Life Space Assessment in Spinal Cord Injury

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Objectives: To examine the Life Space Assessment (LSA) in persons with spinal cord injury (SCI), exploring its psychometric properties, differences between persons with cervical versus thoracolumbar injuries, and cutoff score differentiating a restricted from an unrestricted life space. **Method:** We conducted a test-retest reliability study in a community setting involving 50 persons with SCI (25 injured above C7, 25 injured below T1). Data were collected in 2 phone interviews approximately 9 days apart using the LSA. **Results:** Mean LSA scores were 66 ± 25 ($n = 50$): 62 ± 23 for the cervical group, and 70 ± 25 for the thoracolumbar group. Scores were not significantly different between phone interviews [$t(49) = 0.379$, $p = .706$] or between groups [$t(48) = -1.214$, $p = .231$]. Test-retest reliability intraclass correlation coefficient (ICC) was 0.876 (95% CI, 0.792–0.928). Spearman's rho correlations between the LSA and Reintegration to Normal Living Index total and subscores ranged from .509 to .538 ($p < .001$). LSA scores were normally distributed. The minimum detectable change was approximately 23 points. A cutoff score of 78.5 (sensitivity 76.9%, specificity 81.1%) differentiated between persons with a restricted from an unrestricted life space if equipment and personal assistance were not needed for mobility. If equipment was needed, the cutoff score was found to be 49 (sensitivity of 90%, specificity of 90%). **Conclusions:** The LSA is a reliable and valid measure of life space in persons with SCI and can be used to identify persons with a restricted life space who may be at increased risk of mobility disability. **Key words:** environment, locomotor activity, outcome measures, rehabilitation, spinal cord injury

Residual impairments resulting from spinal cord injury (SCI), along with environmental barriers such as stairs, negatively impact an individual's ability to move about in the home and environment and subsequently the ability to participate in some social and leisure activities.¹ Investigators and clinicians are urged to capture ways to measure these meaningful constructs: mobility, considered to fall under the domain of activity and participation of the International Classification of Functioning, Disability and Health (ICF), and environmental factors, which are external barriers or facilitators of function.^{2–5} In 2012, Ullrich and colleagues outlined the need for “involvement in life” measures (ie, participation⁵) for the SCI population that are appropriate for non-ambulatory persons and account for environmental factors.³ The Life Space Assessment (LSA) may be one tool to help fill this need.

The LSA is a self-report measure capturing the spatial extent and frequency of environmental mobility (ie, life space⁶) while factoring in the use of personal assistance or equipment, both of which are considered environmental factors according to the ICF.⁷ Constricted or restricted life space describes mobility that is limited to near or in the home or neighborhood^{8,9} and has been associated with increased mortality.⁸ The LSA was developed for community-dwelling older adults due to their risk of mobility disability,^{6,7,10} but it has been increasingly utilized in other at-risk populations.^{11–14} Persons with SCI are certainly at risk for mobility disability. Although the LSA has been examined in populations that included persons with SCI,^{15,16} to our knowledge no investigations have examined the LSA in a population limited to SCI. Such studies are important to ensure the appropriateness of outcome tool application.^{3,17} For the SCI

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population, in particular, finding a tool that meets the measurement needs across the spectrum of function possible after spinal injuries, which vary in cause, level, and completeness, can be challenging.

In this study, we characterized LSA scores for persons with SCI and examined whether or not scores differed between those with cervical versus thoracolumbar injuries. We determined test-retest reliability, criterion validity, minimal detectable change (MDC), and normality of distribution of LSA scores. Finally, we examined the sensitivity and specificity of scores for distinguishing between participants with restricted and unrestricted life spaces.

Methods

Fifty participants were recruited: 25 with cervical injuries and therefore tetraparesis (cervical group), and 25 with thoracic or lumbar spine injuries and therefore paraparesis (thoracolumbar group). This sample size was sufficient to detect a test-retest reliability coefficient of 0.80 or greater and correlation coefficients between variables of 0.50 or greater with a statistical power = 0.80 (at $\alpha = 0.05$). A sample size of 50 was additionally sufficient to detect a difference of 20 points on the LSA, assuming a standard deviation of approximately 25 points, at a statistical power = 0.80.

Participants were recruited from the Mayo Clinic SCI database, which included persons injured at least 1 year from the start of the study. To participate, subjects were 18 to 65 years of age, resided in an apartment or home in the United States, spoke English, and were diagnosed with traumatic or non-traumatic SCI with an American Spinal Injury Association Impairment Scale (AIS) score of A, B, C or D.¹⁸ Subjects were excluded if they had a diagnosis of moderate or severe brain injury¹⁹ or suffered multiple trauma at the time of the SCI, reported a memory deficit, reported co-morbidities affecting mobility, lived in a skilled nursing or assisted living facility, or were hospitalized in the 4 weeks prior to the start of the study. Refer to **Figure 1** for the participant recruitment and screening procedure. The Mayo Clinic Institutional Review Board for the protection of human subjects approved this study. All participants provided informed consent.

Outcome measures

Life space was determined using the LSA, which has been validated for use with community-dwelling adults.²⁰ Participants were asked to consider in the prior 4 weeks how frequently they travelled out of the room in which they slept (life-space level 1 [LS 1]), outside of their home to places such as the porch or garage (LS 2), into their neighborhood (LS 3), into town (LS 4), and outside of town (LS 5). Possible responses were never (scored as 0 for that LS level), less than once a week (scored as a 1), 1 to 3 times per week (2), 4 to 6 times per week (3), and daily (4). For each LS level, participants reported if personal assistance (the assistance of another, scored as a 1) or equipment (scored as 1.5) was needed. No reliance on devices or personal assistance was scored as a 2. The composite LSA score is calculated by multiplying the level (1-5) by the frequency of mobility (0-4) and assistance needed (1-2) for each respective LS level and summing those scores⁷; scores can range from life space limited to the bedroom (LSA = 0) to daily travel out of town without equipment or assistance (LSA = 120).²⁰ Persons moving through a life space, the neighborhood for example, to reach a larger life space, such as the town, were given credit for moving through that space at the frequency and with the level of assist needed to travel through it even if they did not “stop” at that level.¹⁰

Because participation in social and leisure roles depends, in part, on the ability to mobilize in the environment, criterion validity was assessed by comparing LSA performance to the Reintegration to Normal Living Index (RNLI), which captures perceived reintegration into family and societal roles.²¹ Eight RNLI questions reflect ability to move around in the environment and participate in work, recreational, and family roles as desired. Responses indicate whether the participant fully (scored as a 2) or partially (scored as a 1) identifies or does not identify (scored as a 0) with the situation asked. These responses are compiled as the physical subscore. Three additional RNLI questions comprise the social subscore, reflecting perceived comfort with self and adaptability to life situations. Physical and social subscores are combined for a total score, ranging from 0 to 22.²² A score of 0 would be interpreted as not having reintegrated into family or social roles, whereas

Figure 1. Illustration of sample recruitment. AIS = American Spinal Injury Association Impairment Scale A complete, B sensory incomplete, C motor incomplete and primarily limited motor function below the lesion, D motor incomplete and primarily antigravity motor function below the lesion; CVA = cerebrovascular accident; HIPAA = Health Insurance Portability and Accountability Act; SCI = spinal cord injury; TBI = traumatic brain injury.

a score of 22 would imply that the person has re-adjusted to life after the injury.²³ The RNLI has been validated for use in persons with SCI.²²

Interview procedure

Outcome measure test-retest responses were determined by 2 phone interviews 9.1 ± 2.7 days apart within the autumn season to minimize the likelihood of winter weather limiting travel.²⁴ To control for survey order effect, participants were randomized so that half answered the LSA first during interviews while the other half answered the RNLI first. During the second phone interview, participants were asked if they had experienced alterations in health

or equipment malfunction since the first interview, which would jeopardize the reliability of the LSA. No changes were reported. Three participants who completed the first phone interview could not be reached for the second, necessitating the screening of an additional 3 participants to meet the target sample size of 50 (**Figure 1**).

Statistical analysis

Data were analyzed with IBM SPSS 21.0 software at $\alpha = 0.05$. Descriptive statistics were used to characterize the sample. Independent and dependent *t* tests compared differences in LSA scores between the cervical and thoracolumbar groups and between

time 1 and time 2, respectively. Demographic data measured with categorical scales of measurement were compared between the 2 groups with chi-square tests. Demographic data measured with continuous scales of measurement were compared between groups with independent *t* tests.

Test-retest reliability was estimated using the mixed-effects model of the intraclass correlation coefficient (ICC) described by Shrout and Fleiss.²⁵ Associations between LSA and RNLI scores were examined with Spearman's rho correlation coefficients since the RNLI items were quantified with an ordinal scale. The MDC was calculated at a 95% confidence interval using the equation $MDC = 1.96 \times SEM \times 2^{1/2}$ where 1.96 represents the z-score at a 95% level of confidence, SEM is the standard error of measurement, and where the $2^{1/2}$ component reflects additional uncertainty introduced by using difference scores at 2 points in time. Kolmogorov-Smirnov tests assessed normality in the distribution of scores.

Receiver operating characteristic (ROC) curves determined the LSA composite score most likely to distinguish between persons with a restricted LS, which we defined as mobility limited to in or around the home (LS 0, 1, or 2), from those with an unrestricted life space (LS 3, 4, or 5). We considered unrestricted life space to include mobility into the neighborhood or beyond, because persons with SCI may use a wheelchair (WC). Uneven terrain encountered in the neighborhood, such as gravel, inclines, and curbs, could be viewed as prohibitive for mobility by WC users, potentially resulting in them using the same mode of transportation in the neighborhood and outside of town.

Results

Characteristics of the sample and mean LSA scores according to the cervical and thoracolumbar subgroups are shown in **Table 1**. The 2 groups did not differ significantly except for equipment usage. Persons in the cervical group were more likely to use a power WC for indoor ($\chi^2 = 13.522, p = .004$) and outdoor ($\chi^2 = 23.892, p < .001$) mobility, whereas those in the thoracolumbar group were more likely to use a manual WC. In addition, only persons in the cervical group reported using a hospital bed ($n = 7, \chi^2 = 8.140, p = .004$). Despite these differences, mean LSA scores were not significantly

different between groups [mean difference = -8 points; 95% CI, -22 to 6; $t(48) = -1.214, p = .231$].

When considering the entire sample ($n = 50$), the mean composite LSA score at the first phone interview was 66 ± 25 and was not significantly different from that of the second interview [$66 \pm 24, t(49) = 0.379, p = .706$]. The ICC for test-retest reliability was 0.876, (95% CI, 0.792-0.928). Moderate²⁶ positive correlations were found between the scores of the LSA and the RNLI total, physical, and social scores (Spearman's rho = .518, .509, and .539, respectively; $p < .001$). The MDC of the LSA was approximately 23 points. Scores were normally distributed across the sample (**Figure 2**).

LSA cutoff scores differentiating persons with a restricted from an unrestricted life space were determined according to whether personal assistance or equipment was needed for mobility. When the sample was divided into restricted and unrestricted life space according to the maximum level attained with or without equipment but no personal assistance, the cutoff score was found to be 49, with a sensitivity of 90% and a specificity of 90% (positive likelihood ratio = 9) (**Figure 3**). Persons who did not require assistance from another to mobilize into the neighborhood or beyond were 9 times more likely to have an LSA composite score greater than 49. Dividing the sample into restricted and unrestricted life space according to the maximum level attained without equipment or personal assistance increased the cutoff score to 78.5 (sensitivity of 76.9%, specificity of 81.1%) (**Figure 4**). In other words, persons who mobilized independent of equipment or assistance into the neighborhood or beyond were 4.1 times more likely to have an LSA score above 78.5. In addition, post hoc analysis revealed that their RNLI scores were significantly greater than those of persons who used equipment or personal assistance and had a restricted life space ($z = -2.349, p = .019$). The RNLI scores were also significantly different between these unrestricted and restricted groups (mean 21 vs 19 total score, 16 vs 14 physical score, 6 vs 5 social score, respectively; $p < .0001$).

Discussion

This is the first study to report LSA scores for an SCI-only population consisting of persons with tetraparesis or paraparesis who were

Table 1. Comparison between the cervical and thoracolumbar groups

	Cervical (<i>n</i> =25)	Thoracolumbar (<i>n</i> =25)	<i>p</i> value
Age, years	46.12 ± 12.70	43.48 ± 13.80	.485
Years post injury	10.24 ± 6.63	11.92 ± 8.84	.451
AIS score (no. of participants)			.232
A	9	14	
B	3	0	
C	2	2	
D	11	9	
Gender			.758
Male	18	17	
Female	7	8	
Primary method of home mobility ^a			.004
Power WC	9	0	
Manual WC	5	14	
Walking aid	3	2	
No equipment	8	9	
Primary method of community mobility ^b			.0001
Power WC	11	1	
Manual WC	1	14	
Walking aid	8	2	
No equipment	5	8	
Ambulation status			.803
Full- or part-time	13	12	
Nonambulatory	12	13	
Hospital bed use ^a	7	0	.004
Need for personal assistance			.069
Yes	16	14	
No	9	11	
Unrestricted life space without equipment or assistance	5	8	.365
Unrestricted life space without personal assistance, equipment may be used	17	23	.182
Unrestricted life space, equipment or assistance may be used	24	25	.951
Mean LSA score			.706
Time 1	62 ± 23	70 ± 25	
Time 2	61 ± 23	70 ± 24	

Note: Information obtained via participant report during first phone interview except age, years post injury, American Spinal Injury Association Impairment Scale (AIS) score, and gender were determined by medical chart review. Means and standard deviations are reported for life space assessment (LSA) data, because the data are normally distributed. WC = wheelchair.

^aCorrelation is significant at the .01 level (2-tailed).

^bCorrelation is significant at the .001 level (2-tailed)

ambulatory or used a wheelchair. The LSA has been characterized as a participation measure in the literature^{13,27,28} and could fulfill a need for outcome measures appropriate for persons with SCI regardless of their means of mobility.²⁹ Life

space scores were normally distributed across the sample, suggesting that the chance for floor or ceiling effects when using the LSA would be low. Scores for our sample indicated their life space was greater than that of older persons who used

Figure 2. Distribution of composite Life Space Assessment (LSA) scores ($N = 50$). Range of participant scores, 12 to 120. No one scored between 0 and 10.

Figure 3. Detecting unrestricted life space in persons with spinal cord injury (SCI) who may use equipment but do not require personal assistance. The area under the receiver operating characteristic curve (AUC) illustrates the accuracy with which Life Space Assessment scores differentiate between people with restricted and unrestricted life spaces who may use equipment but not personal assistance [AUC = .954; 95% CI, (.9 to 1.0); $p < .001$]. A score of 49 distinguishes between restricted and unrestricted life spaces with 90% sensitivity and 90% specificity.

Figure 4. Detecting unrestricted life space in persons with spinal cord injury (SCI) who do not use equipment or personal assistance. The area under the receiver operating characteristic curve (AUC) illustrates the accuracy with which Life Space Assessment scores differentiate between people with restricted and unrestricted life spaces when equipment and assistance are not used [AUC = .852; 95% CI, 0.746-0.958, $p < .001$]. A score of 78.5 distinguishes between restricted and unrestricted life spaces with 76.9% sensitivity and 81.1% specificity.

wheeled mobility, either manual (LSA = 46.99)¹⁶ or power (LSA = 33),¹⁴ but smaller than that reported for a population-based study of persons aged 15 to 90 years (LSA = 98.3).³⁰ Despite the younger age of our sample, their LSA scores were comparable to the average reported for community-dwelling older adults with a mean age of 75 years (64.1 ± 24.9).⁷

Our LSA test-retest reliability was similar to findings in power mobility users (ICC 0.87).¹⁴ Data were collected by phone interview in these studies, which may account for the slightly lower reliability when compared to face-to-face interviews reported in populations of community-dwelling older adults (ICCs of 0.93³¹ and 0.96²⁰).

The LSA correlated moderately²⁶ with the RNLI, indicating that even though the 2 measures are related, they capture different constructs. Our results were similar to Miller and colleagues' report on a sample of community-dwelling adults receiving outpatient rehabilitation, with the exception of the social subscale, which they reported as having no correlation with the LSA (Spearman's $\rho = 0.08$).¹⁵ At the time of data collection, the participants in the Miller et al study had been injured on average just 10 months, which could have affected their ability to reintegrate into social roles. In contrast, our participants were injured on average 11 years, allowing for adequate time, if applicable, for them to learn to use power or manual mobility, obtain equipment needed for

transportation, and resume or adapt to work and other outside activities.

We found that a change of at least 23 points in the LSA would be required to interpret that an actual change in patient performance between 2 assessments has occurred. Changes less than 23 points may result simply from measurement error. Reports from Allman et al³² and Wheeler et al³³ suggested that a change of 10 and 12 points, respectively, was associated with discontinued travel out of town, with even smaller changes potentially being meaningful.³² They did not report the MDC, which is calculated from the SEM based on the standard deviation. A large standard deviation will result in a large MDC. Our standard deviation was comparable to those of the aforementioned studies. Although the threshold for meaningful change may be smaller than the MDC, interpretations about a change score that is smaller than the MDC should be made with caution.

Equipment and personal assistance must provide significant value to the life of persons with SCI, since without assistance only 26% of our sample could mobilize beyond their home. With it, 98% of our population had an unrestricted life space. To apply some meaning to the LSA score, the clinician needs to know whether or not their client uses equipment for mobility, since the maximum score for a full-time wheelchair user can be no greater than 90. We found that scores below 49 if equipment is used and below 78.5 if equipment or assistance is not needed should raise a red flag for restricted mobility, which has been argued to worsen disability and limit participation.⁸ Our own results concur with this supposition; persons in our study with an unrestricted life space without equipment and assistance scored higher on the RNLI, indicating an improved level of return to pre-injury roles compared to those with a restricted life space.

The LSA does not distinguish between gait aid or manual or power WC use; the score is equally, negatively impacted by all devices. Since our 2 subgroups had fairly equal numbers of persons requiring assistance and using equipment for mobility, differences in LSA scores between the 2 could be considered largely derived from

differences in frequency and extent of mobility. We expected scores to be lower in persons with tetraparesis; Benavente et al found that persons with cervical injuries were less mobile than those with thoracic or lumbar spine injuries when assessed with the Craig Handicap Assessment and Reporting Technique.³⁴ The average LSA score of our cervical group was lower than that of the thoracolumbar group, but the difference was not significant. The disparity in findings between the 2 studies was likely due to differences in the characteristics of our sample populations. Incomplete cervical injuries were more common in our sample than complete, which is consistent with national trends.³⁵ Most participants were AIS D, accounting for the large number of persons with some ambulatory ability. Completeness of injury was not controlled for in our study and likely served as a confounding variable. In contrast to participants in the cervical group, the thoracolumbar group was lower functioning than expected, with more than half needing personal assistance for mobility. Dividing this group by high and low paraparesis, like Benavente and colleagues,³⁴ may have helped to further differentiate LSA scores.

Limitations

Interpretations should be made with caution, as ours was a sample of convenience, comprised of persons with chronic injuries who were motivated enough to return their Health Insurance Portability and Accountability Act (HIPPA) form and capable of doing so. Though statistically sound, conclusions regarding cutoff scores were made based on small populations of persons comprising either the unrestricted or restricted groups. Cutoff scores should be tested for predictive validity in a follow-up study. Our study was not powered to compare LSA scores across both level of injury and AIS classification. The large number of persons with incomplete cervical injuries may have elevated the score of that group; findings across level of injury may be considered pilot data, at best. Finally, we did not distinguish between persons with high versus low paraplegia. Dividing our thoracolumbar group

in this manner may have resulted in significant differences between the LSA scores of persons injured at different spinal levels. A follow-up study with a larger sample, powered to consider complete versus incomplete injuries across 3 levels of function (tetraparesis and high and low paraparesis), would be ideal.

Conclusions

The LSA is a reliable and valid measure of life space in persons with chronic SCI regardless of their means of mobility and can be used to

detect restricted life space in persons at risk of mobility disability.

Acknowledgments

All participants of the study provided verbal consent and returned a HIPAA form as directed by the Mayo Clinic Institutional Review Board for the Protection of Human Subjects. We gratefully acknowledge Dr. Patricia Sawyer from the University of Alabama for sharing information and resources regarding the Life Space Assessment at the start of our project.

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