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What We Do and What We Should Do Against Malnutrition in Spinal Cord Injury: A Position Paper From Italian Spinal Cord Injury Network Rehabilitation Centers

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Abstract

Spinal cord injury (SCI) is a traumatic event that significantly impacts body composition and alters energy and nutritional needs. This places patients with SCI at a high risk of malnutrition, which can hinder optimal functional recovery, prolong hospital stays, increase hospital admissions, and contribute to the development of obesity and cardiovascular and metabolic ailments in chronic patients. Consequently, there is an urgent need for clear guidance to support clinicians in managing the nutritional needs of patients with SCI at different stages of the disease, including the acute (0 - 4 months after injury), post-acute (4 - 26 months after injury), and post-discharge phases. This study utilized a cross-sectional survey to assess the strategies employed in seven spinal units across Italy to address the nutritional needs of patients with SCI during the acute, post-acute, and post-discharge phases of the condition. Eight clinicians (five physiatrists, two internists, and one urologist) and one nurse participated in the survey. Following the survey completion, the participants were invited to partake in a round table session to delve deeper into the questionnaire results to gather their opinions and gain insights into clinical practices related to the various challenges surrounding the management of malnutrition in patients with SCI. We here review the available evidence on the energy needs and nutritional requirements of patients with SCI, highlighting the clinical aspects that deserve more attention throughout the distinct phases of the disease. We additionally provide an overview of the scenario regarding the management of malnutrition in patients with SCI across various spinal units in Italy. Through this comprehensive analysis, we aimed to enhance understanding and provide valuable insights for clinicians working with patients with SCI, equipping them with the knowledge and confidence to provide nutritional support to patients with SCI efficiently. By addressing the challenges of defining nutritional needs and presenting a practical guide, we aspire to contribute to the overall management and care of individuals with SCI and the prevention of malnutrition and its associated complications, thereby improving patient outcomes.

Keywords: Spinal cord injury; Malnutrition; Obesity

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Introduction

Spinal cord injury (SCI) impacts body composition and nutritional needs. Following SCI, there is a decrease in lean body mass and energy expenditure, while fat body mass tends to increase [1]. These factors, combined with a sedentary lifestyle and positive energy balance, contribute to a condition known as "neurogenic obesity", which, in turn, predisposes to cardiometabolic alterations [1-9]. Additionally, undernutrition may occur, especially in the first period after SCI, partly due to anxiety and depression; it is associated with longer hospital stays and adverse outcomes [10].

In the rehabilitation phase, approximately 50% of SCI patients experience malnutrition [11], which can coexist with obesity [12]. The World Health Organization defines malnutrition as "deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients" and highlights that the condition includes both undernutrition and overweight and obesity [13]. If untreated, malnutrition can lead to longer hospital stays, increased in-hospital mortality, pressure ulcers, suboptimal functional recovery, obesity and other cardiometabolic issues [14].

Although guidelines are available [2, 15, 16], there is an urgent need for innovative protocols to manage the nutritional status of SCI patients across the different stages of the disease [17]. This work aimed to provide practical guidance for clinicians in spinal units to determine the energy needs and assess the nutritional status of patients with SCI during the acute (0 - 4 months post-injury), post-acute (4 - 26 months post-injury), and post-discharge phases of the disease, with the goal of preventing malnutrition and related complications.

Materials and Methods

A cross-sectional survey was used to initiate a discussion. The survey questionnaire was designed by the project coordinator (AA) to assess the strategies employed in seven spinal units across Italy to address the nutritional needs of SCI patients during the acute, post-acute, and post-discharge phases. Eight clinicians (five physiatrists, two internists, and one urologist) and one nurse participated in the survey, which was administered to participants through SurveyMonkey. Qualitative data from the questionnaires were entered into Excel (Microsoft Office) spreadsheets. Following the survey completion, the participants discussed the results during a round table held on March 2023, and provided their opinions on the clinical management of malnutrition in SCI patients.

Results and Discussion

Acute phase of SCI

During the acute phase of SCI (0 - 4 weeks after the injury), peculiar metabolic changes occur: lower basal energy expenditure, heightened nitrogen excretion, anorexia, weight loss, and depletion of nutritional markers [1, 2, 18, 19]. Despite nutritional support, patients often experience negative nitrogen balance for up to 2 months after injury, which usually improves without intervention [20].

Attempts to correct this imbalance by increasing caloric intake can lead to overfeeding and subsequent hypercapnia, hyperglycemia, uremia, and hypertriglyceridemia [21]. This contributes to the accumulation of adipose tissue and extended mechanical ventilation due to heightened respiratory effort [22]. On the other hand, underfeeding can exacerbate nitrogen loss [23].

Therefore, proper nutritional support is crucial; conducting a nutritional assessment within the first 48 h post-injury improves outcomes [16]. During hospital admission, a registered dietician (RD) should assess body composition and resting metabolism. Estimating the total daily energy expenditure (TDEE) is essential to provide appropriate energy intake recommendations [3].

Energy needs

Patients with acute SCI typically exhibit an energy expenditure up to 54% lower than those without [1, 2, 18], with a TDEE reduced by > 50% in tetraplegia [4]. However, the Spinalis Foundation proposed to estimate the energy requirements of SCI patients by reducing TDEE by 7.5% for people with paraplegia (estimated energy requirements: 28 kcal/kg) and by 12.5% for those with tetraplegia (23 kcal/kg) compared with able body individuals [19].

Indirect calorimetry (IC) is the gold standard for determining energy expenditure [2]. Nevertheless, IC might not be immediately accessible. In such instances, RDs can utilize simplified formulas to estimate energy requirements. The commonly used 25 - 30 kcal/kg/day formula is not different from that used for non-disabled individuals, which can easily result in overfeeding and shows poor correlation with IC results [24]. The accuracy of predictive equations is 40-75% compared with IC [25]. Predictive equations are even less accurate for obese and underweight patients [26]. Generally, equations developed for non-disabled individuals that incorporate anthropometric measures, including the Harris-Benedict equation despite the proposed activity correction factor of 1.15 for SCI individuals [27], could overestimate resting energy expenditure [28, 29], leading to overfeeding in SCI patients [27]. Therefore, clinicians should carefully monitor for signs and symptoms of overfeeding. Notably, equations that utilize the free fatty mass (FFM) to predict basal metabolic rate (BMR) [29-31] result in lower percentages of error, so they should be preferred when analysis of body composition is available [29]. In the absence of data on body composition, models based on anthropometric measures specifically developed for the SCI population [1, 29] can be used, aligning with the recent recommendations of the Practice-based Evidence in Nutrition document by the Dietitians of Canada [32]. TDEE should be reassessed more than once a week, and proactive strategies should be implemented to optimize energy and protein intake [33].

Only one panelist affirmed using available formulas to calculate the resting energy expenditure of patients and to make corrections based on the level of physical activity and severity of pathology. However, during the discussion, the panel deemed simplistic formulas more suitable for patients with less complex conditions. They emphasized that for complex cases (patients with moderate/severe risk of malnutrition, as determined by the spinal nutrition screening tool (SNST), including individuals with a higher level of injury, dysphagia, age greater than 60 years or less than 18 years, severe pressure injuries, high weight loss, or a need for artificial ventilation), the assistance of a dietitian with expertise in using SCI-specific predictive equations described in the literature [1, 29-31] is necessary. Validated SCI-specific predictive equations are needed, especially for the evaluation of complex patients (Fig. 1).

Nutrition assessment

For patients who can consume food voluntarily, RDs should encourage adherence to heart-healthy dietary guidelines [34]. In addition, RDs should address specific vitamin and/or mineral deficiencies through supplementation and consider diet-related ailments, such as neurogenic bowel.

Although surveyed hospitals have a dedicated nutrition team, which includes a clinician, a dietitian conducting ward rounds, a nutrition nurse specialist, especially when managing artificial nutrition is necessary, and a gastroenterologist or an equivalent specialist for issues with artificial nutrition and the management of patients with intestinal problems, only five of the eight panelists reported the presence of protocols for nutrition management in SCI patients, which are, in some cases, limited to selected parameters (e.g., nutritional regimen). Only two of the panel members regularly monitor malnutrition risk at hospital admission with designated tools, which

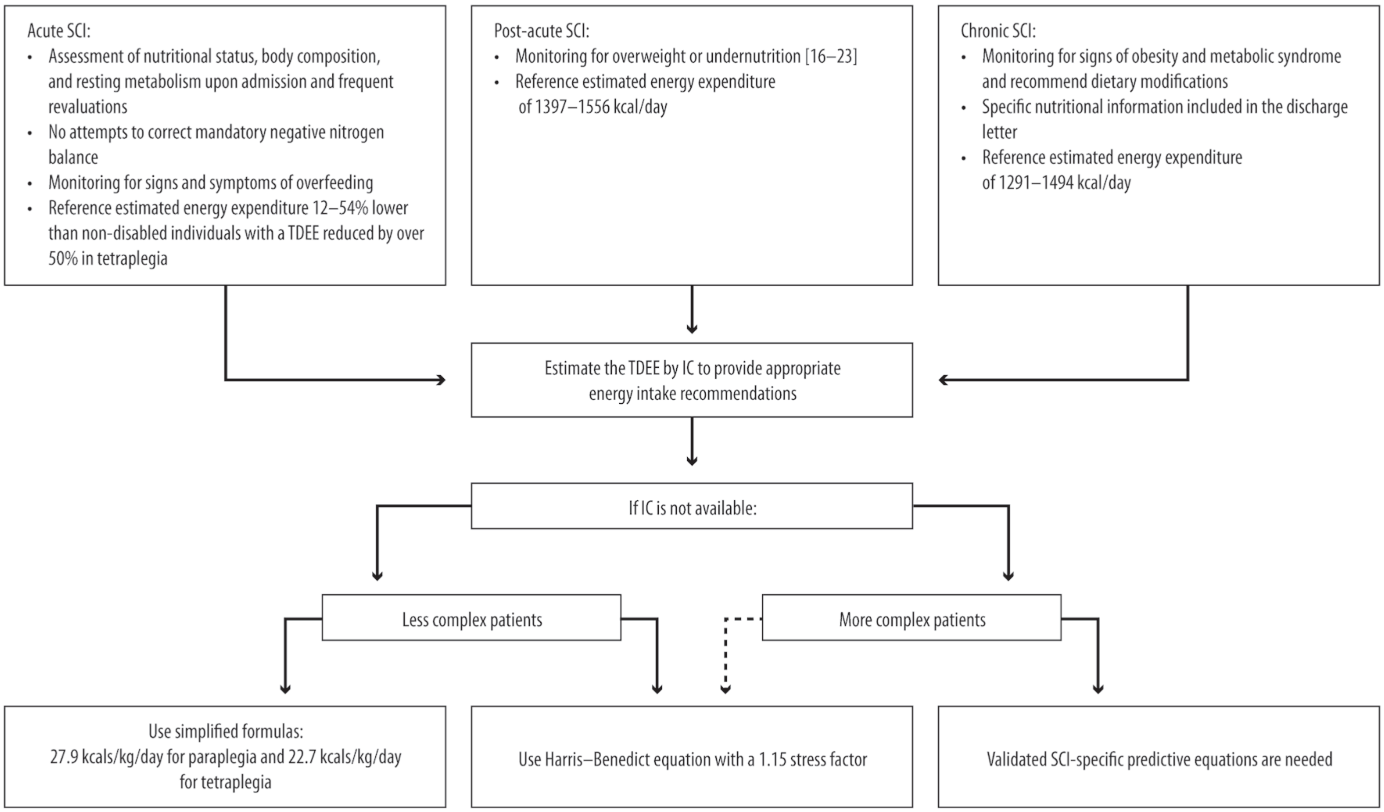

Figure 1. SCI: management considerations for nutritional assessment and energy needs. SCI: spinal cord injury; TDEE: total daily energy expenditure; IC: indirect calorimetry.

vary across different spinal units. A re-evaluation takes place every month or once a week for critically ill patients and every time a change in clinical conditions occurs. The two panelists monitor the nutritional status with blood tests, anthropometric measures, and instrumental tests.

A standardized protocol for assessing nutrition in SCI patients is crucial to address these gaps. The protocol should specify the frequency and duration of assessments and establish a common screening tool for all spinal units. Given the rapid changes in body composition, the panel deems that anthrophometric, biochemical and dietary assessments should be repeated once a week during the acute phase of SCI (Figs. 2, 3).

1) Anthropometric assessment

Body mass index (BMI) is an unreliable method to assess nutritional status in SCI patients, especially in the acute and initial post-acute phases, because of changes in body composition [35]. Similarly, waist circumference (WC) is also not optimal due to paralysis-related variations [36].

However, the panelists emphasized the importance of continuously assessing body weight from the intensive care unit (ICU) using a consistent and reproducible method. Additionally, the patient's height should be measured, with the patient lying in a bed or on a static plane, then vertically, in order to calculate BMI. The panel also emphasized the need to assess BMI possibly once weekly during the acute phase due to the frequent changes in body composition during this phase, taking into account the weight of clothing and shoes.

2) Biochemical assessment and blood tests

Traditional serum protein markers do not accurately reflect the nutritional status in the ICU setting [37]. Albumin and pre-albumin are influenced by acute-phase response and systemic inflammation, so they should not be employed in case of acute stress or increased inflammatory status [38]. The long half-life of albumin (21 days) makes it unsuitable for monitoring the acute response to nutrition therapy [39]. Pre-albumin outperforms albumin as an indicator of recent nutrition because of its shorter half-life (2 - 3 days) [40] and reduced susceptibility to metabolic processes [41]. According to some authors, a pre-albumin level < 11 mg/dL can be considered an index of malnutrition when combined with a C-reactive protein (CRP) level < 15 mg/L, which rules out the presence of an acute inflammatory state [40, 42]. However, a recent American Society for Parenteral and Enteral Nutrition (ASPEN) position paper highlights that both albumin and pre-albumin do not specifically reflect the current nutrition state of a patient [43]. These markers should be used to identify patients likely to be at an increased risk of poor outcomes if adequate nutrition is not provided.

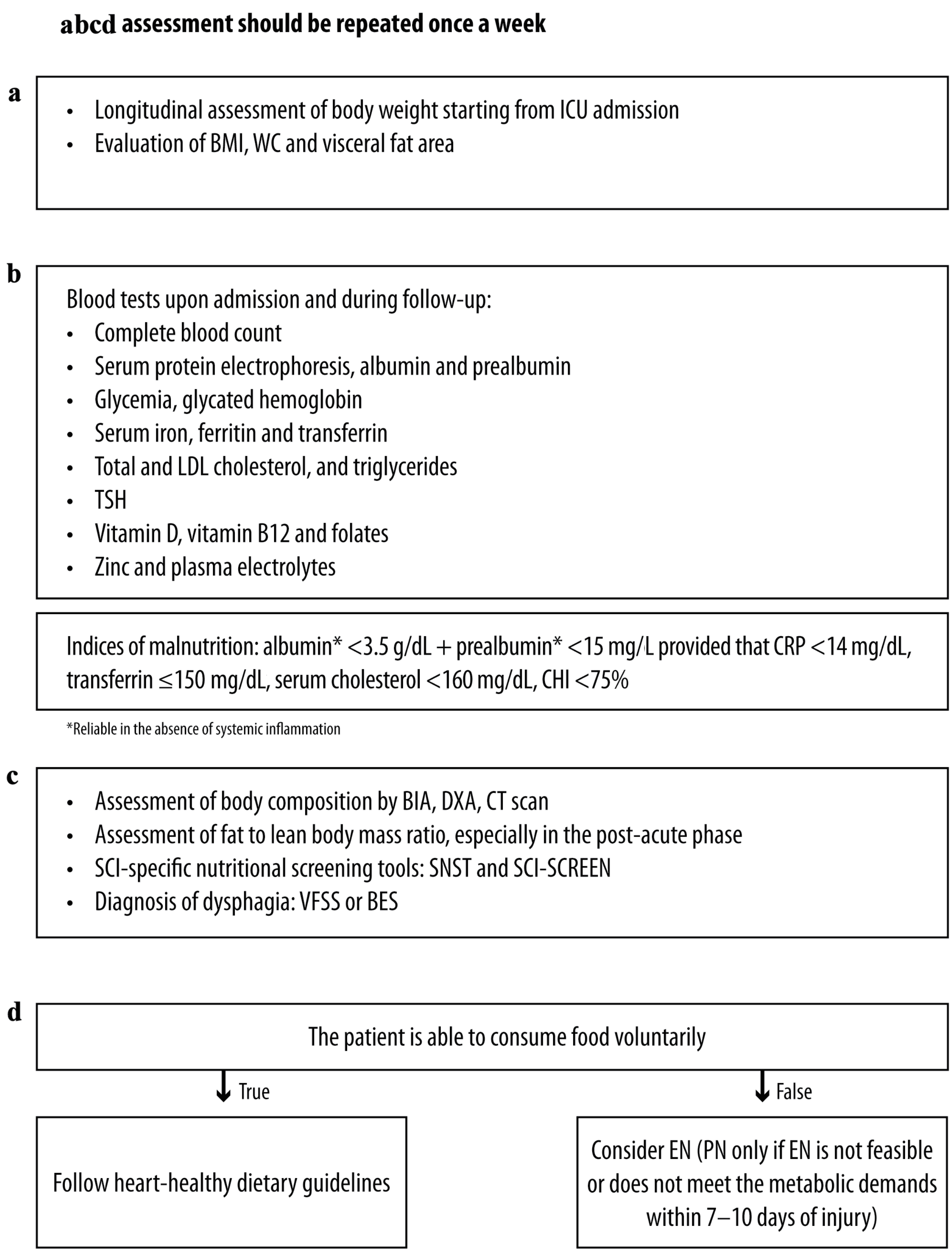

Figure 2. Acute and post-acute SCI: management considerations for (a) anthropometric, (b) biochemical, (c) clinical and (d) dietary assessment. (a-d) Assessment should be repeated once a week. TSH: thyroid-stimulating hormone; BMI: body mass index; ICU: intensive care unit; CRP: C-reactive protein; CHI: creatinine height index; LDL: low-density lipoprotein; DXA: dual X-ray absorptiometry; BIA: bioelectrical impedance analysis; CT: computerized tomography; SNST: spinal nutrition screening tool; BES: bedside swallowing evaluation; VFSS: videofluoroscopic swallow studies; EN: enteral nutrition; PN: parenteral nutrition; WC: waist circumference.

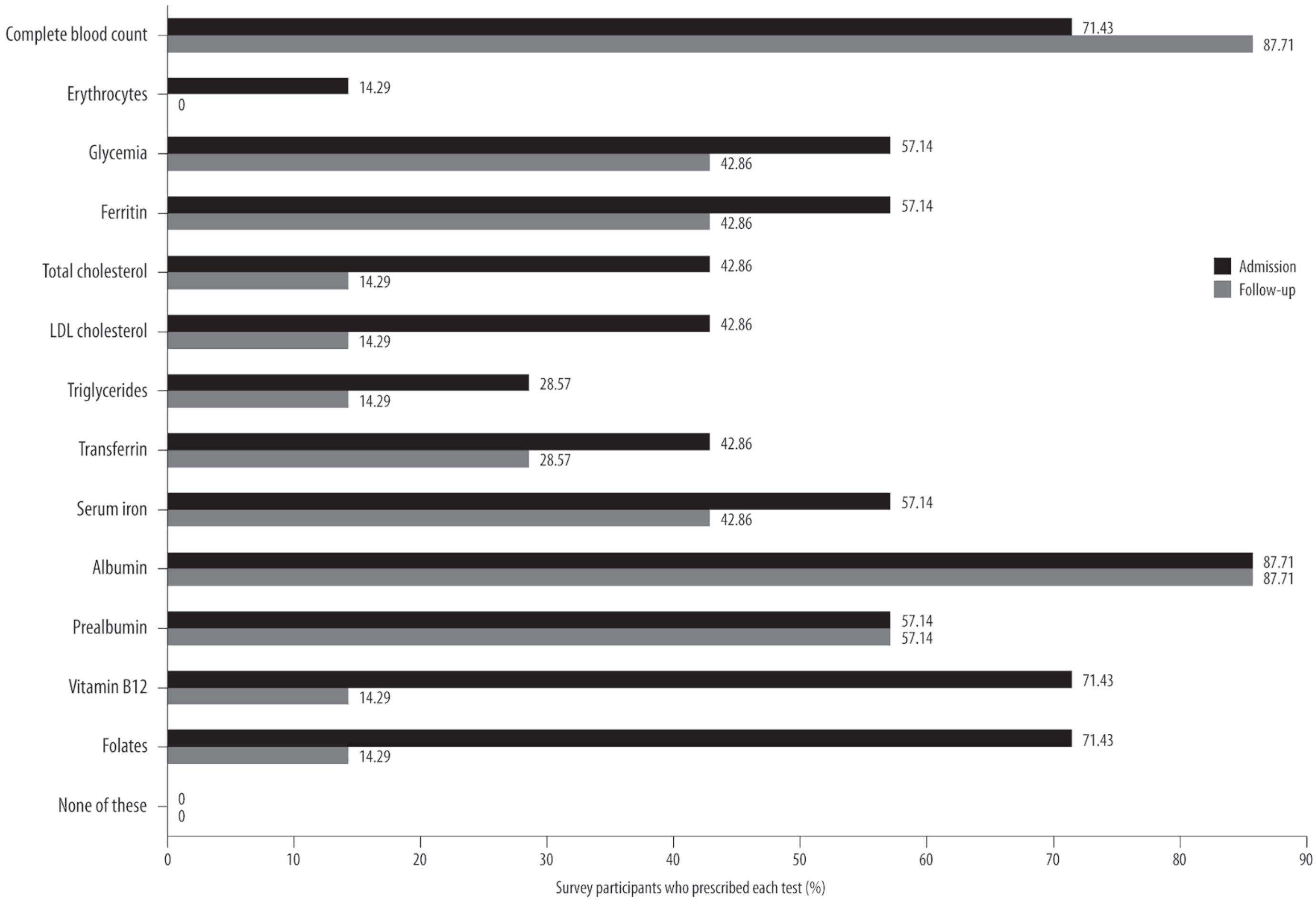

Figure 3. Blood tests commonly prescribed by the panelists upon hospital admission and during follow-up of acute patients with SCI, based on survey results, along with the corresponding percentage of survey participants who prescribe each test. SCI: spinal cord injury; LDL: low-density lipoprotein.

A transferrin level ≤ 200 mg/dL is an additional indicator for adjustment of nutritional support [40]. Serum cholesterol < 160 mg/dL and a creatinine height index (CHI) < 75% (measured by 24-h creatinine excretion) are also considered indices of malnutrition [40].

Figure 3 presents the list of blood serum proteins that the panelists typically assess upon hospital admission and during follow-up for acute patients with SCI.

The panel emphasized the importance of establishing a standardized set of serum protein markers that accurately reflect the nutritional status of acute SCI patients and are suitable for analysis upon hospital admission and periodic monitoring. Additionally, blood tests can assist in developing a nutritional supplementation program.

Furthermore, an evaluation of plasma osmolarity would be beneficial in cases involving parenteral nutrition (PN).

3) Clinical assessment

Regularly monitoring the nutritional status is essential during rehabilitation since medical conditions, nutrient requirements, and other factors change continuously. Complete SCI can lead to 27-56% atrophy at 6 - 24 weeks [44]. The Global Leadership Initiative on Malnutrition (GLIM) identifies reduced muscle mass as an index of fat-free mass < 17 kg/m^2 for men or < 15 kg/m^2 for women [45].

Presently, there is a lack of SCI-specific recommendations or appropriate tools to effectively differentiate among cachexia, age-related sarcopenia, and malnutrition [46]. Screening tools originally developed for the non-disabled population, such as the cachexia score (CASCO) [47] and short portable sarcopenia measure (SPSM), and SARC-F (strength, assistance in walking, rising from a chair, climbing stairs, and falls) necessitate the transportation of specialized equipment and exhibit low sensitivity, respectively [48, 49]. The study by Dionyssiotis et al [46] suggests that, for research purposes, we could classify paraplegics using the current functional definition of the European Working Group on Sarcopenia in Older People (EWGSOP) for sarcopenia. Nonetheless, the accuracy and precision of these measurements are not yet clearly established. Diagnostic approaches for sarcopenia and cachexia include anthropometric measures, such as BMI or estimated weight loss, as well as dual X-ray absorptiometry (DXA), bioelectrical impedance analysis (BIA), computed tomography (CT) scan, and magnetic resonance imaging (MRI), which are difficult to access in some settings and therefore reserved for selected specific cases or clinical studies [50]. BIA is a rapid, simple, noninvasive, and relatively reliable bedside method [51] that is considered equally valuable as DXA in SCI patients [52]. The panel advises that BIA assessment be repeated once a week or every 2 weeks during the acute phase of SCI. While whole-body DXA is reliable in SCI, its accuracy may be limited in individuals with high-fat mass or very low fat-free mass [53]. MRI plays a crucial role in diagnosing vertebral injury and abnormalities of soft tissues [54]. CT provides precise quantification of skeletal muscle and adipose tissue depots, but it is highly costly [53]. Ultrasound measures muscle mass and changes in muscle tissue at the bedside, making it suitable in the ICU [55]. However, in patients with SCI, ultrasound may be influenced by changes in tissue thickness.

The panel uses ultrasound to assess muscle thickness, BIA with a longitudinal evaluation of angle phase, and DXA, whenever available, to assess the nutritional status of SCI patients. As for DXA, there are no specific cut-off values for SCI exist. However, given the aforementioned potential applicability of the current functional definition of EWGSOP for sarcopenia to paraplegic SCI patients for research purposes [46], the panel suggests that the cutoffs for appendicular lean mass divided by height squared (ALM/height^2) proposed by EWGSOP (men B 7.23 kg/m^2 and women B 5.67 kg/m^2) [56, 57] may be applicable to paraplegic SCI patients. The panel deemed that elastosonography, if conducted for other reasons, can provide information on skeletal muscle fibrosis and the risk of skeletal muscle bleeds.

Individuals with SCI often experience dehydration, edema, and fluid fluctuations, which can impact the body's hydration, decreasing intracellular and increasing extracellular water [58]. Fluctuations of the hydration status can result in over- or under-estimation of body fat when assessing body composition with BIA [59], ultrasound [60], and DXA [61]. Equations to calculate total body water (TBW) in healthy subjects are not valid in SCI patients [58].

The panel emphasized the importance of accurately monitoring the hydration status of patients, especially those catheterized in the ICU. Patients are often overhydrated, which can improve bowel functions but pose challenges for intermittent catheterization. Water intake can be reduced to minimize the frequency of catheterization, putting patients at risk of dehydration. Assessing water balance becomes difficult when the catheter is removed, but the bladder diary closely monitors it.

Existing tools for the assessment of nutritional status have been developed for the general population and may not accurately capture the nutritional status of patients with SCI [62]. To overcome this limitation, a SCI-specific nutritional screening tool, the SNST, was developed to assess the risk of malnutrition in adult patients with SCI and can predict outcomes [14, 62].

All the panelists agreed on the importance of monitoring nutritional status, since malnutrition impacts prognosis. Despite its current low use, the SNST should be implemented for initial nutritional assessments and follow-up.

The SCI-SCREEN is a screening model designed to identify malnutrition risk and to detect underweight and overweight, offering a cost-effective and user-friendly approach [63]. According to the panel, although SCI-SCREEN has not been validated specifically for individuals with SCI, its specificity is evident and offers a rapid assessment process.

Dysphagia commonly accompanies cervical SCI and can lead to adverse consequences, often requiring the implementation of a texture-modified diet associated with weight loss or malnutrition [64]. Clinical assessments for dysphagia should include bedside swallowing evaluation (BES), videofluoroscopic swallow studies (VFSS) and fiberoptic endoscopic evaluation of swallowing (FEES). VFSS and BSE are suitable and comparable methods for diagnosing dysphagia in SCI patients [65]; however, a meta-analysis failed to establish a correlation between FEES findings and dysphagia [66].

Typically, the initial assessment involves a BES of water intake, followed by a logopedic assessment. If necessary, a FEES is conducted.

4) Dietary assessment

The panel believes that an RD should conduct dietary assessment. However, in severe cases where enteral or PN is planned, the involvement of an expert nutritionist is necessary.

a) Enteral nutrition (EN)

While concerns about ileus and other complications have historically led to delayed enteral feeding in SCI patients, studies have shown that initiating within the first 72 h is safe [67, 68].

Tailoring the nutrition therapy to each patient's specific needs is important to optimize clinical outcomes. A well-defined protocol is essential to ensure optimal EN in ICU settings. This protocol should incorporate the following: an initial feeding rate determined upon the patient's tolerance, a gradual increase in the feeding rate, a clear rate goal established in collaboration with an RD, the implementation of a comprehensive bowel management program, and the use of a prokinetic agent if the patient exhibits three consecutive elevated gastric residual volumes [69, 70]. Adherence to this protocol promotes early initiation of EN, increases the volume of feed delivered, optimizes caloric intake, and leads to shorter hospital stays and improved morbidity and mortality outcomes [69, 70].

Despite the absence of SCI-specific studies, EN is preferred over PN following SCI due to its association with reduced infectious morbidity, hyperglycemia, ICU length of stay and mortality in several trauma populations [20, 71]. Nasogastric administration is the recommended initial route for EN, while the nasojejunal route serves if nasogastric feeding is not tolerated [20]. In most critical patients, initiating EN in the stomach is acceptable, but if there is a risk of aspiration or intolerance to gastric EN, the infusion level should be adjusted to

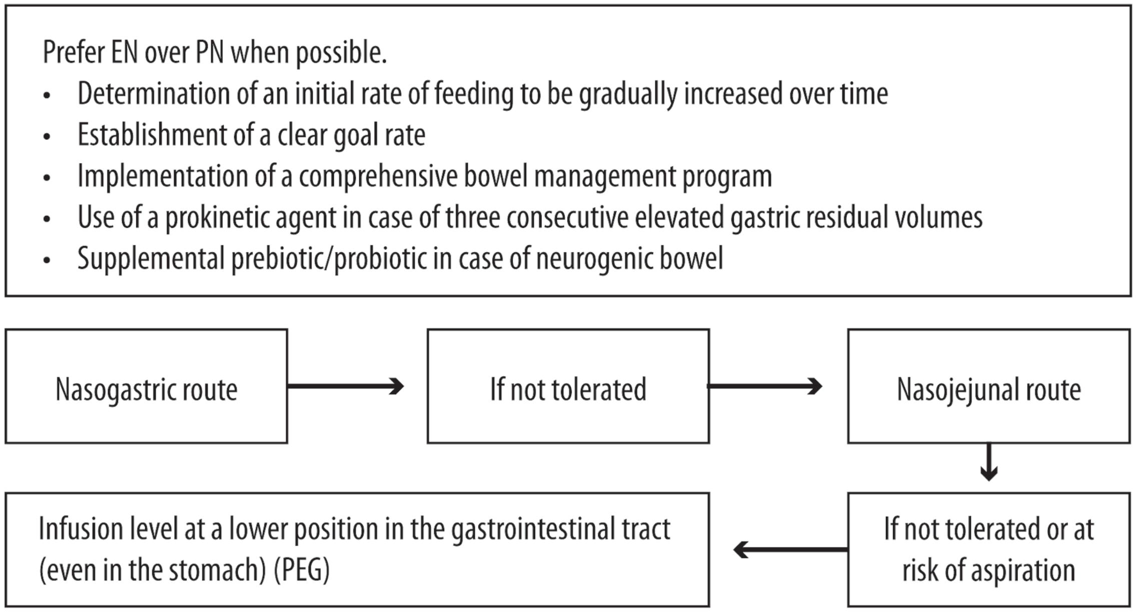

Figure 4. Acute SCI: management considerations for enteral nutrition. SCI: spinal cord injury; EN: enteral nutrition; PN: parenteral nutrition; PEG: percutaneous endoscopic gastrostomy.

a lower position [71]. A percutaneous endoscopic gastrostomy is the preferred approach for feeding tube placement [20]. In cases of neurogenic bowel, prebiotic/probiotic supplementation provided enterally to the patients may be beneficial.

Figure 4 shows the management considerations for EN during acute SCI.

b) PN

If EN does not meet the metabolic demands within 5 - 10 days of injury, total PN should be started [20, 71].

The panel suggests that PN should be limited to severe cases, given the risk of altered osmolality, infection, thrombosis and refeeding syndrome. In the survey, five out of seven panelists reported a higher prevalence of patients receiving EN than PN, with one panelist not being aware of this information.

Commercially available standardized PN provides no benefit in clinical outcomes versus compounded PN admixtures in ICU patients [71]. However, during discussion, the panel emphasized the importance of supplementing PN formulas with vitamins and trace minerals.

Safe prescribing of PN involves ensuring appropriate intravenous access, maintaining sterility, and clearly identifying and documenting the therapeutic goals of PN therapy. Reliable vascular access is crucial, and in-line filters should be used [72]. Monitoring for central line-associated bloodstream infection (CLABSI) is necessary, and blood sampling through vascular access devices should be avoided to minimize its risk [73]. Implementing a PN infusion schedule over 10 - 14 h can provide benefits in selected circumstances [74]. It is advisable to prevent unplanned infusion interruptions to avoid potential metabolic disruptions and suboptimal nutrient delivery and to refrain from interrupting PN administration for medication purposes [75]. However, PN should be discontinued before discharge [75].

Close monitoring of fluid requirements, blood electrolytes, triglyceride and glucose, liver and kidney function, and any complication is vital during PN, especially in patients with preexisting electrolyte imbalances, at risk of refeeding syndrome, or in unstable clinical condition [71]. Blood glucose levels should be maintained within 140 - 180 mg/dL for the general ICU population [71]. Blood glucose monitoring should align with the PN infusion schedule and the patient's clinical status [76]. Careful consideration is necessary when administering subcutaneous insulin before planned PN interruptions [71]. The panel deems that blood glucose and electrolytes should be monitored every other day or at least twice a week during PN. Some panelists extend the frequency of monitoring to three times a day for acute-phase patients who receive PN for 24 h and reduce the frequency when PN is integrated with voluntary feeding.

Survey results indicate that six out of eight panelists can monitor patients under PN with blood tests, including amylase and lipase tests, glycemia, and blood gas analysis (medium consensus among participants). The panelists also suggested considering liver transaminases, lipid profiles, blood electrolytes, and cholestasis indices. Peripheral access should be favored over central access to reduce the risk of infection and thrombosis. Some strategies to reduce the risk associated with peripheral access in surgical patients, such as cyclical infusion through the 18 G cannula or using silicone or polyurethane cannulas in addition to anti-phlebitis solutions, have been recently proposed and may also be applicable to SCI patients [77]. When positioning vascular access, limb mobilization should be allowed. If central access is used, it should be promptly removed when inflammation occurs.

Figure 5 shows the the management considerations for PN

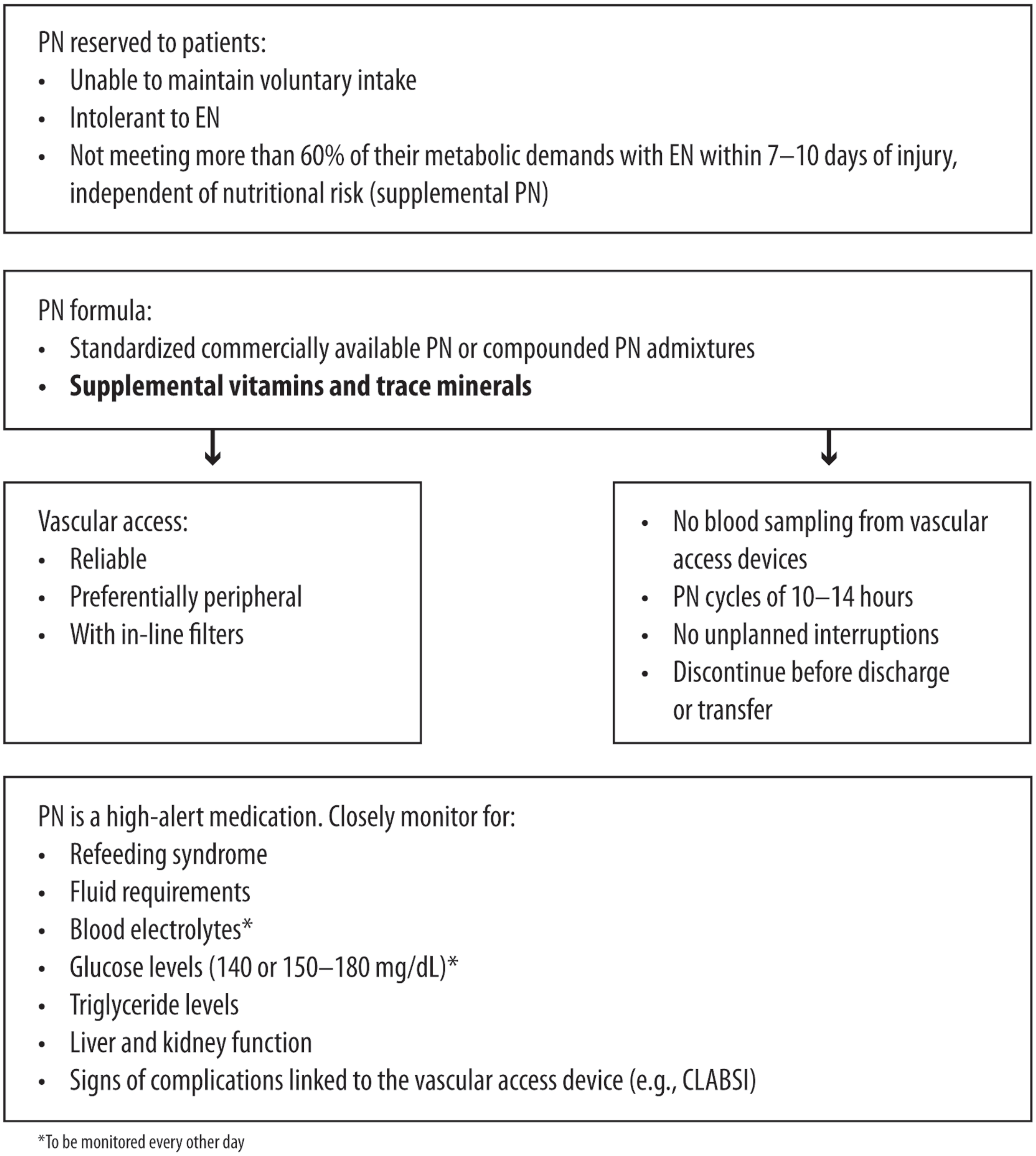

Figure 5. Acute SCI: management considerations for parenteral nutrition. SCI: spinal cord injury; EN: enteral nutrition; PN: parenteral nutrition; CLABSI: central line-associated bloodstream infection.

during acute SCI.

Post-acute phase of SCI

The post-acute phase occurs 4 - 26 weeks after trauma, aligning with the rehabilitation program [18]. It is a critical period, with an overall risk of malnutrition of 40-60% in patients with SCI [78]. The risk of undernutrition during the post-acute phase of SCI is up to 47%, while the risk of being overweight can reach 80% [79, 80]. A recent Swiss longitudinal study reported a significant and 2 - 3-fold higher malnutrition risk in individuals aged > 65 years compared to those aged ≤ 65 years during rehabilitation [78].

Patients with tetraplegia tend to have a higher risk of malnutrition than those with paraplegia [37]. Additionally, comorbidities such as dysphagia, ventilator dependence or pressure injuries increase the risk of malnutrition [78].

Energy needs

While resting energy expenditure decreases during the acute phase, it remains steady during the post-acute phase (1,400 - 15,00 KCal/day) [18, 81]. The Academy of Nutrition and Dietetics (AND) guidelines recommend estimating energy needs at 22.7 kcal/kg for individuals with quadriplegia and 27.9 kcal/kg for those with paraplegia [16]. However, these formulas have not been widely replicated nor considered other factors that may affect TDEE [81, 82] and are not deemed accurate in the recent recommendation of Dietitians of Canada [32] (Fig. 1).

Nutrition assessment

The anthropometric, biochemical, clinical, and dietary assessments employed during the post-acute phase of the disease are similar to those described for the acute phase of SCI (Fig. 2). The panel deems they should be repeated with comparable frequency, especially if the patient experiences sudden significant weight loss or has pressure injuries, dysphagia, or is subjected to artificial nutrition. Specific obesity cutoffs have been proposed for established post-acute and chronic patients, ranging from a BMI of 20.2 kg/m^2 (with a WC of 81.3 cm) [83] to 22 kg/m^2 to 25.3 kg/m^2 [84]. Overall, BMI cutoffs of 22 for overweight and 27 for obesity seem adequate to identify patients at risk of overnutrition [78, 85].

Correlations exist between obesity indicators, such as a visceral fat area > 100 cm^2, a WC > 81.3 cm, a BMI > 22.5 kg/m^2, and increased cardiometabolic risk [86, 87]. Notably, even a BMI < 22 kg/m^2 can be associated with a percentage of body fat considered obese [82]. WC may be a better indicator of obesity and cardiovascular risk in SCI patients than BMI and waist-to-hip ratio [9, 88].

As for dietary habits, a study found similarities between patients in rehabilitation and those with chronic SCI, with excessive fat intake, inadequate consumption of carbohydrates, and low intakes of vitamins C, D, E, biotin, folic acid, potassium and iron [89].

It is advisable to regularly assess fat mass and lean body mass in SCI individuals in the post-acute phase. In particular, the ratio of fat body mass/lean body mass may serve as a more reliable metric than body fat percentage, especially considering the substantial reduction in lean body mass in patients with SCI, particularly in cases of tetraplegia [90]. However, assessing body fat in individuals with SCI poses challenges because of the need for specialized equipment, technical expertise, and time commitment. Therefore, surrogate measures like BMI and WC are commonly employed [7].

Obesity can have both favorable and unfavorable effects on individuals with SCI. Those with higher body weight and BMI upon initiation of rehabilitation tend to show greater improvements in activities of daily living [91]. However, obesity also increases the risk of complications [92]. The panel highlighted the need to monitor the lipid profile and to provide regular electrocardiographic assessments during rehabilitation for the reduction of cardiovascular risk.

The panel emphasized the challenge of accurately measuring the volitional food intake of inpatients. Indeed, since the food provided by the hospital can be unappetizing, patients may rely on food brought by visitors, the amount of which is difficult to quantify. Only four out of eight panelists reported monitoring the amount of food intake in their spinal unit. Keeping a nutritional diary during hospitalization may help address this issue.

Post-discharge phase of SCI

Metabolic syndrome is highly prevalent in individuals with chronic SCI, with higher rates among those with tetraplegia [6]. Dietary and nutritional modifications targeting the energy mismatch are recommended to prevent and treat cardiometabolic syndrome [92].

The panel suggested to provide specific nutritional information in the discharge letter, including details of nutritional supplementation during the hospital stay, and the patient's nutritional status in relation to anthropometric measures and BMI. Six out of eight panelists reported including blood test results and nutritional recommendations; two included anthropometric data, and only one provided estimated energy needs.

Energy needs

A further decrease in resting energy expenditure was reported among patients after they returned home and at 2.5 years post-injury [18]. This decrease may be attributed to reduced activity after rehabilitation and a return to pre-trauma nutritional habits. The resting energy expenditure is 1,291 - 1,494 kcal/day in patients with chronic SCI and is influenced by the severity of the injury and patients' characteristics [18] (Fig. 1). However, energy expenditure in SCI individuals is lower than in the non-disabled population due to decreased metabolically active tissue and reduced physical activity [93]. The panel highlights that energy needs have to be assessed whenever possible during visits and also in this phase; in particular, a re-evaluation is strongly advised in case of a change in clinical conditions (e.g., need for artificial ventilation, the appearance of a pressure lesion, multiple septic states). Farkas et al [27] assessed the impact of the level of SCI on TDEE. They found that individuals with paraplegia exhibited a significantly higher BMR and TDEE compared to those with tetraplegia. Accordingly, other studies have reported a 54% reduction in TDEE for individuals with tetraplegia [94] and around 20% for those with paraplegia [95]. As regards the influence of sex on energy expenditure, Buchholz et al reported a lower RMR in women compared to men [95]; in contrast, Gorgey et al did not observe significant differences in BMR in the two sexes [96].

Regarding energy intake, studies have reported values of 1,250 - 2,100 kcal/day in SCI patients, but the reliability of estimates depends on the accuracy of the dietary questionnaires; therefore, the actual values may be higher, and the difference in energy intake between individuals with chronic tetraplegia and paraplegia remains uncertain [97, 98]. However, the metabolic rate and total caloric intake are increased by 150 - 400 kcal/day in individuals with chronic SCI, contrasting with the 15-20% deficit recommended [97].

Nutritional assessment

The nutritional assessment in chronic SCI patients should be repeated at each follow-up visit, at least every year, to identify signs of malnutrition as early as possible and immediately if a

a

- Ideal body weight reduced by 10–15% in quadriplegia and by 5–10% in paraplegia compared with non-disabled individuals of equivalent height and weight
- Evaluation of BMI, WC, and IC measurements during each outpatient visit
- Reference thresholds: BMI <22 kg/m^2, WC <81.3 cm, visceral fat area <100 cm^2

b

Monitoring of:

- Dyslipidemia: if total initial cholesterol levels >5.2 nmol/L → standard dietary; counseling (reduced total fat (<30% of kcal), saturated fat (<10% of kcal), cholesterol (<300 mg), and increased carbohydrate intake (60% of kcal)
- Glycemia (especially in tetraplegia)
- Vitamin deficiencies (vitamin A, B5, B7, B9, B12, C, D, and E)
- Trace minerals deficiency (potassium, magnesium, calcium)

c

- If possible, assessment of % body fat by DXA
- Assessment of the nutritional status by using SNST and SCI-SCREEN tools

d

- A carbohydrate intake equal to 45% of the total daily calories (fats 30% and protein 25%) may help to optimize training program outcomes
- Saturated fat intake: 5–6% of total caloric intake (favoring unsaturated fats)
- 15–30 g of fiber per day as tolerated (decrease in case of constipation)
- 0.8–1.0 g/kg of protein of body weight (in the absence of pressure ulcers or infection)
- Daily calcium intake of 1000–1200 mg (without calcium oxalate stones) or 750–1000 mg/day (with calcium oxalate stones)
- Supplemental vitamin D3 (cholecalciferol) ranging from 25–50 µg/day (1000–2000 IU/day)
- Supplemental oral alendronate in case of low bone mass and moderate-to-high fracture risk

Figure 6. Post-discharge SCI: management considerations for (a) anthropometric, (b) biochemical, (c) clinical and (d) dietary assessment. SCI: spinal cord injury; IC: indirect calorimetry; BMI: body mass index; DXA: dual X-ray absorptiometry; SNST: spinal nutrition screening tool; WC: waist circumference.

change in the clinical condition occurs (Fig. 6).

1) Anthropometric assessment

A BMI ≥ 25 kg/m^2 is associated with metabolic syndrome in SCI [6]. A lower BMI was observed in individuals with tetraplegia compared with paraplegic ones but with higher total body fat percentage, lower lean body mass, and increased visceral fat area and volume [99].

According to the AND guidelines, the ideal body weight for SCI patients should be reduced by 10-15% in the case of quadriplegia and 5-10% in the case of paraplegia compared with non-disabled individuals [16].

Measuring BMI, WC and IC during each outpatient visit is recommended. However, relying solely on these tools may not comprehensively assess nutritional status. The panelists unanimously agreed that patients must maintain an optimal weight, determined based on the individual characteristics of each patient (e.g., age, sex, height, thoracic, abdominal and thigh circumference, percentage of fat mass), residual activity and the impact on the quality of life, especially when dealing with comorbidities, such as diabetes, cardiovascular disease, and hypertension, in order to reduce cardiovascular risk and complications from malnutrition. The authors suggest that formulas, such as that developed by Lorenz et al [100], and comparison with percentiles of healthy people [101] may be used to increase the accuracy of the estimate.

2) Biochemical assessment and blood tests

The panel recommends repeating biochemical assessments and blood tests at each follow-up visit during the post-discharge phase or more frequently if a change in clinical conditions occurs. SCI patients have a higher risk of dyslipidemia than the general population, and this risk is higher in those with paraplegia [5]. Furthermore, the injury level affects the degree of dyslipidemia, with higher serum triglycerides and low-density lipoprotein (LDL) cholesterol in people with SCI below T5 - 6 compared with those with SCI above T4 [102, 103]. The severity of dyslipidemia appears closely linked to the duration of SCI and with both visceral and subcutaneous abdominal fat [104]. Men with SCI generally exhibit a higher cardiometabolic risk and lower high-density lipoprotein (HDL) cholesterol than women [105]. Furthermore, a correlation exists between low HDL cholesterol and low testosterone [106].

The panel recommends an evaluation of neurogenic obesity and cardiometabolic risk to be performed at least annually, with second-level tests, such as cardiac echography, myocardial scintigraphy, cardiac MRI or cardiac CT scan, and stress tests performed when deemed necessary.

Diet, pharmacology, and exercise can effectively address adiposity and dyslipidemia in SCI individuals [107]. If total initial cholesterol levels are > 5.2 nmol/L, standard dietary counseling should be provided (total fat: < 30% of kcal; saturated fat: < 10%; cholesterol: < 300 mg; carbohydrate intake: 60%) [108].

About 50-60% of SCI patients show impaired glucose tolerance, with a higher prevalence in those with tetraplegia than in those with paraplegia [109]. SCI patients are also more prone to insulin resistance and have a higher incidence of diabetes [110]. Differences in hemoglobin, white blood cell count, albumin, prealbumin, serum iron, and percentage saturation levels have been reported in SCI patients compared with controls; however, all values are usually within the normal range [111].

The most common deficiencies in individuals with SCI include vitamins A, B5, B7, B9, B12, C, D, and E, and potassium, magnesium, and calcium [112, 113].

3) Clinical assessment

An increased body fat percentage of ≥ 30% was reported, with a lower increase in younger patients and those with tetraplegia [114]. Unfortunately, based on the panel's experience, time constraints during outpatient visits pose challenges in conducting precise body composition assessments. Therefore, using fast and reliable tools such as the SNST and the SCI-SCREEN to assess nutritional status is preferable. However, the general criteria for diagnosing malnutrition remain applicable. In this regard, both the AND and the ASPEN define malnutrition as the presence of at least two of the following characteristics: insufficient caloric intake, weight loss, loss of muscle mass, loss of subcutaneous tissue, localized or generalized fluid accumulation (which may sometimes obscure weight loss), and reduced functional status as indicated by handgrip strength [38]. The GLIM criteria adopt a comprehensive approach that combines at least one phenotypic indicator (such as nonvolitional weight loss, low BMI, or decreased muscle mass) with one etiologic indicator (such as reduced food intake, impaired absorption or disease burden, or inflammatory condition) [45]. Despite the fact that SCI patients experience sarcopenia secondary to the injury, the panel highlights that these criteria remain applicable. Muscle loss due to SCI needs to be acknowledged and treated along all the phases of the disease: acute-phase patients require monitoring to maintain an adequate caloric intake, and post-acute and chronic patients need longitudinal follow-up of the considered parameters, comparing each set of data with observations from the previous 6 months.

4) Dietary assessment

Carbohydrate and fat intake are usually above the recommended values in patients with chronic SCI, while fiber intake is too low [89] and associated with an increased risk of fat storage [115], insulin resistance, and type 2 diabetes [3, 82, 116]. A standardized dietary protocol for individuals with SCI can comprise carbohydrates for 45% of the total daily calories, fats for 30% and proteins for 25% [117]. The American Heart Association limits the recommended saturated fat intake for persons with chronic SCI to 5-6% of total caloric intake [118]. In the panel's opinion, this recommendation should be implemented as soon as possible, starting from the rehabilitation phase, to prevent fat accumulation. A higher consumption of carbohydrates has been reported among men compared to women with SCI [2]. Additionally, women with SCI were reported to consume more n-3 linolenic acid than men [2]. Groah et al [119] observed that females with SCI had a lower total calorie intake compared to males. Males with paraplegia and tetraplegia, as well as the only women with tetraplegia included in the study, exhibited a higher-than-recommended intake of fat and carbohydrates when compared to women with paraplegia [119]. Although the AND recommends consuming 15 g/day of fiber and increasing it to 20 g/day depending on tolerance following SCI and not for people at risk of gut ischemia in ICU, this recommendation is based on weak and conditional evidence [16]. High-fiber consumption without sufficient fluid intake can lead to constipation. Furthermore, fruit and vegetable consumption falls below the recommended intake for persons with SCI [50].

The protein intake in individuals with SCI typically meets or surpasses recommended values [89, 120]. However, insufficient consumption of protein-rich foods may result in inadequate intake of essential amino acids [91]. In particular, branched-chain amino acids can benefit muscle protein synthesis [121]. Notably, a protein intake within the 1.2 - 2 g/kg/

day range is safe for ICU patients with renal function [122]. Protein recommendations during the chronic phase are 0.8 - 1.0 g/kg/body weight in the absence of pressure ulcers or infections [16].

Calcium intake in individuals with SCI is generally low [123]. Given the high prevalence of osteoporosis in SCI, guidelines recommended a daily calcium intake of 1,000 - 1,200 mg (sex and age-dependent) for individuals without calcium oxalate stones and 750 - 1,000 mg/day for individuals with oxalate stones, preferably by dietary intake [124]. A maintenance dose of vitamin D3 between 25 and 50 µg/day (1,000 - 2,000 IU/day) is also suggested [124]. Education plays a crucial role in promoting diets rich in high-calcium foods, vitamin D, and phosphorus to prevent metabolic dysfunction and osteoporosis [125]. The panel does not recommend periodic X-ray scans aimed at monitoring osteoporosis, as they could lead to dangerous cumulative radiation for people with SCI and a relatively young age. They are not useful for monitoring the acute phase of osteoporosis. The panel deems that people with SCI should adhere to a healthy diet with calcium and vitamin D3 supplementation and try to reduce the risk of fractures. Blood vitamin D levels and immobilization hypercalcemia should be monitored. Low-quality evidence exists for the use of alendronate, and unfortunately, no therapy for the prevention of osteoporosis in people with SCI has been devised so far. For non-pharmacologic interventions, very low-quality evidence exists for the effectiveness of standing with or without treadmill walking in acute SCI [126].

Some studies reported high alcohol consumption among SCI patients, with men consuming more alcohol than women [2]. Alcohol consumption should be investigated during dietary recalls, as it represents a risk factor for malnutrition.

Conclusions

Patients with SCI face a significant risk of malnutrition. Therefore, it is crucial to ensure adequate monitoring of their nutritional status over time, considering the changes in individual TDEE associated with different phases of the disease and identifying suitable tools for nutritional assessment. Since most of the currently available studies predominantly focus on males, further research on the impact of gender on the nutritional status of SCI patients would help clarify the needs of this population. Although the risk of obesity is higher in the chronic phase compared with undernutrition, it is important to address both ends of the nutritional spectrum. Patients should be followed by a healthcare team that includes an RD, who can regularly assess the patient's nutritional status and implement lifestyle and dietary modifications. This comprehensive approach aims to prevent undernutrition, obesity, and associated complications, which can adversely affect prognosis and quality of life and increase the risk of hospital readmissions.

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Conflict of Interest

None to declare.

Author Contributions

Study conception and design: AA, WC, AC, LDP, GDP, FF, and LP. Collection and interpretation of data: AA, WC, AC, LDP, GDP, FF, and LP. Manuscript drafting: AA, WC, AC, LDP, GDP, FF, and LP. Manuscript editing: AA, WC, AC, LDP, GDP, FF, and LP. Approval to submit: AA, WC, AC, LDP, GDP, FF, and LP.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Abbreviations

SCI: spinal cord injury; RD: registered dietitian; IC: indirect calorimetry; BMI: body mass index; AND: Academy of Nutrition and Dietetics; TDEE: total daily energy expenditure; TBW: total body water; ICU: intensive care unit; CRP: C-reactive protein; CHI: creatinine height index; LDL: low-density lipoprotein; GLIM: Global Leadership Initiative on Malnutrition; DXA: dual X-ray absorptiometry; BIA: bioelectrical impedance analysis; MRI: magnetic resonance imaging; SARC-F: strength, assistance with walking, rise from a chair, climb stairs and fall; CASCO: cachexia score; SPSM: short portable sarcopenia measure; CT scan: computerized tomography scan; SNST: spinal nutrition screening tool; BES: bedside swallowing evaluation; VFSS: videofluoroscopic swallow studies; FEES: fiberoptic endoscopic evaluation of swallowing; EN: enteral nutrition; PN: parenteral nutrition; SCCM: Society of Critical Care Medicine; ASPEN: American Society for Parenteral and Enteral Nutrition; CLABSI: central line-associated bloodstream infection; WC: waist circumference

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