Reliability and Validity of the Functional Gait Assessment in Incomplete Spinal Cord Injury

Jennifer H. Kahn, DPT,¹ April Ohlendorf, DPT,¹ Alison Olsen, DPT,¹ and Keith E. Gordon, PhD¹

¹Physical Therapy and Human Movement Sciences, Northwestern University Feinberg School of Medicine, Chicago, Illinois

Background: There are limited psychometrically sound measures to assess higher level balance in individuals with incomplete spinal cord injury (iSCI). **Objectives:** To evaluate interrater and intrarater reliability and convergent validity of the Functional Gait Assessment (FGA) in individuals with iSCI. **Methods:** Twelve participants (11 male, 1 female) 32 to 73 years old with chronic motor iSCI, American Spinal Injury Association Impairment Scale C ($n = 2$) or D ($n = 10$), were included. Participants completed five outcome measures during a single test session including lower extremity motor scores from the International Standards for the Neurological Classification of Spinal Cord Injury, FGA, 10-Meter Walk Test (10MWT), Walking Index for Spinal Cord Injury (WISCI-II), and the Spinal Cord Injury Functional Ambulation Profile (SCI-FAP). **Results:** Inter- and intrarater reliability for the FGA were excellent. Interrater reliability was excellent with intraclass correlation coefficient (ICC) scores greater than 0.92 ($p < .001$). Interrater reliability against an expert was also excellent for all raters, with an ICC greater than or equal to 0.92 ($p < .01$). Intrarater reliability was excellent with an ICC score of greater than 0.91 ($p < .002$) for all raters. Validity of the FGA with 10MWT was -0.90 ($p = .000$), FGA with WISCI-II was 0.74 ($p = .006$), and FGA with SCI-FAP was -0.83 ($p = .001$). **Conclusion:** The FGA is a reliable and valid outcome measure to use when assessing gait and balance in individuals with motor iSCI. The FGA provides clinicians with a single tool to utilize across a variety of neurologic diagnoses. **Key words:** functional gait assessment, incomplete spinal cord injury, reliability, validity

Background

Over half of all spinal cord injuries (SCIs) are classified as motor incomplete,¹ indicating spared sensory and/or motor function below the neurologic level of injury (American Spinal Injury Association Impairment Scale [AIS] C or D).² Given the neurologic damage that occurs following an incomplete SCI (iSCI), these individuals are at risk for balance impairments and falls.^{3,4} Balance impairments contribute significantly to gait dysfunction after iSCI.⁵ Assessing dynamic balance, the ability to anticipate and respond to perturbations during movement in order to maintain a dynamic equilibrium,⁶ during gait is vital for understanding balance impairments and fall risk and identifying areas of therapeutic intervention.

Expert consensus recommendations for use of outcome measures (OMs) in individuals with iSCI have identified a lack of psychometrically sound measures to assess higher level balance in individuals with iSCI.⁷ For example, the Berg Balance Scale (BBS) is a widely accepted measure of standing balance, but it has been found to have ceiling effects in individuals with AIS D.⁸ Even with maximal scores on the BBS, higher functioning

individuals continue to have functional balance impairments during gait-related tasks that are not captured by the measure.⁸ The Spinal Cord Injury Functional Ambulation Profile (SCI-FAP), a measure that includes a variety of walking tasks that require dynamic balance (e.g., walking on different surfaces, carrying objects, stepping over obstacles), was developed to assess functional walking in ambulatory individuals with iSCI.⁹ However, administration of this population-specific measure may be undesirable for clinicians working in settings that serve patients with a variety of neurologic diagnoses and impairments. In these clinical settings, it is advantageous and efficient to have standardized measurement tools with strong psychometric properties for use across neurologic populations.¹⁰ There have been recent efforts to address this issue. Investigators have found both the Mini Balance Evaluation Systems Test (Mini-BESTest)^{11,12} and the Community Balance and Mobility Scale (CB&M)¹³ to be valid measures of balance in high-functioning individuals with iSCI. The current investigation aims to further expand the tools available that both assess gait-related balance and span neurologic populations including iSCI.

Corresponding author: Jennifer H. Kahn, DPT, Physical Therapy and Human Movement Sciences, Northwestern University Feinberg School of Medicine, 645 N Michigan Avenue, Suite 1100, Chicago, IL 60611; phone: 312-908-8239; email: jennifer-kahn@northwestern.edu

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A recent clinical practice guideline recommends the Functional Gait Assessment (FGA) as a core OM to be implemented across neurologic populations.¹⁰ The FGA, modified from the Dynamic Gait Index,¹⁴ is a widely used measure to assess postural stability and balance during various walking tasks. The FGA includes 10 gait-related activities: gait on level surface, change in gait speed, gait with horizontal and vertical head turns, gait and pivot turn, step over an obstacle, gait with narrow base of support, gait with eyes closed, backwards gait, and steps.¹⁴ The FGA has good clinical utility with minimal financial cost and is easy to administer in clinical settings. The FGA has been validated in a variety of patient populations with neurologic diagnoses including stroke,¹² Parkinson's disease,¹³ and vestibular disorders.¹¹ Although the FGA is potentially useful for understanding balance and gait impairments in individuals with iSCI, this measure has not been validated for the iSCI population. Clinical practice guidelines, combined with the consensus recommendations,⁶ suggest the FGA could be used successfully to evaluate balance deficits in the iSCI population.¹⁰ Thus, seeking validation of the FGA in the iSCI population may provide a clinically feasible measure that can accurately and reliably quantify deficits in balance during walking.^{9,10}

Research is beginning to address the need to establish objective measures for higher level balance impairments in the iSCI population that will assist in determining baseline function, progress, and treatment efficacy. Therefore, the purpose of this study is to establish interrater and intrarater reliability and convergent validity of the FGA in individuals with iSCI. Establishing psychometric properties of the FGA will facilitate the clinical use of this measure to assist clinicians in developing an intervention plan addressing functional ambulation and fall prevention for patients with iSCI.

Methods

The study was approved by the institutional review board of Northwestern University, and all participants provided written informed consent.

Participants

Inclusion criteria consisted of individuals with iSCI classified as AIS C or D, at least 6 months post

injury, at least 18 years of age, able to ambulate 10 meters with or without an assistive device, and able to follow testing instructions. Participants were excluded if they had other neurologic impairments affecting balance, significant musculoskeletal injuries, or other medical conditions that might limit participation in physical activity. Participants were recruited from a non-public registry of individuals with SCI. Selection of a sample size was guided by previous reliability and validity studies¹⁴⁻¹⁷ as well as published guidelines for determining sample size for estimating intraclass correlation coefficients.¹⁸

Raters

Data were collected by student physical therapists under the supervision of a licensed expert physical therapist with 16 years of experience in neurologic physical therapy and 9 years of experience as a board-certified neurologic clinical specialist. Prior to beginning the data collection period, students were trained by the expert physical therapist on standardized administration of the FGA and additional OMs used for validation. Two groups each composed of three student researchers performed the battery of tests in one session under the supervision of the expert physical therapist. Within a team, one student was the primary rater and administered and scored all the tests, another student scored only the FGA trials, and the third student researcher guarded the participant to ensure safety throughout the session. Each student group scored six participants for a total of 12 participants. Additionally, the expert physical therapist scored the FGA in eight of the participants to establish reliability of the student physical therapists against the expert. In summary, two student raters scored each participant's FGA, and a third expert rater scored four of the participant's FGA. To maintain anonymity of the results, raters did not review or discuss scoring of the tests within research teams. Scores were only viewed after all data collection had been completed.

Outcome measures

The International Standards for the Neurologic Classification of Spinal Cord Injury Lower Extremity Motor Scores (LEMS)² was collected for baseline characteristics of all participants and to

assist in determining classification as AIS C or D. The FGA includes balance- and gait-related tasks; so to establish convergent validity, three outcome measures previously shown to be reliable and valid in the SCI population were selected that covered both constructs of balance and gait. These measures were the 10-Meter Walk Test (10MWT),¹⁹ the Walking Index for Spinal Cord Injury II (WISCI II),^{19,20,21} and the SCI-FAP.⁹ The 10MWT and the WISCI II are considered the most useful walking measures for individuals with iSCI, and the WISCI II has been utilized to validate other gait measures in iSCI.^{19,22} Both provide valuable information regarding walking speed and general ambulation ability over smooth, flat ground. However, neither OM addresses dynamic balance-related walking tasks. Although the SCI-FAP was developed to assess functional walking, the tasks require dynamic balance, and therefore the SCI-FAP was also included to establish validity.⁹

Protocol

Participants completed the following outcome measures during a single test session in this standardized order: LEMS, FGA trial 1, 10MWT, WISCI-II, SCI-FAP, and FGA trial 2. The two FGA trials were separated by a standardized time of 45 minutes. No discussion of scoring among the research team was permitted during or after testing sessions.

Analysis

All data analyses were performed using SPSS version 25 (IBM Corp., Armonk, New York). Interrater and intrarater reliability were calculated using the interclass correlation coefficient (ICC). Ranking of intrarater and interrater was established as follows: >0.75, excellent; 0.40-0.74, adequate; <0.40, poor.^{23,24} Interrater reliability of the FGA was calculated between raters within each group as well as between each rater and the expert for a portion of the participants. Intrarater reliability of the FGA was calculated between FGA trial 1 and FGA trial 2 for the four individual raters. If reliability was determined to be excellent for all four raters, the primary raters' (those who scored the full test battery) data would be combined to determine

validity. Convergent validity was calculated by Spearman's rho (r). Correlations to establish validity were calculated between the FGA trial 1 total scores and the 10MWT, WISCI-II, and SCI-FAP with >0.6 considered excellent, 0.31-0.59 adequate, and <0.30 poor.^{23,24}

Results

Participants

Twelve participants (11 male, 1 female) 32 to 73 years old (55.41 ± 11.65 years) with chronic motor iSCI (2 AIS C, 10 AIS D) and 1.7 to 29.7 years post injury (7.8 ± 7.8) completed the study. **Table 1** summarizes the baseline characteristics of the participants. No participants dropped out during testing, and all completed the entire battery of tests.

Table 1. Demographic characteristics of participants

Participant ID	Sex	Age	Years since injury	Level of SCI	AIS
1	F	56	15.08	thoracic	D
2	M	51	4.88	thoracic	C
3	M	45	3.34	cervical	C
4	M	50	1.74	cervical	D
5	M	73	3.56	cervical	D
6	M	54	8.51	cervical	D
7	M	57	7.25	cervical	D
8	M	69	6.97	thoracic	D
9	M	72	5.27	thoracic	D
10	M	54	2.08	thoracic	D
11	M	32	5.49	cervical	D
12	M	52	29.68	cervical	D

Note: AIS = American Spinal Injury Association Impairment Scale; F = female; M = male.

Outcome measures

As intended, participants in this study were high functioning as demonstrated by mean values for the 10MWT (0.85 m/s), WISCI II (17.3), SCI-FAP (44.79), and LEMS (40.83). Detailed results of each outcome measure for each participant are presented in **Table 2**.

Table 2. Scores for each participant on the outcome measures collected and average scores across participants

Participant ID	10 MWT (m/s)	WISCI-II	SCI-FAP	LEMS Total
1	0.92	20	31.29	42
2	0.84	18	15.2	32
3	0.56	12	100.05	25
4	1.21	20	8.54	49
5	0.99	20	9.21	48
6	0.54	19	71.02	36
7	0.48	16	73.93	47
8	1.03	20	11.62	49
9	0.41	9	126.41	35
10	1.01	16	38.36	46
11	1.37	20	7.1	50
12	0.73	19	75.68	31
Average	0.85	17.3	44.79	40.83
SD	0.32	3.7	41.77	8.62

Note: LEMS = lower extremity motor scores; 10MWT = Ten Meter Walk Test; SCI-FAP = Spinal Cord Injury Functional Ambulation Profile; WISCI-II = Walking Index for Spinal Cord Injury II.

FGA reliability

Intrarater reliability was excellent for all four raters between FGA trial 1 and trial 2 with an ICC greater than or equal to 0.91 ($p < .01$). Interrater reliability for both groups was excellent with an ICC greater than or equal to 0.92 ($p < .001$). The student physical therapists' interrater reliability against the expert was excellent for all four raters with an ICC greater than or equal to 0.92 ($p < .01$). Reliability data are presented in **Table 3**.

Validity of FGA

As reliability was determined to be excellent for all four raters, the primary raters' (those who scored the full test battery) data were then used to determine validity. Convergent validity for the FGA with the 10MWT, WISCI-II, and SCI-FAP (**Figure 1**) was excellent. Validity of the FGA with 10MWT

Table 3. Intrarater and interrater reliability results including intraclass correlation coefficient (ICC) and confidence intervals (CI)

Intrarater reliability	ICC	<i>p</i>	95% CI lower bound	95% CI upper bound
Rater 1	0.971	0.000	0.812	0.996
Rater 2	0.912	0.002	0.504	0.987
Rater 3	0.956	0.000	0.722	0.994
Rater 4	0.975	0.000	0.832	0.996
Interrater reliability				
Rater 1 and 2	0.976	0.000	0.838	0.997
Rater 3 and 4	0.925	0.001	0.564	0.989
Interrater reliability-expert				
Rater 1	0.921	0.013	0.225	0.995
Rater 2	0.946	0.007	0.401	0.996
Rater 3	0.920	0.013	0.218	0.995
Rater 4	0.978	0.005	0.488	0.997

was 0.90 ($p = .000$), FGA with WISCI-II was 0.74 ($p = .006$), and FGA with SCI-FAP was -0.83 ($p = .001$).

Discussion

The aim of this study was to investigate the reliability and validity of the FGA in individuals with motor iSCI. The results demonstrate the FGA has excellent interrater reliability, excellent intrarater reliability, and excellent convergent validity with the 10MWT, WISCI-II, and SCI-FAP, measures previously validated for ambulatory individuals with iSCI. This study demonstrates that the FGA is a reliable and valid OM that can be used in assessing gait-related balance deficits in individuals with iSCI.

The FGA can be completed quickly with minimal training by both physical therapists and student physical therapists in the clinic. After only a few practice test administrations prior to study initiation, student physical therapists were shown to have excellent reliability when compared to an expert rater. A previous study involving test administration by physical therapy students found

Figure 1a.

Figure 1b.

Figure 1c.

Figure 1. Correlation of the Functional Gait Assessment (FGA) with the (a) 10-Meter Walk Test (10MWT), $\rho = 0.90$, $p = .000$; (b) Walking Index for Spinal Cord Injury II (WISCI-II), $\rho = 0.74$, $p = .006$; (c) Spinal Cord Injury Functional Ambulation Profile (SCIFAP), $\rho = -0.83$, $p = .001$.

similar reliability results.¹⁵ Together, these results support that the FGA can be utilized in the clinic by both experienced and novice clinicians with similar outcomes. Student therapists were able to accurately perform these estimations in real time and with consistency between raters.

Various measures of balance have already been validated for use in the iSCI population, but many of them have limitations in their clinical application. For example, both the WISCI-II and BBS show ceiling effects in individuals with AIS D.⁸ The WISCI-II is a classification system focused on amount of assist required and assistive devices and does not address balance during a variety of functional walking tasks. The BBS does not incorporate ambulation-related balance tasks. Therefore both measures are limited in assessing the construct of gait-related balance.

Most falls in the iSCI population occur while ambulating, and the BBS does not capture this important aspect of dynamic balance.^{25,26} In contrast, the SCI-FAP is a gait-related balance test specifically for individuals with iSCI; however, the test requires increased time to administer and specific standardized equipment.²⁷ The SCI-FAP also utilizes a complex weighted scoring system to emphasize the impact of time and assistance required, resulting in a wide range of possible final scores.²⁷ This may create confusion during final score analysis and limit its clinical utility for goal setting as well as ability to provide timely feedback and education to patients. Though there is benefit to using a measure that includes a specific population's daily balance-related tasks, it requires clinicians to learn and use different measures when treating different neurologic diagnoses. Recent work has established psychometric properties of the Mini-BESTest and CB&M.¹¹⁻¹³ When compared to the BBS, the Mini-BESTest did not show a ceiling effect.¹² The CB&M includes tasks such as running and hopping that may be appropriate to assess when the FGA is no longer able to capture balance impairments. Even though these tests may be useful in individuals with iSCI, they are not included in the core set of outcomes recommended across neurologic populations due to less robust literature on these measures.¹⁰ The FGA can be administered and scored quickly without need for specialized

equipment. Establishing the psychometric properties of the FGA in iSCI further supports the current recommendation for a core set of clinical outcome measures across neurologic populations that includes the FGA.¹⁰ In following these recommendations, clinicians should utilize the FGA across neurologic patient populations, overall improving their efficiency with test administration as well as scoring, goal setting, and developing a plan of care.¹⁰

Study limitations

To ensure standardization of the FGA during testing and the same view of the participant when scoring, the raters only role was to instruct the participant on the task and score the test. A different researcher had the role of guarding the participant. In a clinical setting, often the clinician guarding the individual with iSCI is also scoring the test. Therefore, the research process may differ from true clinical application.

The sample size of the current study may limit the generalizability of the results. The original validation of the FGA had a similar sample,¹⁴ however additional studies validating the FGA had larger sample sizes, though similar results.¹⁵⁻¹⁷

Despite the limited sample size, our current findings were robust with high ICCs and low *p* values.

Future research should include establishing data on responsiveness to help interpretation of change in scores in the FGA in the iSCI population as well as aim to establish cutoff scores for fall risk in iSCI.

Conclusion

The FGA shows excellent inter- and intrarater reliability and convergent validity in the iSCI population. The FGA is a reliable and valid outcome measure for assessing gait and balance deficits. The FGA can provide clinicians with a single efficient tool to use across a variety of neurologic diagnoses.

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Conflicts of Interest

The authors report no conflicts of interest.

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