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Editorial Board Member of *World Journal of Methodology*, Wei Liu, PhD, Assistant Professor, Department of Radiation Physics, the University of Texas MD Anderson Cancer Center, Houston, TX 77030, United States

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Basic Study

# Nutech functional score: A novel scoring system to assess spinal cord injury patients

Geeta Shroff, Jitendra Kumar Barthakur

Geeta Shroff, Nutech Mediworld, New Delhi 110016, India

Jitendra Kumar Barthakur, Department of Statistics, Nutech Mediworld, New Delhi 110016, India

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**Correspondence to:** Geeta Shroff, MBBS, Founder, Medical Director, Nutech Mediworld, H-8, Green Park Extension, New Delhi 110016, India. [geetashroff@hotmail.com](mailto:geetashroff@hotmail.com)  
Telephone: +91-11-26565548  
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## Abstract

### AIM

To develop a new scoring system, nutech functional scores (NFS) for assessing the patients with spinal cord injury (SCI).

### METHODS

The conventional scale, American Spinal Injury Association's (ASIA) impairment scale is a measure which precisely describes the severity of the SCI. However, it has various limitations which lead to incomplete assessment of SCI patients. We have developed a 63 point scoring system, *i.e.*, NFS for patients suffering with SCI. A list of symptoms either common or rare that were found to be associated with SCI was recorded for each patient. On the basis of these lists, we have developed NFS.

### RESULTS

These lists served as a base to prepare NFS, a 63 point positional (each symptom is sub-graded and get points based on position) and directional (moves in direction BAD → GOOD) scoring system. For non-progressive diseases, 1, 2, 3, 4, 5 denote worst, bad, moderate, good and best (normal), respectively. NFS for SCI has been divided into different groups based on the affected part of the body being assessed, *i.e.*, motor assessment (shoulders, elbow, wrist, fingers-grasp, fingers-release, hip, knee, ankle and toe), sensory assessment, autonomic assessment, bed sore assessment and general assessment. As probability based studies required a range of (-1, 1) or at least the range of (0, 1) to be useful for real world analysis, the grades were converted to respective numeric values.

### CONCLUSION

NFS can be considered as a unique tool to assess the

improvement in patients with SCI as it overcomes the limitations of ASIA impairment scale.

**Key words:** Spinal cord injury; American Spinal Injury Association's Impairment Scale; Nutech functional score; Comparison of assessment; Positional scoring system

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**Core tip:** Spinal cord injury (SCI) is a devastating disease which impacts the patient physically, psychologically and financially. American Spinal Injury Association's (ASIA) Impairment Scale is a universally accepted scale to assess the SCI, but this scale does not cover all parameters of SCI. The present study focuses on the development of a new scoring system called nutech functional score for patients with SCI and compare it with internationally used scoring system ASIA.

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## INTRODUCTION

Spinal cord injury (SCI) is a neurological injury that affects conduction of sensory and motor signals across the site(s) of lesion(s) and the autonomous nervous system leading to long-lasting degeneration of locomotor and sensory neurons below the point of injury<sup>[1]</sup>. Spinal cord is generally injured during work or recreation related mishaps, motor vehicle accidents as well as violence<sup>[2]</sup>. According to factsheet of the World Health organization (November 2013), around 250000 and 500000 persons are estimated to suffer from SCI each year<sup>[3]</sup>. Though survival over SCI has improved, yet it is of paramount importance to focus on the issue of assessment of SCI patients as perfectly as possible<sup>[2]</sup>.

There are many international standards available for examination of the neurological damage. "American Spinal Injury Association's (ASIA) Impairment Scale" is a universally accepted scale which consolidates "scores" and assesses the extent of injury, and the overall condition in its own way. These conventional scoring scales examine sensory and motor levels on right and left sides, sensory scores using pin prick and light touch, motor scores for upper and lower limb, etc. They precisely determine neurological levels, the extent of incomplete injury and achieve more consistent and reliable data<sup>[1,4-6]</sup>.

The ASIA impairment scale is a categorical scale which classifies the extent of SCI injury as motor complete and motor incomplete using grades A, B, C, D and E. "A" refers to complete injury where no function,

neither sensory nor motor, has been preserved in the sacral segments S4-S5. "B" is assigned to SCI patients where no motor function is preserved below the neurological level and sacral segments S4-S5, whereas, sensory function is preserved. The SCI patients who are diagnosed with motor incomplete condition, i.e., motor function is preserved below the neurological level, and more than half of key muscle functions below the single neurological level of injury have a muscle grade < 3, are assigned with grade "C". "D" refers to the motor incomplete condition where motor function is preserved below the neurological level, and at least half or more of key muscle functions below the neurological level have a muscle grade > 3. "E" refers to the normal condition of the patient, where sensory as well as motor functions are normal<sup>[1]</sup>. There is a direction of BAD → GOOD from A to E, where → stands for "to" or "moves towards". The routes are distinctly two and they are A → B → E and A → C → D → E<sup>[7]</sup>. These routes only allow counting of ASIA impairment scale which are neither numeric nor ordinal. They disconnect the ability of the sensory symptoms from the motility of the motor symptoms, as both run along two different routes. This confines the analysis with clinical research to count and rank in two streams of the scores. It was refined/improved on various basis from 1989 to 2013 which led to addition of some more parameters, such as T3 sensory examination, motor examination, testing position, wrist extension, hip flexors, ankle dorsiflexors, long toe extension, anorectal examination, etc.<sup>[4,5,8]</sup>. However, there are many parameters such as bed sore assessment, improvement assessment, breathing pattern, etc. that are important to assess in case of SCI patients but are not covered under ASIA impairment scale yet.

The present study focuses on the development of a new scoring system called nutech functional scores (NFS) for patients with SCI and compare it with the internationally used scoring system ASIA. All the important parameters that are missed out in ASIA scale have been included in NFS that makes it more valuable in assessing the complications and improvement after treatment in patients with SCI.

## MATERIALS AND METHODS

The symptoms, either common or rare, with which the patients were evaluated, were recorded in the diagnostic history. We started preparing a list of all the possible symptoms from the diagnostic history of the patients. These lists are revised time and again to maintain accuracy and precision and are used to assess patients with SCI.

Each symptom had five ordinal grades in BAD → GOOD direction. We assessed the SCI patients simultaneously with ASIA impairment scale and our new scoring system. The study was approved by Institutional Review Board of Nutech Mediworld.



**Table 1** Conversion table from categorical grades to numeric range for nutech functional score

No. of scores	Numeric (Y <sub>n</sub> )	Categorical scores (Y <sub>c</sub> )				
		1	2	3	4	5
5	Score (Y <sub>n</sub> )	0.122	0.310	0.500	0.690	0.890
	Range (Y <sub>n</sub> )	0-0.241	0.241-0.379	0.379-0.621	0.621-0.759	0.759-1.00
3	Score (Y <sub>n</sub> )	0.167	0.5	0.833	-	-
	Range (Y <sub>n</sub> )	0-0.333	0.333-0.667	0.667-1.00	-	-

## RESULTS

We developed a 63 point grading system which consisted of five grades in number for each parameter. For non-progressive diseases, 1, 2, 3, 4, 5 denote worst, bad, moderate, good and best (normal), respectively. The symptoms that are found not to be associated with SCI are scored as not afflicted in SCI (NA). Supplementary table presents the parameters assessed with NFS along with their grades. NFS for SCI has been divided into different groups based on the affected part of the body being assessed, *i.e.*, motor assessment (shoulders, elbow, wrist, fingers-grasp, fingers-release, hip, knee, ankle and toe), sensory assessment, autonomic assessment, bed sore assessment and general assessment.

The hypothetical spread of five symptoms ranging in (0.5, 5.5) were treated as equidistant to each other and were continuous. As probability based studies required a range of (-1, 1) or at least the range of (0, 1) to be useful for real world analysis, the grades were converted to respective numeric values. The "0.5" and "5.5" in the range of (0.5, 5.5) was treated as "0" and "1" of the (0, 1) in numeric scale, respectively. The configuration used to convert the range (0.5, 5.5) to the range (0, 1) demonstrated the internal consistency of the two methods of grading. It is now universal and usable for one symptom. An equation has been derived using the polynomial smoothing and graphical methods for converting categorical scores into numeric scores. The equation is as follows:

$$Y_n = 0.096 \times (Y_c + 0.5) - 0.166$$

where, Y<sub>n</sub> = numeric score and Y<sub>c</sub> = categorical score.

Table 1 explains the layout of the conversions. Depending upon the symptoms of parameters assessed by NFS, the five/three categorical grades in the range (0.5-5.5) can be converted to five/three numeric grades in the range (0, 1), respectively.

## DISCUSSION

The spinal cord is the major conduit through which motor and sensory information travels between the

brain and body. It can get injured which leads to SCI affecting the smooth functioning of the body<sup>[1]</sup>. Though, last decade reveals various reports emphasizing the medical management of SCI, still, there is no effective treatment to completely cure SCI. The pathophysiology, either primary injury phase or secondary, involved in SCI is essential to determine the type of possible therapeutic application that can be used after SCI.

Preceding clinical management, it is essential to determine the extent of injury. There are various scales to determine the cord segments affected by SCI<sup>[1]</sup>. ASIA impairment scale is such a tool where its grades relate directly to a case and form categorical distributions of frequencies.

Though, many revisions have taken place in ASIA impairment scale scoring system, few limitations have been observed during assessment of SCI which restrict/limit its use. It doesn't specify the classification score for SCI patients who have patchy motor and sensory functions intact, irrespective of the level. It does not specify if motor or sensory function is non-contiguous or on one side of the body. It gives the classification of function affected below the level of injury, but doesn't describe the gross condition of the patients, such as if breathing is affected; if the patient can sit without support or even maintain the sitting posture. A study by Gündoğdu *et al*<sup>[9]</sup> reported that the ASIA impairment scale to assess the recovery in SCI patient, it can lead to incorrect diagnosis as it may show the worsening of the condition despite of the neurological improvement of the patient. Thus, we may retrieve at an incorrect conclusion when AIS grade is considered alone without observing any motor or sensory changes during recovery<sup>[9]</sup>. Determination of motor levels and differentiation between AIS B and AIS C/D is one of the most difficult classification tasks in AIS scoring system<sup>[10]</sup>.

The major addition made in NFS is the improvement assessment parameter. It documents even the slightest improvement by using parameters which redefined the motor and sensory functions, thereby overcoming one of the important existing limitations of ASIA impairment scale.

In our previous study, we reported several signs of improvement in our study patients who did not show any improvement when assessed with ASIA scale. Their score remained "A", both before and after the therapy. But, these patients showed improvement in sensation of fullness of bowel and bladder and control over bowel and bladder<sup>[11]</sup>. Thus, ASIA scale lacks in assessing these parameters. Other parameters such as bed sore number and size, breathing and swallowing pattern, deformity, sweating below the level of injury, spasticity, deformity, sitting balance, standing balance, flaccidity, bulk/limb atrophy, walking distance and other general assessments including requirement of gait with calipers, calipers for standing and mobility aid, *etc.* are also not assessed by ASIA, but are included in our

**Table 2** A hypothetical example showing nutech functional scores of a spinal cord injury patient before and after therapy

Parameters	NFS score before therapy	NFS score after therapy
Motor assessment (shoulder)		
Flexion	1	4
Extension	1	3
Adduction	2	5
Abduction	NA	NA
Internal rotation	2	5
External rotation	1	5
Motor assessment (elbow)		
Flexion	NA	NA
Extension	NA	NA
Supination	2	5
Pronation	2	5
Motor assessment (wrist)		
Flexion	1	3
Extension	1	4
Radial deviation	2	5
Ulnar deviation	NA	NA
Motor assessment (fingers - grasp)		
Use full palmar grasp	NA	NA
Use radial-digital grasp	NA	NA
Use standard pincer grasp	2	5
Use spherical grasp	3	5
Use intrinsic-plus grasp	3	5
Use power grasp on tool	2	5
Motor assessment (fingers - release)		
Release object freely	1	5
Release 1-inch object in container	1	5
Stack 1-inch blocks	1	5
Release tiny objects	1	3
Throw small ball at least 3 feet	1	4
Motor assessment (hip)		
Flexion	NA	NA
Extension	NA	NA
Adduction	1	3
Abduction	1	5
Internal rotation	1	5
External rotation	2	5
Motor assessment (knee)		
Flexion	1	3
Extension	1	3
Motor assessment (ankle)		
Plantar flexion	NA	NA
Dorsi flexion	NA	NA
Inversion	NA	NA
Eversion	NA	NA
Motor assessment (toe)		
Flexion	1	4
Extension	1	5
Sensory assessment		
Superficial sensation	2	5
Deep sensation	2	5
Autonomic assessment		
Bladder sensation	NA	NA
Bladder control	1	4
Bowel sensation	1	5
Bowel control	2	5
Blood pressure assessment	3	5
Bed sore assessment		
Bed sore number	1	5
Bed sore size	1	5
General assessment		
Breathing	NA	NA
Sweating	NA	NA
Swallowing	2	5
Gait with calipers	NA	NA

Calipers	1	5
Spasticity	1	5
Clonus	NE	NE
Deformity	1	5
Contracture	NA	NA
Flaccidity	3	5
Bulk/limb atrophy	1	4
Sitting balance	2	5
Standing balance	NA	NA
Walking aid	1	5
Walking distance	NA	NA
Total	67	197

NFS: Nutech functional scores; NA: Not afflicting; NE: Not existing.

newly developed NFS scoring system. This has led to a complete assessment of the patient's condition which is lacking in ASIA impairment scale.

All the parameters in NFS scoring system are graded on a scale of 1 to 5 in the range of 0.5 to 5.5, *i.e.*, NFS is ordinal, which provides complete information regarding the condition of the patients before and after the therapy. It is important to note that NFS does not include "0" as a grade. Analytical work based on "count" stays unaffected.

Let's take a hypothetical example to explain how the affected parameters are graded with NFS and ASIA. Table 2 presents a detailed manner of grading a SCI patient with NFS. Addition of scores for each parameter gives us the total score. The total NFS score of the patient before therapy is 67 and increases to 197 after the therapy. This shows a remarkable improvement in the patient after undergoing therapy. When assessed with ASIA, the grade of the patient before therapy is "A" (complete) and moves to "B" (Sensory incomplete) after the therapy. ASIA score "B" is defined as "sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-S5, AND no motor function is preserved more than three levels below the motor level on either side of the body". Thus, it means that patients had no improvement in motor function following the therapy which is contrary to the assessment with NFS. With NFS, we have observed improvement in motor functions of shoulder, elbow, wrist, finger-grasp, finger-release, wrist, ankle, hip and toe (Table 2). In NFS, scores can be added or subtracted; therefore even slightest improvement/deterioration in the patient's condition can be assessed.

At our facility, we have evaluated the effectiveness of NFS in assessing the patients treated with human embryonic stem cell (hESC) therapy. Thus, NFS can be considered as a unique tool to assess the improvement in patients with SCI receiving the hESC therapy. However, the universal use of the NFS will help in determining its usability in assessing the improvement in patients being treated with other therapies.

In conclusion, the NFS scoring system for SCI in numeric form is an adequate instrument to examine and score the patients with SCI. The ASIA impairment scale is based on categorical descriptions which are not

comparable with a numeric based system.

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## COMMENTS

### Background

Spinal cord injury (SCI) is a neurological injury that affects conduction of sensory and motor signals across the site(s) of lesion(s) and the autonomous nervous system leading to long-lasting degeneration of locomotor and sensory neurons below the point of injury. There are many international standards available for examination of the neurological damage.

### Research frontiers

In the current study, the authors have introduced a new scoring system called nutech functional score (NFS) for assessment of patients with SCI and compare it with the internationally used scoring system American Spinal Injury Association's (ASIA) Impairment Scale. All the important parameters that are missed out in ASIA scale has been included in NFS that makes it more valuable in assessing the complications and improvement after treatment in patients with SCI.

### Innovations and breakthroughs

The authors have developed a 63 point scoring system, i.e., NFS for patients suffering with SCI. A list of symptoms either common or rare that were found to be associated with SCI was recorded for each patient. This list is the basis to develop NFS.

### Applications

NFS for SCI patients is a 63 point, positional (each symptom is sub-graded and get points based on position) and directional (moves in direction BAD → GOOD) scoring system that can be used to assess patients with SCI and compare it with the internationally used scoring system ASIA. All the important parameters that are missed out in ASIA scale have been included in NFS.

### Terminology

NFS is a 63 point, positional (each symptom is sub-graded and get points based on position) and directional (moves in direction BAD → GOOD) scoring system.

### Peer-review

The manuscript proposes a new scoring system, for assessing the patients with SCI. It is well written.

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