33]	Sweat gland density and response during high-intensity exercise in athletes with spinal cord injuries	SCI athletes had less active sweat glands compared with the able-bodied athletes
Krempien and Barr[46]	Risk of nutrient inadequacies in elite Canadian athletes with spinal cord injury	Athletes' intake of calcium, magnesium, zinc, vitamins D, B_1, B_2, B_9, and B_{12} were below the recommendations
Miyahara et al.[15]	Effect of sports activity on bone mineral density in wheelchair athletes	Wheelchair athletes had low BMD
Ribeiro et al.[18]	Assessment of nutritional status of active handicapped individuals	Handicapped individuals had low energy and calcium intake. BMD and fat-free mass was low, while fat mass was high.
Dawson et al.[32]	Thermoregulation of paraplegic and able-bodied men during prolonged exercise in hot and cool climates	Lower limb skin temperatures were greater in tetraplegics compared with able-bodied individuals

Received: 29-04-2025 Accepted: 3-09-2025