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Libak Abou & Laura A. Rice

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RESEARCH REPORT

Functional balance assessment for predicting future recurrent falls in non-ambulatory individuals with spinal cord injury: a prospective pilot study

Libak Abou MPT, PT, PhD[a] and Laura A. Rice MPT, ATP, PhD[b,c]

[a]Department of Physical Medicine and Rehabilitation, Michigan Medicine, University of Michigan, Ann Arbor, MI, USA; [b]Department of Kinesiology and Community Health, College of Applied Health Sciences, University of Illinois at Urbana-Champaign, Urbana, IL, USA; [c]Center for Health, Aging and Disability, College of Applied Health Sciences, University of Illinois at Urbana-Champaign, Champaign, IL, USA

ABSTRACT

Background: Functional assessments easy to administer within the clinic to identify non-ambulatory individuals with spinal cord injury at risk of recurrent falls are needed.
Purpose: To examine the ability of functional balance and transfer quality to predict recurrent falls.
Methods: This 6-month prospective study examined remote assessments of transfer quality using the Transfer Assessment Instrument and functional sitting balance with the Function in Sitting Test and the Trunk Control Test. Then, participants prospectively monitored their falls for 6-month using fall diaries. Frequency of falls was categorized as infrequent fallers (≤2 falls) and recurrent fallers (>2 falls). A multivariable logistic regression analysis was conducted. A Receiver Operating Characteristic curve was performed to determine the area under the curve, the sensitivity, and the specificity of the model.
Results: Eighteen non-ambulatory individuals (mean age = 44 ± 16 years, mean time since injury = 7.8 ± 32.6 years) participated in the study. Poor balance (lower Function in Sitting Test score) was associated with higher odds of future recurrent falls (Odds Ratio = 0.70, 95% CI, 0.48 to 1.00, p = 0.05), area under the receiving operating curve = 0.87, sensitivity = 88%, and specificity = 70%.
Conclusions: A comprehensive sitting balance assessment that includes the static, proactive, and reactive components of balance with the integration of sensorial functions as evaluated within the Function in Sitting Test may be useful for predicting recurrent falls among non-ambulatory individuals with spinal cord injury. Replication of the findings in a larger sample is warranted.

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Introduction

More than 60% of non-ambulatory individuals with spinal cord injury (SCI) experience at least one fall during a period of 6–12 months (Abou and Rice, 2022b; Khan et al., 2019). Falling may lead to various severe consequences including: physical injuries (i.e. fractures and head concussion) (Abou and Rice, 2022b; Khan et al., 2019); hospitalizations (Kirby et al., 1994); fear of falling (Abou and Rice, 2022b); limited activity performance (Abou and Rice, 2022b); and reduced quality of life (Gavin-Dreschnack et al., 2005). According to the Center for Disease Control and Prevention (CDC), age-adjusted fall death rates among elderly adults, both ambulatory and those who use a wheelchair in the United States increased 41% from 2012 to 2021 (Center for Disease Control and Prevention, 2021). Furthermore, estimates from the CDC indicate that if rates continue to rise, 7 fall deaths are expected every hour by 2030 (Center for Disease Control and Prevention, 2021). Therefore, falls have been identified as a public health concern and warrant the attention of researchers, clinicians, and policymakers.

The identification and understanding of the risk factors associated with falls are the first steps toward the development of effective fall prevention programs. Also, it is important to identify individuals who are at high risk of falls and refer them to appropriate fall prevention programs. Among people with SCI, most studies that examined predictors of future falls have focused on ambulatory individuals, and full-time wheelchair users (non-ambulatory individuals) have been generally excluded or understudied (Abou, Ilha, Romanini, and Rice, 2019; Butler Forslund et al., 2019; Musselman et al., 2021; Srisim, Saengsuwan, and Amatachaya, 2015). Moreover, most studies have focused on the analysis of a single fall and the analysis of recurrent falls (>2 falls) has been understudied in people with SCI. Falls occurring in isolation often occur due to an extrinsic factor (i.e. equipment failure), whereas recurrent falls are often attributed to intrinsic factors (i.e.

CONTACT Libak Abou abouliba@med.umich.edu Department of Physical Medicine and Rehabilitation, Michigan Medicine, University of Michigan, Bldg. 16, Ann Arbor, MI 48109, USA

poor balance, spasticity, fatigue, cognitive impairment) (Beauchet et al., 2008). Intrinsic factors can be evaluated using commonly available clinical outcome measures targeting balance performance, mobility, transferring ability, or motor-cognitive interference. Additionally, recurrent falls have been associated with more injuries among individuals with SCI (Jørgensen et al., 2017). Therefore, determining which clinical assessment that comprehensively evaluates an intrinsic factor associated with a high risk of falls is essential to determine those who are at high of recurrent falls.

To the best of our knowledge, the literature indicates that few studies had previously evaluated predictors of future falls among wheelchair users with SCI in the community (Butler Forslund et al., 2017, 2019; Nelson et al., 2010). Nelson et al. (2010) identified pain in the previous 2 months, alcohol abuse, greater motor function, history of previous falls, fewer SCI years, and shorter length of wheelchair as predictors of a single fall. Butler Forslund et al. (2019) indicated that history of previous falls was associated with increased hazard ratio of future falls. Meanwhile, Butler Forslund et al. (2017) were the only team to examine predictors of future recurrent falls among wheelchair users with SCI. Despite the bivariate associations between mobility subscore of the Spinal Cord Independence Measure (SCIM III), history of previous recurrent falls, and working or studying reported by authors, history of previous recurrent falls was the only final significant predictor of future recurrent falls found in this population (Butler Forslund et al., 2017). Although history of falls is a quick and effective clinical indicator of future recurrent, supplementing this question with an objective clinical assessment would provide a more comprehensive information and may help guide interventions. In this context, Jørgensen et al. (2016) indicated that age, sex, and SCIM III mobility score were significant predictors of recurrent falls collected retrospectively in this population. SCIM III mobility score appeared to be the only clinical physical evaluation with the ability to predict retrospective recurrent falls. However, the mobility subscore of the SCIM III include items such as moving around outdoors more than 100 m or transfers from wheelchair into the car that are not always appreciable in clinical settings (Fekete et al., 2013). In addition, the mobility subscore of the SCIM III is generally self-reported and the clinical judgment of clinicians is not always taken into consideration with this measure (Fekete et al., 2013). Therefore, an objective and quantitative clinical assessment, such as the assessment of sitting balance or transfer quality, that can be appreciated in clinical settings may a complementary indicator of real risk for future recurrent falls to history of previous falls. This may be necessary to inform clinicians about those wheelchair users with SCI who need to be referred to falls prevention programs. Hence, the aim of this study was to examine the ability of functional assessments such as sitting balance and transfer quality to predict future recurrent falls among wheelchair users with SCI. We hypothesized that a functional sitting balance assessment would be a significant predictor of future recurrent falls among wheelchair users with SCI. The hypothesis was based on the rationale that the ability to maintain sitting balance is critical for wheelchair users with SCI to perform all dynamic daily living activities (Anderson, 2004; Chen et al., 2003). In addition, trunk weakness and poor sitting balance are the most common biological factors associated with falls self-reported by individuals with SCI (Khan et al., 2019).

Methods

Study design

This is a prospective cohort study of wheelchair users with SCI from either traumatic causes or non-progressive diseases at a chronic stage of injury (≥12 months). The study is part of the Fall Prediction (Predi_FALL) study aiming at identifying factors associated with falls among wheelchair users with SCI (Abou and Rice, 2022c). The procedures of the study were approved by the Institutional Review Boards at the University of Illinois at Urbana-Champaign (#20718). The Transparent Reporting for Individual Prognosis Or Diagnosis (TRIPOD) statement was used to report the findings presented in this study. Recruitment and participant assessment were conducted remotely between January 2021 and July 2021. All participants provided electronic informed consent before engaging in the study.

Participants

A convenience sample of wheelchair users with SCI were recruited to participate in the study. Full recruitment details were presented in another study (Abou and Rice, 2022c). Briefly, participants were recruited from SCI support groups across the United States, Facebook posts, personal communications, and magazine or newsletter advertisements. All participants met the following inclusion criteria: 1) adults (≥18 years old) with a chronic SCI for at least 12 months; 2) level of injury between C5 and above L5; 3) Self-report use of a wheelchair full time for mobility activities; 4) able to communicate with the research team through an electronic video conferencing software using a smartphone or laptop; and 5) able to understand English. Potential participants were excluded if they presented with any additional medical conditions that might affect their ability to perform the functional tests (i.e. upper limb or shoulder injury limiting performance of activities).

Study overview

Because of the restrictions placed on human research due to COVID-19 pandemic during data collection, all testing procedures were performed remotely. After signing the informed consent, participants completed a demographic survey including age, sex, years since injury, height, weight, and level of injury and information on number of falls experienced in the previous 6 months, if any. The informed consent, demographics, and history of falls were collected via the Research Electronic Data Capture (REDCap) survey platform. After completion of the online surveys, participants and a researcher met over a video call using Zoom (San Jose, CA) to perform sitting balance and transfer quality assessments. Participants were assisted during the tests by a family member, caregiver, or friend under the guidance of the remote researcher. The remote testing was conducted by a Physical Therapist with 6 years of experience conducting balance assessments in individuals with SCI. Before the assessment day, a paper ruler and a paper goniometer needed for the assessment of transfer quality were sent to participants' home through the mail. Further details about the remote sitting balance and transfer quality assessments can be found in previous studies (Abou et al., 2023; Abou, Rice, Frechette, and Sosnoff, 2021; Worobey et al., 2022). Briefly, on the assessment day, a Zoom video conference call was set up. Each participant had their own, unique meeting code and were required to enter a password to enter the meeting. The screen sharing was then disabled and the meeting was locked so that no one else could join. Only the participant, an assistant to the participant (family member, caregiver etc.), and the researcher were allowed to participate in the remote assessment. Participants were asked to show the assessment surface such as a bed, sofa, or bench without a backrest where they could sit on and perform the remote testing. Depending on the position of the assessment surface, instructions were given to the participants and their assistants on how to position their web camera to maximize the researcher's view during the assessments. Participants were then asked to transfer from their wheelchair to the assessment surface. At this point, the transfer quality assessment was performed using the Transfer Assessment Instrument (TAI). With the verbal guidance from the researcher, participants and their assistants were instructed on the correct placement of the paper ruler to measure the distance from the front corner of their wheelchair to the closest point of the assessment surface (item #1 on the TAI) (Abou et al., 2023). Similarly, the paper goniometer was used by the participants and their assistants to measure the angle between their wheelchair and the assessment surface (item #2 on the TAI) (Abou et al., 2023). Participants were asked to read aloud the distance and angle measured. Next, participants were asked to transfer as they normally would in their daily routines. The TAI as described below was then scored by the researcher.

After participants successfully transferred and sat on the assessment surface, their posture was verbally corrected by the researcher to maintain their hips and knees flexed at approximately 90° (Abou, Rice, Frechette, and Sosnoff, 2021). A step/stool or any other solid object found in participants' home was used for positioning and foot support when needed. The researcher once again provided feedback on the positioning of the camera and necessary adjustments so the participants full body was in frame. Participants were asked to position their web camera lateral to their sitting position for the remote balance assessments. General instructions were then given to participants about safety procedures of the remote sitting balance assessments. To minimize the risk of falling during the assessment, participants' assistants were asked to remain as close as possible to participants during the entire assessment (Abou, Rice, Frechette, and Sosnoff, 2021). Participants sitting balance and transfer quality were evaluated according to the measures described below.

Independent variables

Function in sitting test (FIST)

The FIST is a functional sitting balance assessment that aims to examine the ability of participants to maintain their sitting balance while performing several daily living activities such as sitting without support eyes closed and open, reaching for an object, and scooting (Abou, Sung, Sosnoff, and Rice, 2020; Palermo, Cahalin, Garcia, and Nash, 2020). The FIST assesses the static, dynamic, and reactive components of sitting balance with the integration of sensorial function assessments (i.e. eyes open and eyes closed) (Abou, Sung, Sosnoff, and Rice, 2020; Palermo, Cahalin, Garcia, and Nash, 2020). The FIST was found to be reliable with partially established validity to assess sitting balance among wheelchair users with SCI (Abou, Sung, Sosnoff, and Rice, 2020; Palermo, Cahalin, Garcia, and Nash, 2020). Preliminary findings indicate that the FIST was also found to be valid and reliable to be used remotely (Abou, Rice, Frechette, and Sosnoff, 2021). Intraclass Coefficient Correlation (ICC) between in-person and remote assessment with the FIST was found to be 0.98 with very high agreement on the Bland-Altman plot (Abou, Rice, Frechette, and Sosnoff, 2021). Total FIST scores range from 0 to 56 with higher scores indicating better balance performance (Abou, Sung, Sosnoff, and Rice, 2020; Palermo, Cahalin, Garcia, and Nash, 2020).

Trunk control test (TCT)

The TCT is also a functional sitting balance assessment that measures the static and dynamic balance control while performing 13 functional tasks including maintaining a sitting position for 10 seconds, touching the feet, rolling, and reaching activities (Quinzaños, Villa, Flores, and Pérez, 2014). The TCT has been validated and recommended for use to assess sitting balance among people with SCI (Abou, de Freitas, Palandi, and Ilha, 2018; Quinzaños, Villa, Flores, and Pérez, 2014). The preliminary validity and reliability of the remote assessment using the TCT is fully described elsewhere (Abou, Rice, Frechette, and Sosnoff, 2021). Intraclass Coefficient Correlation (ICC) between in-person and remote assessment with the TCT was found to be 0.982 with very high agreement on the Bland-Altman plot (Abou, Rice, Frechette, and Sosnoff, 2021). Total TCT scores vary from 0 to 24 with higher scores indicating better balance performance (Quinzaños, Villa, Flores, and Pérez, 2014).

Transfer assessment instrument (TAI 4.0)

The TAI 4.0 is a measure of transfer quality comprised of 18 items categorized into 3 phases: wheelchair set-up, body set-up, and flight/landing (Worobey et al., 2018). The in-person and remote TAI 4.0 were found to be valid and reliable among wheelchair users with SCI (Worobey et al., 2018, 2022). The full description of TAI scoring is available elsewhere (Worobey et al., 2018). Briefly, each item receives a score of 0 or 1 indicating low or high quality, respectively. Partial credit (0.5) or not applicable answer options are allowed for some items. All item are summed together, multiplied by 10, and averaged, resulting in a score varying from 0 to 10 points (Worobey et al., 2018). Higher TAI scores indicate better transfer quality (Worobey et al., 2018). ICC for interrater reliability of home-based assessment of the total TAI score used in this study was found to range between 0.57 and 0.90 and ICC for intrarater reliability was found to be 0.90 (Abou et al., 2023).

Dependent variables: Fall frequency

After completing the surveys and functional tests at baseline, participants received falls diaries to monitor their falls for a 6-month period. Participants were provided with postage paid, self-addressed envelopes, and paper-based fall diaries to be returned to the research team monthly. Fall tracking using fall diaries has been recommended by the International Multiple Sclerosis Fall Prevention Research Network (Coote, Sosnoff, and Gunn, 2014). Instructions were given to participants to mark an X on any date when they experienced a fall and provide a short description and location of the fall. To ensure compliance with fall monitoring, a trained research assistant contacted participants through phone calls every 2 weeks to remind them to collect the fall data and mail their diaries to the research team. A fall was defined as "an unexpected event in which an individual comes to rest on the ground, floor, or other lower level" (Lamb, Jørstad-Stein, Hauer, and Becker, 2005). The findings after 6 months falls tracking were used to classify participants into infrequent fallers (0 to 2 falls) and recurrent fallers (>2 falls) (Jørgensen et al., 2016; Lord, Allen, Williams, and Gandevia, 2002).

Statistical analyses

Data were coded and analyzed using IBM-SPSS Statistics version 28 (SPSS Inc. Chicago, IL, USA). Counts and frequencies were used to describe the categorical variables. Due to the relatively small sample size, Mann-Whitney U tests were used to investigate the differences in continuous variables between infrequent fallers and recurrent fallers. The differences between categorical variables were examined using Chi-square or Fisher exact tests (<5 counts).

Independent variables including functional assessments with the FIST, TCT, and TAI were entered into a multivariable logistic regression analysis using a "backward stepwise" mode. A backward stepwise method because it removes early on in the regression model the least important variables (Chowdhury and Turin, 2020). A p value ≤ 0.05 was used to determine significant predictors of recurrent falls in the regression model due to the small sample size (Fisher, 1950). Assumptions of logistic regression analysis (i.e. significant outliers, multicollinearity of independent variables, and linearity) were examined before model-building. Goodness-of-fit of the model was assessed using the Hosmer and Lemeshow test and the Nagelkerke R^2. A Hosmer and Lemeshow test >0.05 indicates that the data fits the model and the Nagelkerke R^2 informs about the explanatory power of the model. Results of the regression analysis were presented as Odds Ratios (OR) and 95% confidence intervals (CI). Additionally, a Receiver Operating Characteristic (ROC) curve was performed to determine the area under the ROC curve (AUC), the sensitivity, and the specificity of the model. AUC values varying from 0.8 to 0.9 and between 0.9 and 1 were considered very good and excellent predictive ability of the model, respectively (Hajian-Tilaki, 2013).

Results

Participants

In total, 18 participants (age range from 19 to 77 years, 12 males (66.7%), with a median of 7.8 years since injury) were assessed at baseline and monitored their falls during the 6-month period. Table 1 depicts participants characteristics and the differences between infrequent fallers and recurrent fallers. Briefly, there were no significant differences ($p > .05$) following Mann-Whitney U test and Chi-square for age, sex, time since injury, levels of injury, history of previous falls, BMI, FIST, TCT, and TAI score between infrequent fallers and recurrent fallers included in this study.

Reported falls

Of the total sample, 16 (89%) reported falling at least once during the previous 6 months (min = 0 and max = 45) and 11 (61%) reported falling at least once during the 6 months prospective period (min = 0 and max = 9). Among the total sample, 8 (44%) reported recurrent falls (>2 falls). Figure 1 displays the proportion of prospective number of falls reported during the 6 months period. Of the potential 108 fall diary returns (18 participants × 6 months = 108), 22 were missing (return rate = 80%). Eight participants misplaced 1 monthly calendars, 7 misplaced 2 monthly calendars, and 3 participants mailed back all their monthly calendars. The research team was successfully able to supplement the misplaced calendars with the biweekly phone calls.

Factors associated with recurrent falls

The results of the multivariable logistic regression analysis that included the FIST and TAI are presented in Table 2. Participants who had lower FIST score were found to be at higher risk of experiencing future recurrent falls (OR = 0.70, 95% CI, 0.48 to 1.00, p = .05). For every point decrease on the FIST score, there is 30% higher odds of wheelchair users with SCI to experience recurring falls in the next 6 months.

The results of the ROC curve of the multivariable logistic regression resulted in an AUC of 0.87 (95% CI, 0.71 to 1.00), $p < .05$, indicating a very good ability of the model to discriminate between infrequent fallers and recurrent fallers (Figure 2). The sensitivity and specificity of the model were estimated at 0.88 (95% CI, 0.66 to 0.98) and 0.70 (95% CI, 0.58 to 0.92), respectively.

Discussion

This study investigated the ability of functional tests including balance and transfer quality assessments to predict future recurrent falls among non-ambulatory individuals with SCI. Compared to previous studies that evaluated predictors of future falls in this population (Butler Forslund et al., 2017; Nelson et al., 2010) this study performed a remote assessment of

Table 1. Participants demographics presented as median (interquartile range) for continuous variables and count (%) for gender.

Variable	Total *n*=18	Infrequent Fallers *n*=10 (56%)	Recurrent Fallers *n*=8 (44%)	P value
Age (years)	40.0 (27)	33.5 (24)	53.0 (30)	0.27
Sex, n (%)	12 (66.7)	7 (70.0)	5 (62.5)	1.00
Male	6 (33.3)	3 (30.0)	3 (37.5)	
Female				
Height (m)	1.8 (0.1)	1.8 (0.1)	1.81 (0.2)	1.00
Weight (Kg)	79.4 (23.5)	81.6 (25.4)	78.2 (25.9)	0.52
BMI (m/Kg^2)	24.7 (6.5)	25.1 (6.3)	24.4 (11.6)	0.52
Chronicity (years)	7.8 (32.6)	7.8 (28.8)	11.3 (35.5)	0.63
Level of Injury, n (%)	3 (17)	-2 (67)	-1 (33)	0.65
Cervical (C3 – C8)	3 (17)	1 (33)	2 (67)	
High Thoracic (T1-T7)	9 (50)	6 (67)	3 (33)	
Low Thoracic (T8-T12)	1 (6)	0 (0)	1 (100)	
Lumbar (L1 – L5)	2 (11)	1 (50)	1 (50)	
Unknown				
FIST	43.5 (12)	43.5 (10)	44.5 (16)	0.46
TCT	21.5 (7)	23.0 (7)	19.0 (8)	0.36
TAI	8.2 (1.1)	8.0 (2.2)	8.2 (0.5)	0.52
History of falls	2.0 (4)	1.5 (2)	4 (5)	0.27

BMI: Body Mass Index; C: Cervical; FIST: Function in Sitting Test; L: Lumbar; T: Thoracic; TAI: Transfer Assessment Instrument; TCT: Trunk Control Test; %: percentage; m: meter; Kg: Kilogram; m/Kg: meter per kilogram.

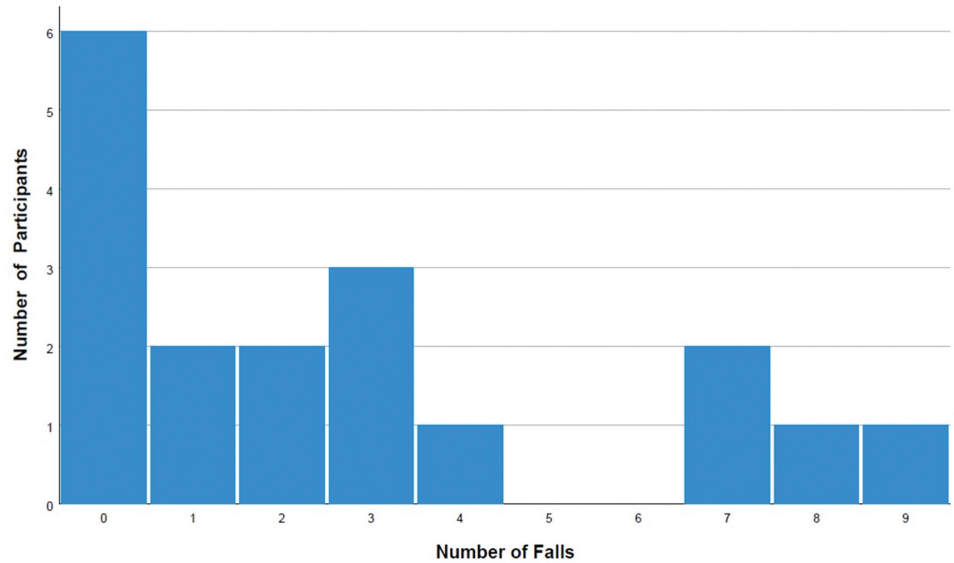

Figure 1. Frequencies of falls reported during the 6 months prospective monitoring period.

Table 2. Examination of sitting balance (Function in sitting test) and transfer quality (transfer assessment Instrument) as potential predictors of future falls among full-time wheelchair with SCI.

Predictors	β	S.E.	OR	Odds ratio (95% CI)	*p*-value
Initial model					
Age	0.26	0.13	1.30	0.99–1.70	0.06
Sex (Male)	1.24	2.70	3.48	0.01–69.35	0.64
BMI	−0.31	0.33	0.72	0.37–1.40	0.34
History of falls (Yes)	2.01	2.89	7.49	0.02–21.92	0.48
FIST	**−0.58**	**0.28**	**0.56**	**0.32–0.98**	**0.04**
TCT	0.35	0.36	1.42	0.70–2.91	0.33
TAI	2.02	1.39	7.58	0.49–11.61	0.14
Final model*					
Constant	−9.13	9.19	0.01	-	0.32
FIST	**−0.35**	**0.18**	**0.70**	**0.48–1.00**	**0.05**
TAI	1.88	1.22	6.56	0.59–71.88	0.12

CI: Confidence Interval; FIST: Function in Sitting Test; OR: Odds Ratio; S.E: Standard Error; TAI: Transfer Assessment Instrument; * The regression model fits X^2 = 9.04, p = .03, Nagelkerke R^2 = 0.53. Hosmer and Lemeshow Test, p = .72 (> 0.05).

participants' sitting balance and transfer quality, and monitored participants' falls for 6 months. Sitting balance and transferring are crucial for non-ambulatory individuals with SCI to perform their daily living activities. Eight (44%) of the total participants reported falling more than twice during the 6-month prospective falls tracking period. Among the functional tests included in the regression analysis, only the FIST was significantly associated with prospective recurrent falls. The pilot findings indicate that non-ambulatory individuals with SCI who have poor sitting balance ability are more likely to experience recurrent falls in the following 6 months. Although, this is a pilot study due to the small sample size analyzed, our results suggest that a comprehensive sitting balance assessment including the assessments of the static, proactive, and reactive components of sitting balance as evaluated within the FIST, alongside history of previous recurrent falls, may help to address the challenges associated with future recurrent falls in this population. The clinical implications of the findings include the potential identification of non-ambulatory individuals with SCI at high risk of falls, communicate the risk to patients and family, and facilitate their referral to falls prevention programs.

The findings reported in this study corroborate with the results reported in a previous study by Jørgensen et al. (2016) that pointed out the ability of a functional test to predict recurrent falls collected retrospectively among non-ambulatory individuals with SCI. Although, the functional test described in the study by Jørgensen et al. (2016) (SCIM III mobility) is different from the functional test analyzed in our study (sitting balance) and retrospective falls were evaluated, there is evidence indicating a strong association between mobility and

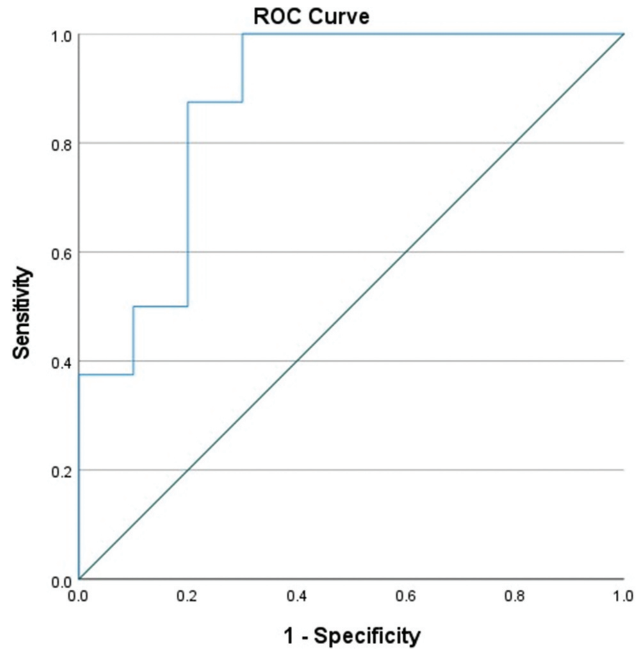

Figure 2. Receiver Operating characteristics (ROC) curve of the final regression model, area under the curve (AUC) = 0.88 (95% CI, 0.71 to 1.00) $p < .05$.

sitting balance in non-ambulatory individuals with SCI (Abou and Rice, 2022a; Gao, Chan, Purves, and Tsang, 2015). Therefore, the inclusion of both mobility and sitting balance measures into the same regression model may have resulted in a multicollinearity of the variables. However, as history of previous recurrent falls was shown to be a significant predictor of future recurrent falls above and beyond the effect of SCIM III mobility, age, sex, and working or studying (Butler Forslund et al., 2017) we recommend that the assessment of sitting balance in clinical settings supplements the question about history of previous recurrent falls to enhance the ability of clinicians to predict future recurrent falls among wheelchair users with SCI. Moreover, our results indicate that our regression model presented with very good predictive abilities. These predictive values suggest that using our model, only a few prospective recurrent fallers will be missed. Nonetheless, the model needs to be validated in an external sample. The pilot findings suggest that clinicians such as physical and occupational therapists should include the evaluation of sitting balance in their protocol when the goal is to identify non-ambulatory individuals at risk of future recurrent falls.

The appropriate clinical assessment of sitting balance should include the assessments of the static, proactive, and reactive components of sitting balance together with the integration of the sensorial function (i.e. items with eyes closed vs eyes open) (Abou, Sung, Sosnoff, and Rice, 2020). In addition, a clinical sitting balance assessment should be quick to administer and the scores easy to interpret to align with the dynamism of clinical settings. To the best of our knowledge, the FIST is the only quick to administer sitting balance assessment validated for non-ambulatory individuals with SCI that includes the assessments of all the aforementioned components of sitting balance (Abou, Sung, Sosnoff, and Rice, 2020; Palermo, Cahalin, Garcia, and Nash, 2020). Specifically, some challenging items of the FIST evaluate the ability of the individuals to recover from a displacement of the center of mass out of the base of support due to voluntary perturbation (proactive items, i.e. pick-up an object from the floor) and unexpected external perturbations (reactive items, i.e. lateral nudge) (Abou, Sung, Sosnoff, and Rice, 2020; Palermo, Cahalin, Garcia, and Nash, 2020). The ability to recover from voluntary and unexpected external perturbations may be essential to prevent some falls from occurring (i.e. near falls) (Armstrong et al., 2018; Noamani, Agarwal, Vette, and Rouhani, 2021). Moreover, poor sitting balance is often a modifiable risk factor that can be addressed by clinicians to enhance functional independence and quality of life among non-ambulatory individuals with SCI (Abou et al., 2020; Goel, Sharma, Gehlot, and Srivastav, 2021; Qi et al., 2018). Improving the ability to maintain sitting balance has also shown potential to reduce fall incidence in SCI in a pilot study (Rice et al., 2020). In the study by Rice et al. (2020) the authors indicated that 18 participants who underwent a 1:1, 45 minutes, in-person intervention focused on transfers skills and seated postural control decreased their fall incidence 12 weeks after the intervention ($p = .047$, dz = 0.51). Future studies should investigate whether more robust study design (i.e. randomized clinical trials) aiming at improving sitting balance effectively reduce the frequency of single and recurrent falls in a bigger sample size of non-ambulatory individuals with SCI.

Surprisingly, transfer quality assessed with the TAI was not found as a significant predictor of future recurrent falls in this sample. Since transfer has been commonly self-reported as a factor associated with falls by non-ambulatory individuals with SCI (Abou and Rice, 2022b; Khan et al., 2019) the non-significant ability of the TAI to predict future recurrent falls may be primarily due to the characteristics of the study sample. An inspection of the distribution of the TAI scores of the infrequent fallers and frequent fallers' groups indicates that most study participants had a good to very good transfer ability resulting in high TAI scores. A future study with a bigger sample of individuals with SCI with a variety of levels of transfer quality would be more informative.

The main strength of this study is that the functional tests were performed remotely in participants' usual home environments. This study inform about the ecological validity of sitting balance assessment to predict future recurrent falls among non-ambulatory individuals with SCI. If confirmed, our findings have the potential to help clinicians improve assessments of this vulnerable population when in-person care is limited. In-person care may be limited due to difficulties with transportation, financial stretch, or living in rural areas (Best, Kirby, Smith, and MacLeod, 2005; Davidsson and Södergård, 2016). In addition, telehealth and telerehabilitation have become important topics since the recent COVID-19 pandemic (Hollander and Carr, 2020). Our findings may help improve the ability of clinicians to practice telehealth and telerehabilitation with this vulnerable population.

Limitations

The study presents with some limitations that are important to mention. First, our sample of convenience imply that people with interests in falls might have agreed to participate in this study which might introduce a selection bias. In this line, a sample size was not calculated which led to the analysis of a sample size of convenience. Thus, our findings are underpowered which may affect the regression model conducted and the precision of the estimates (i.e. OR and 95% CI). Our findings with the current sample size yielded a power of only 0.30 when considering a Type I error rate α of 0.10. Our inability to follow the rule of thumb of 10:1 ratio of cases to predictors suggested in regression analyses indicates that our findings should be considered with caution and further validation of the results are imperatively warranted. Future studies with larger sample size are needed to expand on the findings presented in this study. The findings in this study may also serve as foundation to estimate the appropriate sample size required in future studies. Another limitation of the study is related to the inability of the current study due to the small sample size to determine the optimal cutoff point of the FIST indicating the threshold score of individuals who are high risk of recurrent falls. The remote nature of the study may have led to less accurate clinical information self-reported by study participants. The Hawthorne effect common in fall monitoring studies may have also impacted the findings (Sedgwick and Greenwood, 2015). Participants may have changed their behavior and fell less frequently during the falls monitoring period because of their enrollment in the current study (Sedgwick and Greenwood, 2015). Finally, the risk of recall bias associated with the fall tracking method may be considered an important inherent limitation. Although fall calendars are considered the gold standard to monitor falls prospectively (Coote, Sosnoff, and Gunn, 2014), filling out those paper calendars daily may be a burden to participants and some participants may complete them any time before returning them to the research team, resulting in recall bias. Also, some participants may misplace the fall calendars or forget to fill them out. We tried to minimize this bias by calling participants every two weeks to remind them to fill out their diaries which led to the high envelope return rate of 80%. A potential innovative solution to overcome limitations associated with falls monitoring method is the use of automated fall detection devices specific for wheelchair users (Abou et al., 2021) or the use of Ecological Momentary Assessment where participants have the opportunity using a wrist-worn device to respond to prompted fall-related questions several time throughout the day or at the end of the day (Salaffi, Sarzi-Puttini, and Atzeni, 2015).

Conclusions

In summary, this study highlights the importance of a comprehensive evaluation of sitting balance to identify non-ambulatory individuals with SCI who are at high risk of recurrent falls. Individuals with poor sitting balance may be at higher risk of recurrent falls and thus exposed to the consequences of falls including physical injuries, fear of falling, hospitalizations, or deaths. Identifying individuals at risk of recurrent falls is crucial to refer them to fall prevention interventions. Studies replicating our methodology in a larger sample size are warranted to externally validate the regression model developed in this study and determine the cutoff point of the FIST to predict future recurrent fallers.

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