Research Article

The associations of functional independence and quality of life with sitting balance and wheelchair skills among wheelchair users with spinal cord injury

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Context/Objective: To examine the associations of functional independence and quality of life (QOL) with sitting balance and wheelchair skills among individuals living with Spinal Cord Injury (SCI) who use a wheelchair full time.

Methods: Secondary data analysis of a total of 59 wheelchair users living with SCI. Eighteen individuals were included in all analyses involving sitting balance. Demographics information and characteristics of SCI were collected through a survey. Participants reported their wheelchair skills performance, confidence, and capacity; functional independence; and QOL using the Wheelchair Skills Test Questionnaire (WST-Q) 5.0, Spinal Cord Independence Measure (SCIM III), and World Health Organization QOL (WHOQOL-BREF), respectively. Sitting balance was assessed remotely using the Function in Sitting Test (FIST). Correlations between variables were analyzed using the Spearman rank correlation test.

Results: All the measures of SCIM III (total, selfcare, and mobility) correlated with the FIST (ρ = 0.52–0.66, p < 0.01 and p < 0.05). SCIM III-Mobility correlated with WST-performance, capacity, and confidence (ρ = 0.38–0.51, p < 0.01). WHOQOL-physical health and environment significantly correlated with WST-capacity and confidence (ρ = 0.26–0.33, p < 0.05). The FIST, WST-Performance, and level of injury did not correlate with any WHOQOL domain.

Conclusions: Lower functional independence and mobility are associated with poor sitting balance and poor wheelchair skills. Higher QOL may be associated with higher wheelchair skills. Future research is warranted to examine these relationships longitudinally to establish causality.

Keywords: Postural control, Spinal cord injury, Functional status, Quality of life, Mobility, Wheel chair skills, Sitting balance

Introduction

Spinal cord injury (SCI) can impact all components of the postural control system, including information processing due to the disconnection of the spinal cord with the brain.[1] SCI also impacts afferent and efferent pathways of the spinal cord leading to disturbance in somatosensory input, trunk muscles deficits, and balance impairments.[2,3] These impairments of the body functions experienced by individuals living with SCI result in limitation of activities of daily living (ADLs)

performance and a reduced quality of life (QOL).[4] As a result, the goal of SCI rehabilitation is to train individuals to reduce secondary complications, improve functional independence, and enhance their QOL.[5]

For individuals with SCI who use a wheelchair full-time, most ADLs, such as dressing, bathing, and transferring, are performed in a seated position. In addition, to move around and get involved in communities-based activities, an individual must have at least basic wheelchair skills. Therefore, the initial development and maintenance of functional seated posture and wheelchair skills are crucial for those individuals with SCI who use a wheelchair to perform functional mobility activities and complete ADLs.[6] Due to their

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importance, clinicians working with this population often assume that the ability to maintain sitting balance and operate a wheelchair are proportionally associated with the functional independence in a wheelchair. However, the scientific evidence supporting this topic is scarce.

In 2003, Chen *et al.* examined the relationship between the composite weight-shift test used to assess sitting balance and the timed upper-body dressing and undressing test used to evaluate functional independence among wheelchair users with SCI.[7] The study did not result in clinically meaningful findings because the authors did not have access to developed or validated outcome measures that would evaluate the specificities of individuals with SCI.[7] Therefore, use of valid, reliable, and sensitive outcome measures reflecting the specificities of sitting balance and functional independence in SCI have been suggested to appropriately evaluate this relationship and guide the evidence-based practice in this field.[7,8] In the recent years, valid and reliable outcome measures to evaluate sitting balance, *i.e.* Function in Sitting Test-FIST[9,10] and the Trunk Control Test,[11,12] and functional independence, *i.e.* Spinal Cord Independence Measure-SCIM III[13] have been developed or adapted for individuals with SCI.

Gao *et al.* indicated there is a proportional relationship between the limits of stability, sequential weight shifting, and functional independence measured with the SCIM III.[14] However, the limits of stability and sequential weight shifting used to assess sitting balance in this study are not easily feasible in a clinical setting due to the expertise required to analyze and interpret the data. In addition, the equipment is relatively costly and requires time to calibrate. Therefore, there is a need to explore the relationship between sitting balance and functional independence using specific SCI outcome measures that can be easily applied in clinical settings and guide assessments and clinician's choice of interventions for individuals with SCI who use a wheelchair full-time.

In addition to the ability to maintain sitting balance, wheelchair skills are important for individuals with SCI who use a wheelchair full-time to operate their wheelchair and transfer from their wheelchair to another surface or vice-versa.[15,16] Those wheelchair skills are essential to complete mobility tasks such as moving inside and outside the house. Hosseini *et al.* indicated that wheelchair skills are important predictors of community integration and life satisfaction among wheelchair users with SCI.[17] Being able to move inside and outside of the house may also be important for the

functional independence and an essential component of the QOL of wheelchair users with SCI.

To date, it is not known how much functional independence and QOL are influenced by sitting balance and wheelchair skills training using outcome measures specifically developed for individuals with SCI who use a wheelchair full-time. The exploration of these associations will help guide the development of interventions to achieve the overreaching goals of improving the functional independence and QOL in this population. Therefore, the purpose of this study is to examine the associations between functional independence and sitting balance and wheelchair skills among individuals with SCI who use a wheelchair full-time. In addition, the study aims to examine the associations between QOL and sitting balance and wheelchair skills. The authors hypothesized that there will be a proportional association between functional independence, QOL, sitting balance, and wheelchair skills in this population.

Methods
Study design and setting
This is a secondary data analysis of data collected as part of a research study aiming to investigate factors associated with falls among wheelchair users with SCI. The procedures of the study were reviewed and approved by the Institutional Review Board at the University of Illinois at Urbana-Champaign (#20718). Online informed consent was obtained from all participants before data collection.

Participants
In this study, participants were recruited from the community. Inclusion criteria were: (a) older than 18 years old with a SCI; (b) self-report use of a wheelchair as a main form of mobility (> 40 h/wk); (c) motor complete injury classified as American Spinal Injury Association Impairment Scale (AIS) A or B; (d) able to communicate with the research team through smartphone or laptop video conferencing software; and (e) ability to read and understand English. Exclusion criteria were: (a) inability to sit unsupported for at least 30 s to perform the sitting balance test and (b) presence of additional medical conditions that might affect their ability to appropriately read and understand instructions.

Outcome measures
The procedures for the data collection were performed remotely because of restrictions placed on human research due to the COVID-19 pandemic.

Demographic information collected to characterize the sample included age, sex, race, height, and weight. SCI-related information collected included time since injury and level of injury. In addition, the following outcome measures were extracted from the data collected:

Functional independence

Functional independence was evaluated using the SCIM III. This measure was specifically developed for individuals living with SCI.[13] The 17 items of the SCIM III assesses domains related to self-care, respiration and sphincter control, and mobility. Self-care scores vary from 0 to 20, 0–40 for respiration and sphincter control, and mobility scores vary from 0 to 40. Total scores vary from 0 to 100. Higher scores indicate greater functional independence. SCIM III-Total, SCIM III-Selfcare subscale, and SCIM III-Mobility subscale were analyzed in this study.

Table 1 Clinical and demographics characteristics of the participants.

Characteristic	Total sample
Age (years), median (IQR)	52.5 (21)
Sex (men), n (%)	28 (47.5)
Race, n (%)	
Asian	3 (5.1)
African American	6 (10.1)
Caucasian	48 (81.4)
Hispanic	2 (3.4)
Height (cm)	171.5 (17.1)
Weight (Kg), median (IQR)	75 (27)
Cause of SCI, n (%)	
Traumatic	43 (72.9)
Non-traumatic	16 (27.1)
Time since injury (years), median (IQR)	16.5 (27.25)
Level of injury, n (%)	
Cervical	12 (22)
High thoracic	15 (25.4)
Low thoracic	22 (37.3)
Lumbar	5 (8.5)
Unknown	4 (6.8)
Sitting balance, median (IQR), n = 18	
FIST	44 (12)
Functional independence, median (IQR)	
SCIM-Total	62 (16)
SCIM-Mobility	16 (6)
SCIM-Selfcare	18 (3)
Wheelchair skills, median (IQR)	
WST-Performance	65 (31)
WST-Capacity	83 (22)
WST-Confidence	82 (21)
Quality of life	
WHOQOL-Physical Health	65 (11)
WHOQOL-Psychological	69 (12)
WHOQOL-Social Relationships	65 (31)
WHOQOL-Environment	88 (25)

IQR: interquartile range; FIST: Function in Sitting Test; SCIM III: Spinal Cord Injury Measures III; WHOQOL: World Health Organization Quality of Life; WST: Wheelchair Skills test
The number of participants n = 59 unless otherwise stated.

Quality of life

The 26-item World Health Organization Quality of Life- Brief version (WHOQOL-BREF) was used to quantify QOL.[18] The WHOQOL-BREF is a reliable and valid self-reported outcome measure that evaluates domains of physical health, psychological health, social relationships, and environment. Scores vary from 4 to 100 for each domain. Higher scores indicate a greater perceived QOL. All the WHOQOL domains including WHOQOL-Physical Health, WHOQOL-Psychological, WHOQOL-Social relationships, and WHOQOL-Environment were analyzed in this study. The WHOQOL-BREF has been previously validated for use among individuals with SCI presenting with good internal consistency (Cronbach $\alpha = 0.75–0.87$), intra-rater reliability (intraclass correlation coefficients-ICC of 0.84–0.98), and inter-rater reliability (ICC = 0.56–0.95).[19]

Sitting balance

The ability of the participants to maintain their sitting balance while performing several daily living activities was assessed using the Function in Sitting Test (FIST).[9] The FIST was validated for use among non-ambulatory individuals with SCI.[9,10] The preliminary validity and reliability of the remote assessment using the FIST is fully described elsewhere.[20] Total scores of the FIST range from 0 to 56.[21] Higher scores indicate better balance performance.

Wheelchair skills test

Participants' wheelchair skills were assessed using the Wheelchair Skills Test 5.0 Questionnaire (WST-Q).[22] The WST-Q for power or manual wheelchair users is a questionnaire version of an in-person test that evaluates the capacity, confidence, and performance of participants' wheelchair skills. Raw scores are converted into a percentage score (0% to 100%). Higher percentages indicate greater capacity, confidence, and/or performance of wheelchair skills. All the domains WST-Capacity, WST-Confidence, and WST-Performance were included in the study. The WST-Q showed good content, construct, and concurrent validity.[23] The ICC reported for the WST-Q is 0.99.[24]

Statistical analysis

Descriptive statistics were calculated for all variables to characterize the sample. Normality of data was assessed using the Kolmogorov–Smirnov test. Due to the non-normal distribution of the data, Spearman's rank correlation coefficient (ρ) was used to examine correlations between scores of the SCIM III and the FIST, WST-

Q, and characteristics of SCI. Spearman's rank correlation coefficient was also used to examine correlations between WHOQOL-BREF score and the FIST, WST-Q, and characteristics of SCI. The strength of the correlations was ranked using the following categories: 0.00–0.19 as no association, 0.20–0.39 as low, 0.40–0.59 as moderate, 0.60–0.79 as moderately high, 0.80–1.00 as high.[25] All data analysis was performed using IBM-SPSS Statistics for Macintosh version 25 (SPSS Inc., Chicago, IL, USA).

Results

Data from 59 individuals with SCI, median age 52.4 years (IQR: 21), 47.5% male who use wheelchair full-time were available and analyzed. Data on sitting balance was available for 18 individuals, therefore, all analyses including sitting balance were performed with this subsample. The demographics characteristics and SCI clinical information of the included participants are presented in detail in Table 1.

Functional independence

SCIM III total, SCIM III-Selfcare, and SCIM III-Mobility positively and significantly correlated with FIST score. The correlations were moderate to moderately high ($\rho = 0.52$–0.66, $p < 0.01$ and $p < 0.05$) (Table 2).

SCIM III total and SCIM III-Mobility scores positively and significantly correlated with WST-performance and WST-confidence scores. The correlations were low to moderate ($\rho = 0.25$–0.42, $p < 0.01$ and $p < 0.05$). While SCIM III-Selfcare and SCIM

III-Mobility presented with low to moderate correlations with WST capacity ($\rho = 0.30$–0.51, $p < 0.01$ and $p < 0.05$) (Table 2).

SCIM III total, SCIM III-Selfcare, and SCIM III-Mobility presented with significant moderate negative correlations with level of injury ($\rho = -0.40$ to -0.47, $p < 0.01$) (Table 2).

Quality of life

WHOQOL domains did not correlate with the FIST score and level of injury (Table 3). However, WHOQOL-Physical Health, WHOQOL-Social relationships, and WHOQOL-Environment positively and significantly correlated with time since injury. The correlations were low to moderate ($\rho = 0.26$–0.47, $p < 0.01$ and $p < 0.05$) (Table 3). Also, WHOQOL-Physical Health and WHOQOL-Environment positively and significantly correlated with WST-capacity and WST-confidence. The correlations were low ($\rho = 0.26$–0.33, $p < 0.05$) (Table 3).

Discussion

This study indicates that functional independence is proportionally associated with sitting balance and wheelchair skills among individuals with SCI who use a wheelchair full-time. The findings also confirm that functional independence is inversely proportional to level of injury. Additionally, the findings confirm that QOL is significantly associated with time since injury but poorly related to wheelchair skills. These findings can serve as preliminary evidence to guide the development of interventions aimed at improving the

Table 2 Correlations between functional independence and the FIST, WST, and SCI characteristics for all the participants included in the study.

Outcome	SCIM-Total	SCIM-Selfcare	SCIM-Mobility
FIST	0.66** (n = 18)	0.52* (n = 18)	0.56* (n = 18)
WST-Performance	0.25# (n = 59)	0.19 (n = 59)	0.42** (n = 59)
WST-Capacity	0.17 (n = 59)	0.30* (n = 59)	0.51** (n = 59)
WST-Confidence	0.31* (n = 59)	0.20 (n = 59)	0.38** (n = 59)
Level of injury	−0.47** (n = 59)	−0.47** (n = 59)	−0.40** (n = 59)
Time since injury	0.08 (n = 59)	0.14 (n = 59)	0.03 (n = 59)

FIST: Function in Sitting Test, SCIM: Spinal Cord Independence Measure, WST: Wheelchair Skill Test.
* p < 0.05.
** p < 0.01.
# p = 0.05.

Table 3 Correlations between QOL and FIST, WST, and SCI characteristics for all the participants included in the study.

Outcome	WHOQOL-PH	WHOQOL-PsH	WHOQOL-SR	WHOQOL-E
FIST	0.32 (n = 18)	0.41 (n = 18)	0.29 (n = 18)	0.46 (n = 18)
WST-Performance	0.12 (n = 59)	0.24 (n = 59)	0.05 (n = 59)	0.18 (n = 59)
WST-Capacity	0.17 (n = 59)	0.32* (n = 59)	0.11 (n = 59)	0.30* (n = 59)
WST-Confidence	0.14 (n = 59)	0.33* (n = 59)	0.07 (n = 59)	0.26* (n = 59)
Level of injury	−0.18 (n = 59)	−0.18 (n = 59)	−0.01 (n = 59)	−0.06 (n = 59)
Time since injury	0.19 (n = 59)	0.29* (n = 59)	0.26* (n = 59)	0.47** (n = 59)

E: Environment, FIST: Function in Sitting Test, PH: Physical Health, PsH: Psychological Health, SR: Social Relationships, WHOQOL: World Health Organization Quality of Life, WST: Wheelchair Skill Test.
* p < 0.05.
** p < 0.01.

functional independence and QOL of wheelchair users with SCI.

Our results on the association between overall functional independence and sitting balance are congruent with prior studies examining the relationship between sitting stability and a functional performance measure in individuals with paraplegia.[7,14] The association may be explained by the importance of sitting stability in this population to perform ADLs evaluated by the SCIM III such as selfcare activities (*i.e.* grooming, bathing, dressing, reaching for an object)[6] and mobility activities (*i.e.* transferring).[15] Due to the importance of sitting balance in the performance of ADLs in a wheelchair,[11] it seems evident that clinicians aiming to improve the functional independence of wheelchair users with SCI should develop specific strategies to enhance sitting stability. In the literature, there are reports of only a few sitting balance interventions to guide the evidence-based practice in this population.[26–29] Among those interventions studies, only Khurana *et al.* evaluated the influence of virtual reality and real-world sitting balance interventions on the functional independence of individuals with SCI using the SCIM III.[29] The authors indicated significant improvement of SCIM III after the interventions.[29] More studies are therefore needed to develop interventions to improve sitting balance and examine its influence on the functional independence of individuals with SCI.

Our findings also point out a significant association between mobility, sitting balance, and wheelchair skills capacity. Keeler *et al.* indicated in a systematic review that wheelchair skills training program significantly improved functional independence and mobility outcomes of wheelchair users with various disabilities including individuals with SCI.[30] Our findings were also supported by a study conducted by Yeo & Kwon where the authors showed an improvement in functional performance after 8 weeks of wheelchair skills training among individuals with cervical SCI.[31] The association between sitting balance, wheelchair skills, and mobility may be explained by the fact that maintaining balance and high-quality wheelchair skills are important for mobility in a wheelchair including mobility indoors, moderate distance, and outdoors which are items evaluated within the SCIM III-Mobility. The significant proportional association between SCIM III-Mobility and wheelchair skills suggests that clinicians aiming to improve mobility of individuals with SCI should also include wheelchair skills and balance trainings in their intervention strategies. Interventional studies are also needed to confirm these associations.

Additionally, our findings indicate that selfcare activities presented with a weak association ($\rho = 0.30$, $p < 0.05$) with WST-capacity. This weak association may be explained by the fact that selfcare activities including grooming, bathing, dressing, reaching for an object do not primarily depend on the capacity to operate a wheelchair. Rather, trunk functions and upper limb functions that depend on motor coordination, influence of spasticity, strength, dexterity, and sensation are very important to perform selfcare activities. Unfortunately, upper limb function was not evaluated in this study. Therefore, we suggest that future studies include upper limb functions' assessment in the analysis of interventions aiming to improve selfcare activities.

Functional independence was also found to be associated with level of injury in this population. The correlations analyses indicate that higher levels of injury may be associated with lower levels of functional independence. The results align with the findings reported by Aidinoff *et al.*[32] and Osterthun *et al.*[33] where the authors also indicated a negative significant correlation between level of injury and the SCIM III. This may be explained by the fact that individuals with a lower level of injury present with more remaining function to facilitate performance of ADLs.[34] For example, an individual with a complete T10 injury will present with innervation of trunk muscles which will be important to maintain sitting stability with less compensation. Meanwhile, an individual with a complete C7 injury will present with impairment of more trunk muscles which will affect sitting stability and therefore, the performance of ADLs. The association between the level of injury and functional independence confirms that clinicians should be aware of the potential gain in functional independence that individuals with SCI can achieve and develop interventions according to their level of injury.

Regarding QOL, only WST-confidence and capacity were related to the physical health and environmental domains of the WHOQOL. The experience using a wheelchair, determined by the perceived wheelchair skills confidence and capacity assessments, often improves over time, which might be important factors of QOL. The finding is supported by Hosseini *et al.* indicating that wheelchair skills capacity is associated with better QOL.[17] Also, time since injury was shown to be associated with QOL. Sakakibara *et al.* have previously reported that QOL was found to be consistently good and excellent over time in SCI populations.[35] Our findings confirm that wheelchair users with more time after injury may learn to better manage their health

condition which might support better QOL. However, our results indicate that WST-performance, level of injury, and sitting balance were not associated with QOL. Indeed, an intervention developed to reduce fall frequency with a focus placed on improving seated postural control and transfers quality did not influence most domains of QOL.[28] Also, a previous research has indicated no difference in QOL among individuals with paraplegia and tetraplegia.[36] The absence of associations may be explained by the fact that QOL is broad and does not depend solely on the level of injury, the capacity and confidence to perform activities in a wheelchair, or to operate a wheelchair.[18] QOL also depends on other factors such as psychological metrics, social context, cultures, resources in the surrounding environment, and other personal factors (*i.e.* employment status or marital status). Therefore, a multidisciplinary approach should be considered including, physicians, physical and occupational therapists, psychologists, social workers, and policymakers in order to improve the QOL of wheelchair users with SCI.

Strengths of this study include that it is the first study to examine the associations between sitting balance, functional independence, and QOL using specifically developed and validated outcome measures for wheelchair users with SCI. Prior to this study, data published in 2003 demonstrated a relationship between sitting balance and functional performance among individuals with paraplegia using outcome measures that are not specific for this population.[7] Studying these relationships will serve as a guidance to clinicians working with wheelchair users with SCI and improve the evidence-based practice of therapists working in this field. Also, the data analyzed in this study was collected remotely due to the COVID-19 pandemic which confirms the feasibility of remote assessments previously demonstrated in this population.[20] The evidence of remote sitting balance assessments and the association between sitting balance and functional independence indicate that clinicians may be able to provide remote sitting balance assessment. This will be important to those wheelchair users who do not have access to transportation or those who do not have access to healthcare professionals to receive care.

Limitations

Limitations of this study include the risks inherent in any secondary data analysis. Being a cross-sectional study design, our findings do not inform about the cause-effects relationships. Also, the data analyzed in this study were not collected originally to answer the research questions developed in this report. Therefore, the planned sample size was not estimated based on the outcomes included in the analyses reported in this study. Indeed, the sub-analysis of the associations between functional independence and QOL and sitting balance were performed with 18 individuals. This may hinder the power of our analysis and the interpretations of our results. However, the results may serve as important preliminary data to guide clinicians in their clinical practice. Another limitation that may hinder the evaluation of the representativeness of our sample is related to the percentage of male full-time wheelchair users included in our study (47.5%) who range from 1 to 57 years post injury. This percentage is lower than the national average of all new SCI cases that are male (about 78%).[37] However, no comparison data exists to determine the percentage of male full-time wheelchair users living with SCI 1–57 years post injury. Upper limb function, as previously discussed, was not evaluated in our study which may also limit the full interpretation of our results. Also, most correlations reported in this study were classified from low to moderately high which indicates that the findings should be interpreted with cautions. We suggest that future studies should develop prospective study designs, with appropriate sample size calculations based on the results presented in this study. Finally, the validation of the remote assessment using the FIST was a preliminary study conducted with a small number of people with SCI.[20] This may hinder the interpretation of the findings presented in this study.

Conclusions

This research indicates that lower functional independence, lower independence in selfcare activities, and lower mobility are associated with poor sitting balance, poor wheelchair skills, and higher level of injury of wheelchair users with SCI. Also, the findings indicate that higher QOL may be associated with more time since injury and higher quality wheelchair skills in this population. Although further research is needed to better understand the causal relationships between these outcomes, our current results can be applied to clinical practice to aid in the decision-making process of therapists working with this population. Improving our understanding of the connections between functional independence, sitting balance, and wheelchair skills may help clinicians more effectively to develop and select interventions targeting the functional independence and QOL of wheelchair users with SCI.

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References

1 Lemay JF, Gagnon D, Duclos C, Grangeon M, Gauthier C, Nadeau S. Influence of visual inputs on quasi-static standing postural steadiness in individuals with spinal cord injury. Gait Posture. 2013;38(2):357–360.

2 Milosevic M, Gagnon DH, Gourdou P, Nakazawa K. Postural regulatory strategies during quiet sitting are affected in individuals with thoracic spinal cord injury. Gait Posture. 2017;58:446–452.

3 Ilha J, Abou L, Romanini F, Dall Pai AC, Mochizuki L. Postural control and the influence of the extent of thigh support on dynamic sitting balance among individuals with thoracic spinal cord injury. Clinical Biomechanics (Bristol, Avon). 2020;73: 108–114.

4 WHO. International classification of functioning, disability and health: ICF. Geneva: World Health Organization; 2001.

5 Simpson LA, Eng JJ, Hsieh JT, Wolfe DL. The health and life priorities of individuals with spinal cord injury: a systematic review. J Neurotrauma. 2012;29(8):1548–1555.

6 Gauthier C, Gagnon D, Grangeon M, et al. Comparison of multi-directional seated postural stability between individuals with spinal cord injury and able-bodied individuals. J Rehabil Med. 2013;45(1):47–54.

7 Chen CL, Yeung KT, Bih LI, Wang CH, Chen MI, Chien JC. The relationship between sitting stability and functional performance in patients with paraplegia. Arch Phys Med Rehabil. 2003;84(9): 1276–1281.

8 Boswell-Ruys CL, Sturnieks DL, Harvey LA, Sherrington C, Middleton JW, Lord SR. Validity and reliability of assessment tools for measuring unsupported sitting in people with a spinal cord injury. Arch Phys Med Rehabil. 2009;90(9):1571–1577.

9 Abou L, Sung J, Sosnoff JJ, Rice LA. Reliability and validity of the function in sitting test among non-ambulatory individuals with spinal cord injury. J Spinal Cord Med. 2020;43(6):846–853.

10 Palermo AE, Cahalin LP, Garcia KL, Nash MS. Psychometric Testing and clinical utility of a modified version of the function in Sitting Test for individuals with chronic SCI. Arch Phys Med Rehabil. 2020.

11 Abou L, de Freitas GR, Palandi J, Ilha J. Clinical instruments for measuring unsupported sitting balance in subjects with spinal cord injury: A systematic review. Top Spinal Cord Inj Rehabil. 2018;24(2):177–193.

12 Quinzaños J, Villa AR, Flores AA, Pérez R. Proposal and validation of a clinical trunk control test in individuals with spinal cord injury. Spinal Cord. 2014;52(6):449–454.

13 Itzkovich M, Gelernter I, Biering-Sorensen F, et al. The spinal Cord Independence measure (SCIM) version III: reliability and validity in a multi-center international study. Disabil Rehabil. 2007;29(24):1926–1933.

14 Gao KL, Chan KM, Purves S, Tsang WWN. Reliability of dynamic sitting balance tests and their correlations with functional mobility for wheelchair users with chronic spinal cord injury. J Orthop Translat. 2015;3(1):44–49.

15 Gagnon D, Nadeau S, Noreau L, Eng JJ, Gravel D. Trunk and upper extremity kinematics during sitting pivot transfers performed by individuals with spinal cord injury. Clinical Biomechanics (Bristol, Avon). 2008;23(3):279–290.

16 Gagnon DH, Roy A, Gabison S, Duclos C, Verrier MC, Nadeau S. Effects of seated postural stability and trunk and upper extremity strength on performance during manual wheelchair propulsion tests in individuals with spinal cord injury: An exploratory study. Rehabil Res Pract. 2016;2016. doi:10.1155/2016/6842324.

17 Hosseini SM, Oyster ML, Kirby RL, Harrington AL, Boninger ML. Manual wheelchair skills capacity predicts quality of life and community integration in persons with spinal cord injury. Arch Phys Med Rehabil. 2012;93(12):2237–2243.

18 Skevington SM, Lotfy M, O'Connell KA, Group W. The World Health Organization's WHOQOL-BREF quality of life assessment: psychometric properties and results of the international field trial. A report from the WHOQOL group. Qual Life Res. 2004;13(2):299–310.

19 Lin MR, Hwang HF, Chen CY, Chiu WT. Comparisons of the brief form of the World Health Organization Quality of Life and short form-36 for persons with spinal cord injuries. Am J Phys Med Rehabil. 2007;86(2):104–113.

20 Abou L, Rice LA, Frechette ML, Sosnoff JJ. Feasibility and preliminary reliability and validity of remote sitting balance assessments among wheelchair users. Int J Rehabil Res. 2021;44(2):177–180.

21 Gorman SL, Rivera M, McCarthy L. Reliability of the Function in Sitting Test (FIST). Rehabil Res Pract. 2014;2014:593280.

22 Kirby R, Rushton P, Smith C, et al. Wheelchair skills program manual version 5.0. 2019. www.wheelchairskillsprogram.ca/eng/manual.php.

23 Kirby RL, Worobey LA, Cowan R, et al. Wheelchair skills capacity and performance of manual wheelchair users With spinal cord injury. Arch Phys Med Rehabil. 2016;97(10):1761–1769.

24 Passuni D, Dalzotto E CFG, et al. Reliability of the Spanish version of the wheelchair skills test 4.2 for manual wheelchair users with spinal cord injury. Disabil Rehabil Assist Technol. 2019;14(8):788–791.

25 Safrit M, Wood T. Introduction to measurement in physical education and exercise science. 3rd ed. St. Louis: Times Mirror/Mosby; 1995.

26 Abou L, Malala VD, Yarnot R, Alluri A, Rice LA. Effects of virtual reality therapy on gait and balance Among individuals with spinal cord injury: A systematic review and meta-analysis. Neurorehabil Neural Repair. 2020;34(5):375–388.

27 Boswell-Ruys CL, Harvey LA, Barker JJ, Ben M, Middleton JW, Lord SR. Training unsupported sitting in people with chronic spinal cord injuries: a randomized controlled trial. Spinal Cord. 2010;48(2):138–143.

28 Rice LA, Sung JH, Keane K, Peterson E, Sosnoff JJ. A brief fall prevention intervention for manual wheelchair users with spinal cord injuries: A pilot study. J Spinal Cord Med. 2020;43(5): 607–615.

29 Khurana M, Walia S, Noohu MM. Study on the effectiveness of virtual reality game-based training on balance and functional performance in individuals with paraplegia. Top Spinal Cord Inj Rehabil. 2017;23(3):263–270.

30 Keeler L, Kirby RL, Parker K, McLean KD, Hayden JA. Effectiveness of the wheelchair skills training program: a systematic review and meta-analysis(). Disabil Rehabil Assist Technol. 2019;14(4):391–409.

31 Yeo SS, Kwon JW. Wheelchair skills training for functional activity in adults with cervical spinal cord injury. Int J Sports Med. 2018;39(12):924–928.

32 Aidinoff E, Front L, Itzkovich M, et al. Expected spinal cord independence measure, third version, scores for various neurological levels after complete spinal cord lesions. Spinal Cord. 2011;49 (8):893–896.

33 Osterthun R, Tjalma TA, Spijkerman DCM, et al. Functional independence of persons with long-standing motor complete spinal cord injury in the Netherlands. J Spinal Cord Med. 2020; 43(3):380–387.

34 Seelen HA, Potten YJ, Drukker J, Reulen JP, Pons C. Development of new muscle synergies in postural control in spinal cord injured subjects. Journal of Electromyography and

Kinesiology: Official Journal of the International Society of Electrophysiological Kinesiology. 1998;8(1):23–34.

35 Sakakibara BM, Hitzig SL, Miller WC, Eng JJ. An evidence-based review on the influence of aging with a spinal cord injury on subjective quality of life. Spinal Cord. 2012;50(8):570–578.

36 Tavakoli SAH, Kavian M, Bakhsh SC, *et al*. Is level of injury a determinant of quality of life Among individuals with spinal cord injury?
A tertiary rehabilitation Center report. Oman Med J.s 2016;31(2): 112–116.

37 National spinal cord injury statistical center, facts and figures at a glance. University of Alabama at Birmingham; 2021. [cited 2021 July 26] Available from: https://www.nscisc.uab.edu/Public/Facts%20and%20Figures%20-%202021.pdf.