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Research Summary – American Spinal Injury Association Impairment Scale (AIS): International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) – Neurological Impairment

Author Year Country Research Design Setting	**Demographics and Injury Characteristics of Sample**	**Validity**	**Reliability**	**Responsiveness Interpretability**
Lena et al. 2021 Prospective, observational study 3 Italian rehabilitation hospitals	N=140 non-traumatic SCI, 92M, 48F Mean age: 60 ±16 years (range 15–86) Level: Cervical: 30 Thoracic: 78 Lumbar: 32 AIS A: 32 AIS B: 11 AIS C: 33 AIS D: 64	The correlation between the SCIM self-care subscore and the upper extremity motor score (UEMS) was fair, although significant ($r = 0.407$; $p < 0.001$). The correlations between the lower extremity motor score (LEMS) and the SCIM mobility subscore and between the total MS and the total SCIM score were moderate and significant ($r = 0.666$ and $r = 0.683$ respectively; $p < 0.001$). The correlations improved by considering persons with tetraplegia and paraplegia separately, dividing the assessment at	Inter-rater reliability gave excellent results for MSs ($r = 0.965$; $p < 0.001$); the correlation for sensory scores was lower, but still excellent ($r = 0.905$ for light-touch and 0.902 for pin-prick; $p < 0.001$). Cronbach's alpha highlighted an excellent internal consistency of the ISNCSCI. The comparison of the data of the two examiners did not show any significant difference	

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		admission from one at follow-up and dividing incomplete and complete lesions.		
Marino et al. 2020 Longitudinal cohort study 5 spinal cord injury model system centers	N=51 acute traumatic SCI, 44M, 7W Tetraplegia: 25 Paraplegia T1-T9: 17 Paraplegia T10-T12: 9 AIS A: 29 AIS B: 9 AIS C: 13		Test–retest reliability was almost perfect for all sacral sparing and alternative sacral sparing components. Reliability was perfect (kappa = 1.0) for DAP, VAC and VHTC and almost perfect (kappa = 0.96) for S3P, where only 1/49 exams differed. In the case that differed, exams were performed by different examiners.	
Chun et al. 2020 Prospective, single blinded study AIR unit	N=40, 22M, 18F Mean age: 33y (18-83y) Traumatic: 21 Nontraumatic: 19	Agreement between S-A-ISNCSCI results and I-A-ISNCSCI responses was good for S4–S5 sensation to LT (k = 0.71, 95% CI 0.52–0.90, N = 36), PP (k = 0.68, 95% CI 0.48–0.87, N = 38), and DAP		

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	Tetraplegia: 14 Paraplegia: 26 AIS A: 11 AIS B: 3 AIS C: 7 AIS D: 19	(*k* = 0.77, 95% CI 0.53–1.00, *N* = 37); but only poor for VAC with insufficient statistical significance (*k* = 0.29, 95% CI −0.01 to 0.59, *N* = 36) Agreement was also good for the identification of overall injury completeness vs. incompleteness based on all ISNCSCI sacral sensory criteria combined (*k* = 0.72, 95% CI 0.47–0.97, *N* = 40)		
Harkema et al (2016) Prospective multicenter observational; NRS 13-item version	N=152 (123M, 29F) Mean (SD) age: 36 (15) Median (range) time since SCI: 0.9 (0.1-45.2) years Level of Injury: 110 cervical, 42 thoracic	Pearson's r (95%CI) with ASIA Motor Scales: UEMS with: Berg Balance: 0.3 (0.19, 0.41) 6MWT: 0.24 (0.15, 0.34)		**Responsiveness** Standardized Response Means after Locomotor Training: UEMS: All individuals: 0.38 AIS-A/B: 0.21 AIS-C: 0.64 AIS-D: 0.35

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6 outpatient rehabilitation centers in the Christopher and Dana Reeve Foundation NRN	AIS-A/B/C/D: 43/21/39/49 Physician-referred outpatients without progressive lesions above T11, capable of stepping using body weight support, with ability to wean off anti-spasticity medication Median (range) number of sessions of NRN-standardized locomotor training: 70 (23-520)	10MWT: 0.24 (0.15, 0.34) LEMS with: Berg Balance: 0.79 (0.74, 0.85) 6MWT: 0.7 (0.64, 0.76) 10MWT: 0.69 (0.63, 0.75) ASIA Motor Score with: Berg Balance: 0.75 (0.69, 0.81) 6MWT: 0.64 (0.58, 0.71) 10MWT: 0.63 (0.57, 0.69)		LEMS: All individuals: 0.23 AIS-A/B: -0.10 AIS-C: 0.72 AIS-D: 0.16 ASIA Motor Score: All individuals: 0.33 AIS-A/B: -0.01 AIS-C: 0.82 AIS-D: 0.27 Median (range) number of sessions of NRN-standardized locomotor training: 70 (23-520) **Interpretability** Mean (SD) UEMS: All individuals: Enrollment: 35 (14) Discharge: 37 (13) AIS-A/B: Enrollment: 33 (16) Discharge: 34 (15)

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		Pearson's r (95%CI) with Neuromuscular Recovery Scale (NRS): NRS Overall Phase with: ASIA UEMS: 0.41 (0.31-0.50) ASIA LEMS: 0.70 (0.63-0.77) ASIA Motor: 0.73 (0.67-0.78) NRS Summary Score with: ASIA UEMS: 0.49 (0.39-0.59) ASIA LEMS: 0.80 (0.74-0.86) ASIA Motor: 0.84 (0.80-0.88) NRS Body Weight Supported Treadmill Subscale with:		AIS-C: Enrollment: 31 (12) Discharge: 35 (10) AIS-D: Enrollment: 40 (10) Discharge: 42 (9) Mean (SD) LEMS: All individuals: Enrollment: 16 (18) Discharge: 18 (19) AIS-A/B: Enrollment: 1 (6) Discharge: 0 (1)AIS-C: Enrollment: 13 (11) Discharge: 20 (16) AIS-D: Enrollment: 39 (8) Discharge: 40 (10) Mean (SD) ASIA Motor Score: All individuals: Enrollment: 51 (25)

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		ASIA UEMS: 0.24 (0.13, 0.36) ASIA LEMS: 0.72 (0.65, 0.80) ASIA Motor: 0.66 (0.59, 0.73) NRS Trunk & Leg Subscale with: ASIA UEMS: 0.39 (0.28, 0.50) ASIA LEMS: 0.87 (0.84, 0.91) ASIA Motor: 0.85 (0.81, 0.89) NRS Arm & Shoulder Subscale with: ASIA UEMS: 0.63 (0.54, 0.71)		Discharge: 54 (26) AIS-A/B: Enrollment: 34 (18) Discharge: 34 (15) AIS-C: Enrollment: 44 (16) Discharge: 55 (21) AIS-D: Enrollment: 79 (13) Discharge: 81 (14) * Enrollment = pre-intervention; discharge = post-intervention; median (range) number of sessions of NRN-standardized locomotor training: 70 (23-520)

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		ASIA LEMS: 0.38 (0.25, 0.51) ASIA Motor: 0.61 (0.52, 0.69) NRS Arm & Shoulder + Trunk & Leg Subscales with: ASIA UEMS: 0.54 (0.44, 0.63) ASIA LEMS: 0.78 (0.71, 0.84) ASIA Motor: 0.85 (0.81, 0.89)		
Kalsi-Ryan et al. (2016) Multicenter, observational, longitudinal, cohort study	N =53 (48M, 5F) Mean (SD) age 49.6 (15.6) All acute SCI, 0-10 days post-injury AIS-A/B/C/D: 11/5/16/21			**Responsiveness** Mean Difference, Std Error, Std Response Mean and Effect Sizes (Mean diff; SE; SRM; ES) at different post-injury intervals: ISNCSCI (ASIA) UEMS:

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5 centers (7 sites) in Ontario, Canada	Level of injury: 51 cervical, 2 thoracic			1 month -> 3 month: 5.06; 0.72; 1.00; 0.38 1 month -> 6 month: 7.21; 0.99; 1.10; 0.54 1 month -> 12 month:10.03; 1.24; 1.31; 0.76 ISNCSCI (ASIA) Light Touch: 1 month -> 3 month: 1.06; 0.49; 0.31; 0.12 1 month -> 6 month: 0.82; 0.46; 0.27; 0.09 1 month -> 12 month: 0.76; 0.49; 0.25; 0.09 Breakdown by motor completeness and other time intervals available in article
Sisto et al (2016)	N=350 (267M, 83F) AIS-C/D: 101/249			**Interpretability** Mean (SD) initial UEMS scores:

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Author Year Country Research Design Setting	**Demographics and Injury Characteristics of Sample**	**Validity**	**Reliability**	**Responsiveness Interpretability**
Cross-sectional; NRS 11-item version 7 NRN outpatient rehabilitation clinics	Mean (SD) age: 42 (16) Median (range) time since SCI: 0.9 (0.1-53.1) Incomplete SCI Presence of nonprogressive lesion above T11 No current inpatient rehabilitation No anti-spasticity medication use in the past 3 months Capable of stepping using body weight support Referred to PT by physician			All patients: 39 (11) Cervical SCI: 35 (10) High Thoracic SCI: 50 (1) Low Thoracic SCI: 50 (0) Mean (SD) initial LEMS scores: All patients: 31 (14) Cervical SCI: 33 (14) High Thoracic SCI: 26 (14) Low Thoracic SCI: 27 (15) Mean (SD) initial ASIA Motor scores: All patients: 70 (19) Cervical SCI: 68 (20) High Thoracic SCI: 76 (14) Low Thoracic SCI: 77 (15) Median (range) initial UEMS scores:

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				All patients: 41 (4-50) Cervical SCI: 36 (4-50) High Thoracic SCI: 50 (48-50) Low Thoracic SCI: 50 (50-50) Median (range) initial LEMS scores: All patients: 34 (0-50) Cervical SCI: 36 (0-50) High Thoracic SCI: 28 (0-50) Low Thoracic SCI: 32 (2-50) Median (range) initial ASIA Motor scores: All patients: 73 (9-100) Cervical SCI: 71 (9-99) High Thoracic SCI: 76 (50-100) Low Thoracic SCI: 82 (52-100)
Tester et al (2016)	N = 72 (57M, 15F) completing 20 sessions of			**Interpretability** Smallest Real Difference (SRD): UEMS: 1.3

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Author Year Country Research Design Setting	**Demographics and Injury Characteristics of Sample**	**Validity**	**Reliability**	**Responsiveness Interpretability**
Prospective; testing the Neuromuscular Recovery Scale 14-item version 6 outpatient sites in the Christopher and Dana Reeve Foundation NeuroRecovery Network	standardized locomotor training Mean (SD) age: 36 (15) Median (range) time since SCI: 0.7 (0.1-14.7) years N=45 longer than 6 months 44 cervical, 28 thoracic AIS-A/B/C/D: 17/10/20/25			LEMS: 1.3
Marino et al (2015) Repeated measures Studying the CUE-Test (CUE-T) Outpatient rehab center	N=50, (36M) Mean age 48.1, SD=18.2, range 17~81 Neurological levels of injury: C2~T6 AIS-A/B = 20/50 AIS-C/D = 30/50	Spearman's correlation btwn AISA UEMS and Capabilities of Upper Extremity Test (CUE-T): 0.827		
Scivoletto et al. (2015)	N = 661 (478M, 183F)	Pearson's r btwn SCI-ARMI gain and:		

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Author Year Country Research Design Setting	**Demographics and Injury Characteristics of Sample**	**Validity**	**Reliability**	**Responsiveness Interpretability**
Validation and further development of the SCI-ARMI formula using data from 6 countries	Mean age at admission: 47.6±18.2 AIS-A/B/C/D: 214/55/144/248 patients 387 traumatic, 274 nontraumatic SCI Patients from: Israel = 233 (151M, 82F) Italy = 237 (183M, 54F) Portugal = 26 (17M, 9F) Spain = 30 (24M, 6F) UK = 58 (47M, 11F) US = 77 (56M, 21F)	ASIA Motor Score at admission: -0.14, p<0.0001 ASIA Motor Score gain: 0.13, p<0.0006 Age: -0.23, p<0.0001		
Velstra et al. (2015) Prospective longitudinal multicenter study 5 European SCI centers;	N = 74 (51M) Mean age 49, SD=18 SCI patients <= 10 days post-injury at enrollment AIS at 1 month: A=18, B=12, C=10, D=34 69/74 traumatic SCI	Spearman Correlations (p<0.0001): At 1 month postinjury: GRASSP-MMT subscale & ASIA UEMS = 0.95 GRASSP-SWM subscale & ASIA LT = 0.58		**Responsiveness** SRMs with respect to 1~3, 1~6, 1~12, 3~12, 3~6, 6~12 months post-injury: In all patients: ASIA UEMS: 0.69~1.29 ASIA Light Touch: -0.08~0.30 In AIS-A/B patients:

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Recruitment between Jan 2009 ~ Jun 2011		At 3 month postinjury: GRASSP-MMT subscale & ASIA UEMS = 0.94 GRASSP-SWM subscale & ASIA LT = 0.64 At 6 month postinjury: GRASSP-MMT subscale & ASIA UEMS = 0.94 GRASSP-SWM subscale & ASIA LT = 0.65 At 12 month postinjury: GRASSP-MMT subscale & ASIA UEMS = 0.88		ASIA UEMS: 0.79~1.21 ASIA Light Touch: 0.02~0.39 In AIS-C/D patients: ASIA UEMS: 0.63~1.33 ASIA Light Touch: -0.29~0.33 Breakdown by motor completeness and other time intervals available in article

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		GRASSP-SWM subscale & ASIA LT = 0.66 (GRASSP-MMT = Manual Muscle Testing subscale – based on Daniels and Worthington, 1995)		
Oleson and Marino (2014) Longitudinal, with convenience sample Studying the revised CUE-Questionnaire (CUE-Q; 5pt instead of 7pt scale) "Data were obtained at admission and discharge from acute inpatient rehabilitation"	N = 46 (42M) Median age 44±21 yrs AIS-A = 14, B = 5, C = 8, D = 19 Right motor level: C1-C4 = 11, C5 = 25, C6 = 7, C7-C8 = 3 Left motor level: C1-C4 = 9, C5 = 27, C6 = 5, C7-C8 = 5 28 Caucasian, 18 African-American Etiology: fall = 18, MVA = 17, sports = 8	Spearman correlations btwn ASIA UEMS and: Revised CUE-Q total at: Admission: r=0.89 Discharge: r=0.70 FIM Self-care subscale at: Admission: r=0.76 Discharge: r=0.73 Spearman correlations btwn change in ASIA UEMS and:		**Responsiveness** Effect size of admission-discharge ASIA UEMS change: 0.87

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		Change in CUE-Q total: r=0.07 Change in FIM Self-care subscale: r=0.41		
Ovechkin et al. (2013) Prospective cohort study University of Louisville, Louisville, KY, USA.	N= 11 (3F, 8M) Age: 48 ± 19 AIS A: 4 AIS C: 1 AIS D: 6	AIS Spearman's rho with: FIM Motor Score: r= 0.57 (not significant) SCIM III total: r=0.72 (p< 0.01) SCIM III mobility: r=0.76 (p<0.05) WISCI: r= 0.71 (p<0.05)		
Aidinoff et al. (2012) Development of SCI-ARMI and examination of its validity and utility Loewenstein Rehabilitation	N = 226 (65%M, 35%F) Mean age: 51.3(18.6) 42% tetraplegia, 58% paraplegia AIS-A/B/C/D at admission: 19%/2.7%/23.9%/54.4% 38.9% traumatic, 61.1% nontraumatic	Pearson's r btwn SCI-ARMI and ASIA Motor Score at discharge: 0.28, p=0.00001		

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Hospital, Raanana, and the Statistical Laboratory, School of Mathematics, Faculty of Exact Sciences, Tel-Aviv University, Israel.	250 successive spinal cord lesion (SCL) inpatients treated in the Spinal Department of Loewenstein Rehabilitation Hospital between 2004 and 2010			
Scivoletto et al. (2013) Analysis of prospectively collected data Studying the ISNCSCI N=600 SCI unit of a rehab hospital in central Italy	N = 600 (440M) Mean age 50.35±18.8 Mean time from lesion 51.6±36.8 days Mean time in rehab 123.6±86.3 days 334 traumatic, 266 nontraumatic Lesion level: cervical 192, thoracic 289, 110 lumbar			**Interpretability** Total Motor Score: SEM=0.67, MDC95=1.87, MCID=4.48, ES-based estimate for small change=4.26, substantial change = 10.65 Total Sensory Score: SEM=1.40, MDC95=3.87, MCID=5.19, ES-based estimate for small change=5.1,

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	233 AIS-A, 67 B, 158 C, 142 D			substantial change = 12.75 Admission mean =74.4, SD=25.5, Discharge mean = 79.9, SD=26.4 Upper Extremity Motor Score: Admission mean =40.15, SD=14.9, Discharge mean = 42.9, SD=12.2 MCID=2.72, ES-based estimate for small change=2.98, substantial change = 7.45 Lower Extremity Motor Score: Admission mean =13.8, SD=16.8, Discharge mean = 20.2, SD=19.7 MCID=3.66, ES-based estimate for small change=3.36, substantial change = 8.4

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				Breakdown of Means, SEMs, MDC95s, MCIDs, Substantial and small changes are available according to level of injury and AIS grade (A/B/C/D).
Marino et al. (2012) Cross-sectional study of the CUE-Test (CUE-T) N=30	N = 30 (23M, 7F) Mean age 44.8 Chronic SCI participants SCI participants with level of injury at: C4-6: 9 complete, 6 incomplete C7-T1: 7 complete, 4 incomplete T2-6: 4 complete, 0 incomplete	Spearman correlation of ASIA UEMS with Capabilities of Upper Extremity Test (CUE-T): 0.91		

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Burns et al. (2011) Cross-sectional validation of WISCI II Canada	Patients who are able to ambulate >= 10m N = 76 (79%M) Mean age: 43.3±13.8 Mean post-injury time: 6.32±5.99 years 45% paraplegia, 55% tetraplegia AIS-A/B/C/D: 3%/1%/8%/88%	Spearman correlations: Btwn ASIA Upper Extremity Motor Score (tetraplegic only, N=41) and: Self-selected WISCI level: 0.496 ($p<0.0001$) Self-selected WISCI Speed: 0.491 ($p<0.05$) Max WISCI level: 0.502 ($p<0.0001$) Max WISCI speed: 0.469 ($p<0.0001$) Btwn ASIA Lower Extremity Motor Score (N=76) and: Self-selected WISCI level: 0.704 ($p<0.0001$)		

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Interpretability</th></tr>
<tr><td></td><td></td><td>Self-selected WISCI Speed: 0.509 (p<0.05)
Max WISCI level: 0.717 (p<0.0001)

Max WISCI speed: 0.572 (p<0.0001)
More details of paraplegic/tetraplegic values available in article.</td><td></td><td></td></tr>
<tr><td rowspan="2">Rudhe et al. (2009)
Cross-sectional analysis. Part of larger international multicenter GRASSP study.
N=29</td><td>N = 29 with traumatic or ischemic SCI
Time since injury = 1-15 months (mean = 4.5 ± 3 months)
Age= 19-81 years (mean = 50 ± 18 years)
16 males, 13 females
ASIA-A/B/CD: 12/4/13</td><td>SCIM III scores correlated well with UEMS, MMT and hand capacity tests total scores (P<0.001):

Please see Table 1 below.

Estimation of SCIM-III Self care score using ASIA UEMS: $R^2_{adjusted}$ = 0.69</td><td></td><td></td></tr>
<tr><td colspan="3">Table 1
<table><tr><th colspan="4">Spearman’s correlations between SCIM-III and other measures</th></tr><tr><th>SCIM III</th><th>UEMS</th><th>MMT</th><th>Hand Capacity Tests</th></tr></table></td></tr>
</table>

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<tr><td></td><td colspan="3"><table>
<tr><td>Feeding</td><td>0.73</td><td>0.75</td><td>0.67</td></tr>
<tr><td>Bathing upper body</td><td>0.80</td><td>0.77</td><td>0.77</td></tr>
<tr><td>Bathing lower body</td><td>0.72</td><td>0.76</td><td>0.71</td></tr>
<tr><td>Dressing upper body</td><td>0.73</td><td>0.76</td><td>0.76</td></tr>
<tr><td>Dressing lower body</td><td>0.64</td><td>0.70</td><td>0.60</td></tr>
<tr><td>Grooming</td><td>0.88</td><td>0.89</td><td>0.80</td></tr>
<tr><td>Self-care Total</td><td>0.82</td><td>0.84</td><td>0.80</td></tr>
<tr><td>Respiration & Bladder Total</td><td>0.63</td><td>0.68</td><td>0.65</td></tr>
<tr><td>Mobility Total</td><td>0.65</td><td>0.71</td><td>0.72</td></tr>
<tr><td>Total Score</td><td>0.78</td><td>0.78</td><td>0.76</td></tr>
<tr><td colspan="4">UEMS = upper extremity muscle score
MMT = manual muscle testing</td></tr>
</table></td><td></td></tr>
<tr><td>Ditunno et al. (2008)

Prospective cohort study to demonstrate validation for the formulation of hierarchical rankings

Prospective Cohort in Denmark,</td><td>N = 150 (USA = 112; Europe = 38)

AIS A: Tetra = 18, Para = 41
AIS B: Tetra = 12, Para = 7
AIS C: Tetra = 22 , Para = 10
AIS D: Tetra = 32, Para = 8</td><td>WISCI II Total Spearman correlation w/ Lower Extremity Motor Score (LEMS) (p<0.001):

Initial = 0.47
Final = 0.91
Improvement = 0.59
Final for those who progressed = 0.71</td><td></td><td></td></tr>
</table>

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<tr><td>Germany, Italy and the USA.</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Marino et al. (2008)
Inter-rate and intra-rater reliability study.

Inpatients and outpatients from the Kessler Institute for Rehabilitation.</td><td>N = 16 patients with SCI (2 inpatient, 14 outpatient)
10 men, 6 women, age range from 18-65 years

N = 16 examiners (8 physicians, 8 physical therapists)
> 2 years of experience in field of SCI</td><td>Test-retest, Inter-rater, Intra-rater
Inter-rater:
Please see Table 2 below.

Intra-rater:

Excellent AIS Light Tough ICC= 0.99

Excellent AIS Pin-Prick ICC = 0.99

Excellent AIS UEMS ICC = 0.98</td><td></td><td>Interpretability
Minimal Detectable Change:
Smallest Real Difference
- Light tough = 4.1
- Pin-prick = 5.9
- UEMS = 2.0</td></tr>
<tr><td colspan="4">Table 2
<table>
<tr><th></th><th>All Patients</th><th>Complete</th><th>Incomplete</th></tr>
<tr><td>AIS light touch</td><td>0.96[a]</td><td>0.99[a]</td><td>0.86[a]</td></tr>
<tr><td>AIS pin-prick</td><td>0.89[a]</td><td>0.99[a]</td><td>0.69[b]</td></tr>
<tr><td>AIS total motor</td><td>0.98[a]</td><td>1.00[a]</td><td>0.95[a]</td></tr>
<tr><td>UEMS (tetra)</td><td>0.96[a]</td><td>n/a</td><td>n/a</td></tr>
<tr><td>LEMS</td><td>n/a</td><td>n/a</td><td>0.98[a]</td></tr>
</table></td></tr>
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Author Year Country Research Design Setting	Demographics and Injury Characteristics of Sample	Validity	Reliability	Responsiveness Interpretability
	a- Excellent reliability(ICC ≥0.75) b- Adequate reliability(ICC 0.4<0.74)			
Ditunno et al. (2007) Single-blinded, parallel-group, multicenter randomized clinical trial 6 regional SCI inpatient rehab. USA	N = 146 (114M, 32F) Mean age = 32 years (range 16 – 69 years) Incomplete spinal cord injury patients who had a Functional Independence Measure locomotor score for walking of < 4 on entry.	WISCI II Spearman correlation w/ LEMS (P < 0.001): At 3 months: r = 0.85 At 6 months: r = 0.85 At 12 months: r = 0.88 WISCI II @ 12 months Spearman correlation w/ LEMS: Baseline: 0.73 At 3 months: 0.81 At 6 months: 0.86		
Savic et al. (2007) Prospective observational study to examine inter-rater reliability of motor and sensory examinations performed by two	N=45 (38M, 7F) Mean age=40.3 Injury level Cervical=15 Thoracic=29 Lumbar=1 AIS A (complete SCI)=24 AIS B (sensory incomplete)=4		**Test-retest, Inter-rater, Intra-rater** **Total motor scores:** Pearson correlation: Patients who had motor examination performed by both examiners r=0.999 Patients remaining after exclusion of cases with complete paraplegia r=0.990	

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experienced examiners National Spinal Injuries Centre, Stoke Mandeville Hospital, Buckinghamshire Hospitals NHS Trust, UK.	AIS C=4 AIS D=13 Time since SCI ranged from 3 months – 43 years		ICC: Patients who had motor examination performed by both examiners=0.999 Patients remaining after exclusion of cases with complete paraplegia=0.998 Total light touch r=0.994 ICC=0.997 Pin prick r=0.978 ICC=0.988 Analysis by myotomes The agreement for individual muscle testing of the 10 ASIA key muscles showed substantial to almost perfect agreement for all the muscles	

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			(weighted Kappa coefficient 0.649-0.993, P<0.01, depending on the muscle tested) Secondary analysis The agreement was substantial to almost perfect (weighted Kappa coefficient 0.785-0.981, P<0.05, depending on the muscle tested) Agreement in neurological level Kappa Motor level Right: 0.76 Left:0.68 Sensory level Right:0.78 Left:0.70 All P-values were P<.01	

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			For total ASIA scores, the agreement was slightly better for motor than for sensory scores, and better for light touch than for pin-prick scores, but still well in the "substantial" range for all three scores (all ICCs>0.96, P<.01)	
Graves et al. (2006) Retrospective medical record analysis USA	N = 6,116 AIS motor scores 80% male 48% paraplegia	Separate UE/LE motor scores more accurately represented motor function than a single combined score : P<.0001 (82% in 1D model and 87% of variance in 2-D model)		
van Hedel et al. (2006) Longitudinal study	N = 22 (18M, 4F) Mean age = 45.5 years (range 17 – 78 years)	Spearman correlation of ASIA LEMS with other measures at various post-injury time:		

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European Multicenter Study of Human Spinal Cord Injury	Incomplete spinal cord injury patients who were able to stand or walk withIn the first month after SCI.	WISCI II: Within 1 month: 0.49 (P=0.02) After 3 months: 0.50 (P=0.02) After 6 months: 0.38 (P=0.08) After 12 months: 0.32 (P=0.15) 6 Minute Walk Test: Within 1 month: 0.54 (P=0.01) After 3 months: 0.34 (P=0.12) After 6 months: 0.49 (P=0.02) After 12 months: 0.55 (P<0.01) 10 Meter Walk Test: Within 1 month: -0.45 (P=0.04) After 3 months: -0.30 (P=0.18) After 6 months: -0.40 (P=0.06)		

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		After 12 months (P=0.07)		
Johnston et al. (2005) Cross-sectional survey New Jersey Outpatient SCI Center	N = 107 (88M, 19F) Mean age 39.1(11.16) Median age 38.0 Mean post-injury time: 11.36(9.56) yrs Median post-injury time: 8.71 yrs Community-living traumatic SCI individuals AIS-A/B/C/D: 56.4%/20.2%/14.9%/8.5% Neurologic Category: Tetraplegia complete: 38.7% Tetraplegia incomplete: 15.1% Paraplegia complete: 37.6%	Pearson's r btwn ASIA Motor Score and: CHART Total: 0.07 (P=0.54) CHART Physical Total: 0.46 (P=0.001) CHART Mobility Total: 0.04 (P=0.75) CHART Occupational Total: -0.11 (P=0.37) CHART Social Interaction Total: -0.22 (P=0.06) CHART Economic Total: -0.04 (P=0.72)		

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	Paraplegia incomplete: 8.6%			
Morganti et al. (2005) Retrospective analysis A large rehabilitation hospital in the center of Italy.	N = 284 patients (184M, 100F) Mean age: 50.4±19.3 years Mean (SD) time since SCI at admission to spinal unit: 56.9(43.9) days Concurrent validity sample: N=76 "Traumatic or non-traumatic SCLs admitted between 1997-2001. Non-traumatic etiology was present in the majority of the patients (177/284): inflammatory (40), vascular (36), neoplastic (39),	"The initial ASIA [impairment] grade was predictive of mobility outcome in WISCI" Correlation btwn ASIA LEMS and WISCI: For all patients (N=200): 0.58 (P<0.001) For WISCI lvls 1-19 only (N=63): 0.57 (P<0.001) For patients aged <50 (N=35): 0.50 (P<0.01) For patients aged >= 50 (N=28): 0.64 (P<0.01)		

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	degenerative (62); traumatic lesions (107/284): car accident (38), motorcycle accident (15), sport accident (7), act of violence (6), suicide attempts (6), and accidental falls (31)."	For traumatic SCI patients (N=37): 0.49 (P<0.01) For non-traumatic SCI patients (N=26): 0.58 (P<0.01)		
Catz et al. (2004) Development of instrument and preliminary comparative before-after study Spinal department in a rehabilitation hospital in Israel.	N = 79 (60M, 19F) Mean age 46±18 33 tetraplegia, 46 paraplegia AIS-A/B = 27, AIS-C/D = 52 41 traumatic, 38 nontraumatic SCI	Pearson's r btwn SCI-ARMI & AIS motor score: Admission to rehabilitation: 0.296 (p<0.01) During rehabilitation: -0.248 (p<0.16, nonsignificant) At rehabilitation completion: -0.123 (p<0.62, nonsignificant) Pearson's r btwn SCI-ARMI (regression-based score) &		

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		Time since rehabilitation admission: 0.46 ($p<0.01$) No significant correlation found btwn SCI-ARMI improvement and Patient age, gender, or spinal cord lesion level or severity ($p>0.05$)		
Fattal (2004) Metrological investigation Open study aimed at studying the feasibility and acceptability; Intermediate study aimed to assess inter-rater reproducibility.	Open Study: N = 33 (23 had undergone surgery) Intermediate Study: N=30 (10 had undergone surgery) (23M, 7F) Age: 32±13.3, (17-72 years) Prefinal Study: n=52 (41 male, 11 female)	Correlation between the ASIA and an instrument measuring the same construct: ASIA motor score & Motor Capacities Scale: r=0.744, P<.0001		

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Prefinal study focused on construct validity. Bouffard-Vercelli Centre, Cerbere, France	Age: 38.32±12.76, (18-72 years) Adults Complete motor tetraplegia Level of Injury: C5-C7 level AIS A or B, at least 3 months post spinal cord injury, at least 3 months post surgery			
Marino & Graves (2004) Secondary analysis of prospectively collected data Model Spinal Cord Injury Systems centers.	N = 4338 (3443M, 895F) People with traumatic SCI discharged between Jan. 1994 and Mar. 2003 Median age: 33 (IQR= 22~46) Median time from injury to rehab	R^2 =0.59 for total ASIA MS in predicting total FIM motor. R^2 = 0.71 for separate UE/LE ASIA scores in predicting total FIM (Functional Independence Measure) motor. R^2=0.44 for predicting FIM UE score with total ASIA MS		**Interpretability** Normative data (N=4338): Median ASIA Motor at discharge: 50 (IQR= 31~70) Median Upper Extremity Motor Score at discharge: 44 (IQR= 23~50)

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USA	admission: 15 (IQR= 9~28) days Median time in rehab: 46 (IQR= 29~73) days AIS-A/B/C/D: 2049/511/655/1123 Neurologic category: Complete tetraplegia: 854 Incomplete tetraplegia: 1464 Complete paraplegia: 1195 Incomplete paraplegia: 825	R^2=0.72 for predicting FIM LE score with separate UE/LE ASIA scores R^2=0.60 for predicting FIM LE score with total ASIA MS R^2=0.65 for predicting FIM UE score with separate UE/LE ASIA scores		Median Lower Extremity Motor Score at discharge: 0 (IQR= 0~30) **Flooring and ceiling effect** Upper Extremity Motor Score: 42% of subjects at ceiling (50) Lower Extremity Motor Score: 53% of subjects at floor (0)
Jonsson et al. (2000) Inter-rater reliability Dept PT and Neurology within	N = 23 (15M, 8F) Level of injury = 12 cerivcal, 6 thoracic, 25 lumbar Traumatic/non-traumatic=16/3		**Test-retest, Inter-rater, Intra-rater** Weak inter-rater reliability for 1992 version of AIS for incomplete SCI.	

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Inpatients at Rehab Med Hospital Sweden	Complete = 3 Incomplete = 20 SCI		Before/after standardization Kappa : PP (pin prick) scores 0.02-0.69 / 0.06-0.83 LT (light touch) scores 0.017-0.91 / 0.23-1 Motor scores 0.3-0.87 / 0.46-0.89 The majority of Kappas for PP were in the range of moderate and fair for most dermatomes. Similar for LT & MS (motor scores) except good–moderate. In general a standardizing assessment (i.e. training) involving all assessors (i.e. 4) improved level of agreement, except in classification of neurological level (Kappa 0.7-0.25).	
Cifu et al. (1999)	N = 375 SCI subjects			Please see Table 3 below.

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<tr><td>Block-design, matching sample study

Level I trauma centers 1998-1995 participating in the National Spinal Cord Injury Model Systems</td><td>Age group 1 (18-34): 85M, 15F

Age group 2 (35-64): 85M, 15F

Age group 3 (65+): 69M, 31F</td><td></td><td></td><td>Please see Table 4 below.</td></tr>
<tr><td></td><td colspan="4">Table 3
<table>
<tr><th colspan="5">Outcome Measures for Each Injury Group:</th></tr>
<tr><th></th><th>ASIA Motor Admission</th><th>ASIA Motor Discharge</th><th>FIM Motor Admission</th><th>FIM Motor Discharge</th></tr>
<tr><td>AIS A,B; C2-C4</td><td>4.85</td><td>16.90</td><td>13.20</td><td>23.50</td></tr>
<tr><td>AIS A,B; C5-C8</td><td>14.62</td><td>24.33</td><td>16.53</td><td>33.58</td></tr>
<tr><td>AIS C; C2-C4</td><td>25.08</td><td>57.21</td><td>15.55</td><td>48.58</td></tr>
<tr><td>AIS C; C5-C8</td><td>34.31</td><td>59.93</td><td>20.89</td><td>57.75</td></tr>
<tr><td>AIS D; C2-C4</td><td>63.12</td><td>78.07</td><td>33.63</td><td>73.62</td></tr>
<tr><td>AIS D; C5-C8</td><td>65.32</td><td>78.63</td><td>35.53</td><td>72.43</td></tr>
</table>
Table 4</td></tr>
</table>

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<tr><td></td><td>
<table>
<tr><td colspan="4">Discharge Scores by Age Category:</td></tr>
<tr><td></td><td>18-34yrs</td><td>35-64yrs</td><td>65+yrs</td></tr>
<tr><td>Admission</td><td></td><td></td><td></td></tr>
<tr><td>ASIA Motor</td><td>38.61</td><td>39.02</td><td>43.15</td></tr>
<tr><td>FIM Motor</td><td>25.01</td><td>25.80</td><td>22.82</td></tr>
<tr><td>FIM Cognitive</td><td>31.02</td><td>29.54</td><td>27.65</td></tr>
<tr><td>Discharge</td><td></td><td></td><td></td></tr>
<tr><td>ASIA Motor</td><td>57.67</td><td>57.52</td><td>56.56</td></tr>
<tr><td>FIM Motor</td><td>62.38</td><td>56.37</td><td>49.74</td></tr>
<tr><td>FIM Cognitive</td><td>33.86</td><td>32.54</td><td>29.86</td></tr>
</table>
</td><td></td><td></td><td></td></tr>
<tr><td>Fujiwara et al. (1999)

Cross-sectional

Subjects recruited from National Murayama Hospital (1995-1997)</td><td>N = 14 (12M, 2F)
C6 complete tetraplegic patients

Mean age: 30.7 (13~62)

Mean time since SCI: 462 (169~1080) days</td><td>Spearman’s rho btwn ASIA Motor Score with FIM Motor Score: 0.73 (p<0.01)
Spearman’s rho btwn ASIA Motor Score with FIM Transfer Score: 0.64 (p<0.01)</td><td></td><td></td></tr>
<tr><td>Cohen et al. (1998)

Pre-Post test</td><td>N = 106</td><td></td><td>Test-retest, Inter-rater, Intra-rater
Pre / Post % agreement</td><td></td></tr>
</table>

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Instructional course USA	SCI professionals assessing 2 case studies 39 physicians 31 PTs 15 OTs 15 nurses 6 other rehab professionals		Case 1: Neurological level 71-92 / 73-97 ZPP (zone of partial preservation): 91-95 / 90-93 Overall ASIA: 94 / 98 Complete injury: 96/100 Case 2: Neurological levels: 16-87 / 21-87 ZPP: 19-20 / 65/66 Overall ASIA: 58 /65 Incomplete injury: 95/97 Further revisions to 1992 and further training required.	
Curt et al. (1998) Correlation study on a prospective cohort	N = 70 Acute=36 M/F = 31/5	UE (upper extremity) ASIA MS (motor score) correlated with nonstandardized assessment of hand		**Interpretability** ASIA scores – mean (SD) – of acute and chronic patient groups with cervical SCI

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<tr><td>SCI center, university hospital.

Switzerland</td><td>Median age = 40.5y (17-77)

Chronic=34
M/F = 26/8

Median age = 32y (18-73)
Level of Injury SCI : C2-T1</td><td>function= 0.79 (acute), 0.83 (chronic)

LE (lower extremity) ASIA MS and nonstandardized ambulatory capacity=0.79 (acute), 0.78 (chronic)</td><td></td><td>Please see Table 5 below</td></tr>
<tr><td></td><td colspan="4">Table 5
<table><tr><th>ASIA scores</th><th>Acute SCI – Initial Examination</th><th>Acute SCI - Increment after 6 months</th><th>Chronic SCI</th></tr><tr><td>Motor (total)</td><td>39 (30.4)</td><td>18.4 (19.1)</td><td>44.8 (27.3)</td></tr><tr><td>Upper limb</td><td>23.6 (15)</td><td>8.1 (7.7)</td><td>28.4 (13.2)</td></tr><tr><td>Lower limb</td><td>15.4 (19.9)</td><td>10.3 (14.4)</td><td>14.4 (17.2)</td></tr><tr><td>Light touch</td><td>65.2 (33.4)</td><td>8 (16.8)</td><td>60.4 (34.9)</td></tr><tr><td>Pin prick</td><td>53.3 (36.2)</td><td>12.1 (21.4)</td><td>49.3 (34.9)</td></tr></table></td></tr>
<tr><td>Marino et al. (1998)

Cross-sectional Survey

Regional spinal cord injury center.</td><td>N = 154 tetraplegic patients

Avg. age = 37 years, injured for avg. of 8 years.</td><td>Correlation of ASIA UEMS with:

Capabilities of the Upper Extremity (CUE) Instrument:

Motor incomplete patients (N=49):</td><td></td><td></td></tr>
</table>

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	99% of subjects had neurological examinations within 2 years of completing study. AIS-A/B/C/D: 93/12/24/25	Pearson's r = 0.683, Spearman's ρ = 0.650 Motor complete patients (N=105): Pearson's r = 0.798, Spearman's ρ = 0.815 All patients (N=154): Pearson's r = 0.782, Spearman's ρ = 0.798 Functional Independence Measure (FIM): Motor incomplete patients (N=49): Pearson's r = 0.593, Spearman's ρ = 0.580 Motor complete patients (N=105): Pearson's r = 0.772, Spearman's ρ = 0.825		

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		All patients (N=154): Pearson's r = 0.741, Spearman's ρ = 0.803		
Yavuz et al. (1998) Cross-sectional Ankara Rehabilitation Center	N = 74, 51 male Mean age 49, SD=18 SCI patients <= 10 days post-injury at enrollment AIS at 1 month: A=18, B=12, C=10, D=34 69/74 traumatic SCI	Spearman correlation of ASIA & QIF (Quadriplegia index of function): ASIA motor: r=0.91 (P<.001) ASIA light touch: r=0.64 (P<.001) ASIA pinprick: r=0.65 (P<.01) Dressing: r=0.91 Transfers: r=0.82 Mobility: r=0.90 Bladder program: r=0.79 Bowel program: r=0.79 P<0.001 for the 5 above. Spearman correlation of ASIA & FIM: ASIA motor: r=0.91 (P<.001)		**Interpretability** Improvement of complete and incomplete quadriplegics according to ASIA: Please see Table 6 below.

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		ASIA light touch: r=0.58 (P<.01) ASIA pinprick: r=0.55 (P<.01) Dressing: r=0.80 Transfers: r=0.80 Mobility: r=0.86 Bladder program: r=0.77 Bowel program: r=0.74 P<.001 for the 5 above. The percent improvement indicated by the ASIA motor score correlated strongly with the per cent gain in QIF (r=0.68, P=.001) but did not exhibit such a significant correlation with gain in the FIM score (r=0.38, P<.05).		
	Table 6			

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<tr><td></td><td>
<table>
<tr><th></th><th>Test</th><th>Average score at admission</th><th>Average score at discharge</th></tr>
<tr><td rowspan="2">Complete quadriplegics</td><td>ASIA motor</td><td>21.1 (7.3)</td><td>24.8 (8.8)</td></tr>
<tr><td>ASIA light touch</td><td>30.5 (13.5)</td><td>37.5 (22.6)</td></tr>
<tr><td rowspan="2">Incomplete quadriplegics</td><td>ASIA motor</td><td>68.43 (16.3)</td><td>81.58 (11.8)</td></tr>
<tr><td>ASIA light touch</td><td>77.3 (20.9)</td><td>93.3 (21.6)</td></tr>
</table>
</td><td></td><td></td><td></td></tr>
<tr><td>Saboe et al. (1997)
Prospective longitudinal study

Tertiary care acute, rehabilitation hospitals and home settings.</td><td>N = 29 (20M, 9F)
Mean age 37yrs (range 14-66yrs)

C3-T1 tetraplegic (18 complete, 11 incomplete).
Consecutive patients of the Ankara Rehab Centre between May 1994 and January 1996.
Mean time since injury to admission 20wks (range 2-72wks).</td><td>Correlation coefficient btwn:

ASIA Motor score and ASIA Impairment at rehab admission: 0.74

ASIA Motor score and ASIA Impairment at rehab discharge: 0.74

ASIA Motor score at rehab admission and ASIA Impairment at rehab discharge: 0.55

ASIA Motor score at rehab discharge and ASIA Impairment at rehab admission: 0.78</td><td></td><td></td></tr>
</table>

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		FIM score 2 years after SCI onset and: ASIA Motor Score at rehab admission: 0.68 ASIA Motor Score at rehab discharge: 0.80 ASIA Impairment at rehab admission: 0.50 ASIA Impairment at rehab discharge: 0.53		
El Masry et al. (1996) Longitudinal Spinal Injuries center and Dept of Orthopaedic surgery in Orthopaedic District hospitals	N = 62 (48M, 14F) consecutive adult patients admitted within 7 days of acute SCI (04/83-09/92) Mean age=34.1y(16-76) at time of injury Follow-up=40.6m (1-119) SCI	**Correlation Coefficient** R=0.954-0.996 for MDP (motor deficit percentage) /MRP (motor recovery percentage): CMSvs ASIA/NASCIS. All correlations high between CMS and NASCIS or ASIA		

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	C+T=38, L=12, below L1=12			