Assessing nutritional status after spinal cord injury

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### Abbreviations

<table>
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<th>Abbreviation</th>
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<tr>
<td>BIA</td>
<td>Bioelectrical impedance analysis</td>
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<td>BIS</td>
<td>Bioelectrical impedance spectroscopy</td>
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<td>DEXA</td>
<td>Dual energy x-ray absorptiometry</td>
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<td>FFA</td>
<td>Fat-free mass</td>
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<td>SCI</td>
<td>Spinal cord injury</td>
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<td>TEE</td>
<td>Total energy expenditure</td>
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Executive Summary

Background
Following acute spinal cord injury (SCI) there is a well-documented hypermetabolic, catabolic injury cascade with a consequent reduction in whole-body energy stores, lean muscle mass and a reduction in protein synthesis. Assessment of energy requirements in patients with acute SCI is difficult and challenging with the abrupt decrease in physical activity due to paralysis, denervation and muscle atrophy. Dietitians currently estimate a patient's nutritional requirements using standard equations of normal resting metabolism based on body weight and age, and adjusted for activity and stress levels. These equations have never been validated in the SCI population. Moreover, body weight is a crude measure which does not distinguish between changes in lean muscle mass or body fat.

The doubly labelled water (DLW) technique is the gold standard method for estimation of total energy expenditure (TEE) and total body water, and thereby fat free mass (FFM). Dual energy x-ray absorptiometry (DEXA) is used to measure body composition, however this may not be valid in persons with chronic disease. Another method of monitoring FFM using bioelectrical impedance would be of significant clinical benefit. Bioelectrical impedance spectroscopy (BIS) can be implemented using portable equipment at the bedside. In this study, these three methods were used to determine a) the most appropriate predictive equation for assessing energy requirements in acute spinal cord injury, and b) the validity of BIS to assess body composition.

Main findings
1. The median TEE in the study population was 2,164 kcal/day, and despite the absence of validated equations to estimate energy requirements in this population, study participants were meeting 102% of their total energy expenditure (estimated energy intake 2,309 kcal/day).
2. There was no agreement between TEE estimated using DLW and that estimated by the standard equations (Schofield, Oxford, Harris-Benedict or Nelson equations) that are used clinically.
3. DEXA measures of FFM were highly correlated to those estimated using DLW, however DEXA underestimated FFM with a bias of 2.9%.
4. Five population-specific bioelectrical impedance analysis equations to predict FFM derived from the literature were tested and the equation from Kocina (1997) had the best fit for our population. The limits of agreement were wide, probably due to the small sample size. BIS provides a valid measure of FFM using the Kocina population-specific equation.

Implications
1. The equations used clinically to estimate energy expenditure in acute SCI patients were found to give inaccurate estimates compared with the estimate derived using the gold standard DLW technique. Therefore use of these equations cannot be recommended.
2. BIS provides a valid measure of FFM using the population-specific equation of Kocina. BIS can be undertaken using a portable bioelectrical impedance machine which can be used at the bedside, and avoids the expense and inconvenience of using DEXA.
Purpose

The main purpose of this study was to calculate energy requirements in people with spinal cord injury by using doubly labelled water in order to validate the Schofield equation that is currently used by dietitians clinically. Additionally bioelectrical impedance analysis (BIA) was compared with dual x-ray absorptiometry (DEXA), the current gold standard, as a measure of body composition.

Rationale

Acute spinal cord injury (SCI) can lead to malnutrition, with loss of lean body mass as a result of an initial hypermetabolic response to the stress of injury as well as an abrupt decrease in activity because of paralysis [1]. This is associated with decreased immune function, delayed wound healing and early mortality [2]. Assessment of nutritional needs in this population is difficult and challenging, with multiple factors affecting nutritional status and a lack of appropriate reference values. Dietitians use the Schofield and other equations to estimate the basal metabolic rate and the total caloric intake required to maintain body mass, however the equations have not been validated for people with spinal cord injury [3-6].

Validation of this equation is dependent on accurate measurement of energy expenditure for which the gold standard is the doubly-labelled water (DLW) method [7-8]. This method has previously been used to measure energy expenditure in ventilator-dependent tetraplegics in the first four weeks after acute SCI. However, further study is warranted.

Once nutritional recommendations have been made, determination of the adequacy of dietary intake is currently based on the relatively insensitive measure of body weight. Measuring fat-free mass (FFM) is a way of monitoring increased adiposity (weight – FFM = fat mass) in patients with SCI in whom weight loss may result from muscle atrophy. The amount of fat-free mass (FFM) has been shown to correlate well with resting energy expenditure and is usually measured using dual energy x-ray absorptiometry (DEXA). FFM can also be measured at the bedside using a specific technique called bioimpedance spectroscopy (BIS), which utilises multiple currents and frequencies which enable the signal to pass both within and around cells [9]. BIS may be a sensitive indicator of body composition in people with spinal cord injury. This project was undertaken to provide a sound basis for current practice in the estimation of nutritional requirements for people with spinal cord injury, and for the ongoing monitoring of the adequacy of dietary intake in this vulnerable population.

Key research questions

1. What is the energy expenditure of patients with recent spinal cord injury?
2. Are the Schofield and other clinically used equations for estimation of energy expenditure valid in people with spinal cord injury?
3. Is bioelectrical impedance spectroscopy a valid measure of body composition in people with spinal cord injury?

Methods

Population: Males and females aged 18-70 years with traumatic spinal cord injury less than 6 weeks post-injury and with surgical fixation of the fracture.
Sample size: The sample size of 20 participants is typical of that used to measure energy expenditure using doubly labelled water.

Exclusion criteria: Ventilator-dependent, medically unstable

Intervention: Observational study. Participants were given a single dose of doubly labelled water (99% deuterium and 10% 18O) based on body weight (1.35gm per kg). Urine samples were collected pre-dose and at regular intervals over a two week period post-dose. Participants also had BIA and DEXA.

Comparator: Not applicable

Outcome: Energy expenditure measured by calculation of the elimination rates of deuterium and O-18 through the regular sampling of heavy isotope concentrations in the urine.

Analysis: Energy expenditure estimates derived from mass spectrometry analysis of deuterium dilution in urine samples was used to validate the Schofield, Oxford, Harris-Benedict or Nelson equations which are used clinically to estimate the basal metabolic rate and the total caloric intake required to maintain body mass. Fat mass and fat-free mass derived from BIS were correlated with the values obtained from DEXA and DLW (the gold standard).

Research/review Findings

Twenty participants (18 male) completed the DLW and BIA assessments. Only 13 completed 13 DXA measurements. Mean age was 36.4 (±13.8). Mean time since injury was 36.4 (±13.8) days. Mean BMI was 24.9 (±4). Six participants had complete injuries (4 tetraplegic, 2 paraplegic). Seven participants had incomplete injuries (6 tetraplegic, 1 paraplegic).

The median TEE in the study population estimated using DLW was 2,164kcal/day, and despite the absence of validated equations to estimate energy requirements in this population, study participants were meeting 102% of their total energy expenditure (estimated energy intake 2,309kcal/day). However even though adequate calories were consumed, there was a median decrease in weight of 0.8 kg (interquartile range -2.00 to 0.30) over two weeks.

DXA measures of FFM were highly correlated with those derived through the criterion method of deuterium dilution (DLW). DXA underestimated FFM with a bias of 2.9%. The limits of agreement were +/-11.5% are somewhat wide, probably due to the small sample size.

The generalized predictive equation used to estimate FFM from BIS was highly correlated with deuterium dilution calculations of FFM, however there was a bias of 8.9% with very wide limits of agreement (+/- 17.5%). Furthermore, there was a systematic bias where this BIS equation underestimated FFM in cases of low FFM and overestimated FFM in cases of high FFM. This may be potentially adjusted for by altering the coefficient for body proportions.

Five population-specific bioelectrical impedance analysis equations to predict FFM derived from the literature [10-14] were tested and the equation from Kocina [14] had the best fit for our population. The limits of agreement were wide, probably due to the small sample size. BIS provides a valid measure of FFM using the Kocina population-specific equation.
Discussion, conclusions and implications

To our knowledge, this study was the first to use DLW to measure energy expenditure in acute SCI patients outside of the intensive care unit. The strength of this study was the cross-validation for BIS using DEXA and DLW. We showed that the clinically used equations were inaccurate in estimating energy expenditure compared with the gold standard DLW, and therefore they cannot be recommended.

Measurement of body weight is done routinely in clinical practice, but this is a crude measure which does not distinguish between changes in lean muscle mass or body fat. Dietitians need an accurate and practical method of determining body composition in order to predict metabolic demands. DLW is extremely expensive and therefore tends to be used only for research. DEXA, while less expensive and has low radiation exposure, is impractical for repeated measures of body composition. In this study, we validated a technique for measurement of body composition, BIA, which is undertaken at the bedside using a relatively inexpensive portable device. BIS, a specific application of bioimpedance analysis that utilizes multiple currents with various frequencies, was shown to provide a valid measure of FFM when the population-specific equation of Kocina was used. Our results are in accord with other studies in chronic SCI published since our study commenced [15] and are of clinical importance.

The limitations of this study were as follows:

- The small sample size may have been the reason for the wide limits of agreement between the measures. Because of the small sample size we were unable to generate our own predictive equation for estimation of FFM and to validate this in a second sample, as has been done in other studies.
- We only undertook DEXA measures at baseline, therefore we were unable to determine the validity of change in BIS over time. However, given that the maximum weight loss was only 2kg over a two week period, a future study should test this over a longer time frame.
- It is not known whether the population used to derive the Kocina equation is similar to our sample with regard to ethnicity or level of lesion. However, neither of these factors were required for the predictive equation and may not be relevant.

Potential impact, use of the research and recommendations

On the basis of our findings, the equations used by dietitians to estimate energy expenditure in people with acute SCI yield inaccurate estimates and should not be used.

Bioelectrical impedance spectroscopy provides an accurate estimate of fat-free mass and has clinical utility because it can be done quickly at the patient’s bedside. This measure is more appropriate than the relatively insensitive measure of body weight to determine the adequacy of the diet. BIS has already been adopted in clinical practice by the dietitians in the Victorian Spinal Cord Service at Austin Health and, for the first time, the clinicians have a practical, accurate and objective measure of body composition for people with SCI. This may lead to a change in the dietary recommendations in the acute SCI population. Optimal nutritional support during recovery from SCI will improve important aspects of physical health such as skin integrity, immune function and body composition. Improved health in the acute setting is likely to improve physical health in the chronic stage of SCI.
References
