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ORIGINAL ARTICLE

Proposal and validation of a clinical trunk control test in individuals with spinal cord injury

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Study design: One of the problems that arise in spinal cord injury (SCI) is alteration in trunk control. Despite the need for standardized scales, these do not exist for evaluating trunk control in SCI.
Objective: To propose and validate a trunk control test in individuals with SCI.
Setting: National Institute of Rehabilitation, Mexico.
Methods: The test was developed and later evaluated for reliability and criteria, content, and construct validity.
Results: We carried out 531 tests on 177 patients and found high inter- and intra-rater reliability. In terms of criterion validity, analysis of variance demonstrated a statistically significant difference in the test score of patients with adequate or inadequate trunk control according to the assessment of a group of experts. A receiver operating characteristic curve was plotted for optimizing the instrument's cutoff point, which was determined at 13 points, with a sensitivity of 98% and a specificity of 92.2%. With regard to construct validity, the correlation between the proposed test and the spinal cord independence measure (SCIM) was 0.873 ($P=0.001$) and that with the evolution time was 0.437 ($P=0.001$). For testing the hypothesis with qualitative variables, the Kruskal–Wallis test was performed, which resulted in a statistically significant difference between the scores in the proposed scale of each group defined by these variables.
Conclusion: It was proven experimentally that the proposed trunk control test is valid and reliable. Furthermore, the test can be used for all patients with SCI despite the type and level of injury.
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INTRODUCTION

Spinal cord injury (SCI) is an alteration of the spinal cord that modifies not only muscular strength and sensitivity but also generates a change in all systems of the organism. Damage to the ascending and descending pathways of the spinal cord consequently results in an alteration in the postural control system.[1] Effective control of posture is of utmost importance for standing and walking, as well as for providing support for voluntary movements; therefore, in patients with SCI, functional performance and independence during activities of daily living are deeply affected.[2,3] Furthermore, trunk stability has been identified as the third most important achievement in treatment that can substantially improve the patient's quality of life.[4]

For this reason, a part of the objectives of rehabilitation of individuals with SCI include improvement of trunk control to achieve independence in daily life, diminish complications and, in specific cases, regain the ability to stand and walk.[2,5]

The spinal column, being located in the posterior part of the trunk, acts as a fulcrum for flexion and extension. The abdominal flexors have a long moment arm compared with their antagonists. Meanwhile, the abdominal oblique muscles, which are symmetric, provide strength for lateral stability.[4] In thoracic and cervical injuries, these muscles are weak or plegic resulting in loss of trunk control. The way in which patients with SCI maintain their balance while sitting has been widely studied and it has been shown that persons with SCI adopt different postural strategies to control balance during the performance of various tasks utilizing non-postural muscles, such as the latissimus dorsi and the trapezius, which can be trained with good results. It has also been suggested that patients with thoracic SCI compensate for the instability of the pelvis and the lower column with a passive posterior inclination of the pelvis and by resting on the back of their wheelchair.[2,6]

Analysis of balance relies either on instrumentation or on clinical tests. There are few quantitative measures in SCI for the evaluation of balance. Among these, the ones that use force platforms and electromyography to register changes in the center of gravity and muscle activation patterns are noteworthy.[7,8] Although these measurements provide precise and quantitative data, their use in clinical practice is limited because of time constraints, equipment cost and the need for experience in use and interpretation. Clinical tests have the advantage of being able to be conducted in practically any situation and in every patient. There are tests to clinically assess trunk control in other pathologies of the central nervous system (CNS) that have yielded important data, not only for the initial evaluation of these patients but also for follow-up, prognosis and the degree of functional independence.[9]

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The Berg balance scale, which was originally created to determine the risk of falls among elderly patients, was analyzed for use in SCI patients in two studies.[10,11] Both of them determined that the Berg scale has a ceiling effect. Also, because it has only one item for evaluating balance while the patient is seated, it is probable that in individuals with an SCI who cannot stand or walk there will be a floor effect.

Among all of the clinical tests for the evaluation of trunk balance, only a few are specific for individuals with SCI.[12–16] The ones that are mostly used only evaluate posture in the sitting position. However, trunk balance is defined as the capacity to maintain the postural control of the trunk, including moving and shifting body weight from side to side to release one limb for a particular function, such as reaching or grasping. The weight change can be anterior, posterior, lateral, or diagonal and involves reactions of straightening, balancing, or protecting. Postural control in turn has been defined as the capacity to maintain balance in the face of internal or external disturbances with the purpose of maintaining the center of the body mass within the support base.[4,17] Although maintenance of posture in the sitting position is part of trunk control, it does not reflect the full construct. Thus, these scales should be complemented to evaluate trunk balance in its totality. Furthermore, although these clinical tests are useful in clinical practice, more studies are needed to determine their validity, reliability and minimal detectable change.

Despite the importance of postural control in individuals with SCI and the usefulness of scales that assess trunk control in other CNS pathologies, to date there are no valid clinical tests that evaluate trunk control in all individuals with SCI, regardless of the severity of injury and its neurologic level.

Thus, the main objective of this work was to propose a clinical test of trunk control in individuals with SCI and to determine whether the test is reliable and valid. This scale was developed according to two principal ideas: 1) postural control is based on two main skills: to maintain a certain posture and to ensure balance during position changes; 2) a useful scale must be applicable to all individuals, including those with poor postural performance.

MATERIALS AND METHODS

Study type

Descriptive, observational and transversal.

Study universe

The test was applied to all patients at the Division of Neurological Rehabilitation, External and Hospitalization Consultation of the SCI Service, in the National Institute of Rehabilitation (INR). People between the ages of 15 and 65 years, both male and female, with a clinical diagnosis of SCI of any type and of any neurological level, with any time of evolution and any etiology, were included in the study. The exclusion criteria were as follows: another neurological brain diagnosis, any alteration in sensory organs, any orthopedic, metabolic or cardiovascular condition that impedes the performance of the test, or alterations in mental functions. The ethics committee approved the realization of the study.

Sample size

Sample size was calculated with the Epidat 4 software program (Santiago de Compostela, A Coruña, Spain). With the preliminary results of 96 patients, we performed a sample size calculation. A total of 157 patients are required for a sensitivity of 97%, a specificity of 92.1%, a study power of 80% and a 95% confidence interval (CI).

Description of the study variables

See Table 1.

Procedure

Development of the trunk control test in individuals with SCI. A review of the trunk control tests in other diseases of the CNS was carried out[8,10] and the items that could be used in SCI cases were selected—that is, those that would not require standing or walking and that would not make a distinction between a healthy and an affected hemibody. In addition, three items that correlate with keeping balance during activities of daily living were created. Finally, some tests utilized to assess trunk balance during the performance of activities with the upper limbs were considered.[8–10] Grossly, trunk control can be classified in static and dynamic control depending on the presence of an external force. In the proposed scale, static control was assessed by three items that evaluate the maintenance of the sitting posture for 10 s with variations in posture of the lower extremities. Dynamic control was divided into two parts: (1) dynamic control as such, which evaluates four items for the maintenance of posture during activities (trunk flexion while sitting, in decubitus and while rolling); (2) dynamic control focused on performing activities with the upper extremities, which includes six items that evaluate the maintenance of the sitting posture while performing reaching activities in different positions using the upper extremities. It must be mentioned that these items were adapted from the sitting posture tests found in the literature. Both the scale and a detailed description of the classification for each item are presented in the Supplementary Material. The minimum score is 0 when the patient is unable to perform any task and the maximum is 24. The average time for performing the test is 8 min.

The test was evaluated by an experts committee comprising two specialists in Neurological Rehabilitation and two specialists in Pediatric Rehabilitation with experience in the assessment of patients with alterations in trunk control to determine the validity of the test's contents.

Once content validity was obtained, we proceeded toward evaluation of the patients. After the patients had signed a letter of informed consent, they were examined on mattresses 50 cm high, with an area of 2×2.5 m. We formed a group of experts that consisted of three Physician Specialists in Neurological Rehabilitation and a Physician Specialist in a high-specialty course on Neurological Rehabilitation, all of whom determined the trunk control type that each patient presented; the evaluation was conducted in conjunction but independently. The group of experts evaluated each patient at the same time but independently. They used their clinical criteria to evaluate the patient's sitting posture, their movements in decubitus and their response to an externally applied force in order to determine whether the patient had adequate postural control. Each expert used their own criteria and was trained in different hospitals. All four evaluations were kept in closed envelopes until a researcher who was not involved in the evaluations read them and qualified trunk control as adequate or inadequate when there were at least three identical answers. Immediately after the evaluation by the group of experts, two physicians who were not present during this evaluation applied the proposed test, which is precisely described in Supplementary Material. They both applied the test independently and the tests were identified only by the patients' medical record number.

Immediately after this evaluation, two physicians observed all of the individuals in conjunction, but independently and without knowing the result of the group of experts. In addition, one of the physicians performed the test on each subject 1 day before or 1 day after in an independent manner; determination of whether the evaluation was before or after was randomized. The subjects were evaluated at the same time of day to avoid fatigue-related differences. None of the observers knew the SCI type, the neurological level, the time of evolution, the age of the patient and whether the patient had achieved the ability to stand or walk. For inter-rater reliability, we analyzed two tests of each patient carried out by two observers in conjunction with each other but independently. For the reliability of the test–retest, the tests were performed by the same observer 1 day before or 1 day after they were analyzed.

The assessments were carried out near the patients in order to assist them if they lost their balance.

The data were transcribed onto an Excel table by an investigator who was not present during the evaluation of the patients.

Statistical analysis proposed

The significance level was 0.05.

Table 1 Description of the variables

Variable	*Conceptual definition*	*Operational definition*	*Measuring scale*	*Unit/values*
Trunk control test	Score in the trunk control test	Maximal score reached in trunk control test	Discrete quantitative	Score between 0 and 24 points
SCI type	According to ASIA, with ISNCSCI modifications[19] A: complete, B: incomplete, preservation of only sensory function, C: incomplete, more than one half of key muscles in <3, D: incomplete, more than one half of key muscles in >3, E: total recovery	A, B, C, D, E	Nominal qualitative	0 = A 1 = B 2 = C 3 = D 4 = E
Neurological level of SCI	Most caudal segment of spinal cord with normal function	Upper cervical of C1–C3, Lower cervical of C4–C8, Upper thoracic of T1–T6, Lower thoracic of T6–T12 Sacro-lumbar	Nominal qualitative	1 = Cervical 2 = Upper thoracic 3 = Lower thoracic 4 = Lumbar 5 = Sacral
Time of evolution of BML	Time in months from the SCI to time of questionnaire application	*N* (months)	Continuous quantitative	Months
Age of patient	Years passed from date of birth	Years completed at time of application of test	Discrete quantitative	Years
Standing	Achieves maintaining self on lower limbs	Yes, independently Yes, with stabilizers No	Qualitative	1 = Yes, without stabilizers 2 = Yes, with use of stabilizers 3 = No
Walking	Achieves traveling from one point to another	Yes, independently Yes, with aids No	Qualitative	1 = Yes, independently 2 = Yes, with aids 3 = No
Trunk control according to a group of experts	Consensus of clinical evaluation of trunk control according to 4 experts	Adequate or inadequate	Dichotomic nominal qualitative dichotomic	0 = Adequate 1 = Inadequate
SCIM (Spinal cord independence measure)[20]	Measuring of functional independence in SCI	Degree of independence for performing self-care activities, sphincter control, transfers, locomotion	Discrete quantitative	Score, level of independence, 0–100 points

Abbreviations: ASIA, American Spinal Injury Association; ISBCSCI, International Standards for Neurological Classification of Spinal Cord Injury.

Reliability calculation. Reliability was measured by means of stability measurements (test–retest and inter-rater reliability). The data were analyzed by weighted kappa. In addition, internal consistency measurements were taken by means of the Cronbach alpha coefficient. Acceptable reliability was considered with values >0.75.

Validity calculation

Content validity. The test was evaluated by two specialists in Neurological Rehabilitation and two specialists in Pediatric Rehabilitation, with experience in the assessment of patients with trunk control alterations. The experts evaluated the test to ensure that all 13 items truly reflected the universe, behind the construct of trunk control. We additionally carried out exploratory and confirmatory factorial analyses. The components were chosen for further analysis if they had initial self-values >1.

The self-values (eigenvalues) reflected the components determined by factorial analysis.

Criteria validity. The Mann–Whitney *U*-test was utilized between the proposed test and the assessment by the group of experts, being one quantitative and one qualitative variable. As the data did not have a normal distribution, we applied the Kruskal–Wallis test. Logistic regression was carried out to evaluate the relationship between these variables. By means of receiver operating characteristic curves, the instrument's cutoff point was optimized to achieve maximal sensitivity and specificity.

Construct validity. Construct validity was evaluated by means of a hypothesis test to test the correlation between the proposed test, the SCIM, and time of evolution. The Pearson test was employed for this correlation. A coefficient >0.75 was considered acceptable. For the qualitative variables (SCI type and level, standing, and walking), analysis of variance was carried out by means of the nonparametric Kruskal–Wallis test.

RESULTS

A total of 531 tests were carried out on 177 patients at the National Institute of Rehabilitation (INR).

Descriptive statistics

In all, 72.9% of the patients were male. The average age was 38.1 ± 14.29 years (range, 16–81 years). Regarding SCI, the average time of evolution was 6.65 ± 8.38 months (range 0–60 months). Overall, 53.1% of patients had complete injuries, according to ASIA with ISNCSCI modifications,[15] 18.6% had grade B injuries, 17.5% had grade C injuries and 10.7% had grade D injuries. For neurological level, cervical injuries were present in 39.5% of the patients, high thoracic levels in 32.2%, low thoracic levels in 22% and lumbar injuries in 6.2%.

Reliability

A total of 354 tests of 177 patients were analyzed to determine inter-rater reliability. For determining the reliability of the test–retest, 177 tests were performed by the same observer.

For inter-observer reliability a pondered Kappa of 0.987 ($P = 0.001$) was found. The value for the test–retest reliability was 0.999 ($P = 0.001$). Cronbach's alpha coefficient was also analyzed to determine the scale's internal consistency. It had a value of 0.979.

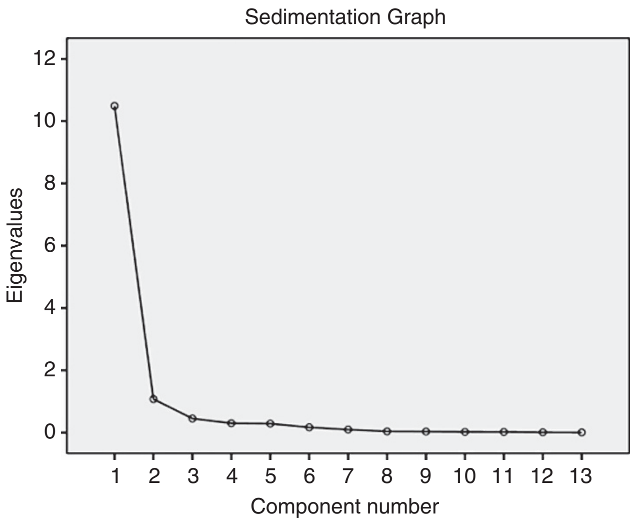

Figure 1 Sedimentation graph. Thirteen components and their respective eigenvalues. Only two of them have an eigenvalue of more than 1 for which only these values were considered in the rest of the factorial analysis.

Table 2 Matrix of rotated components

	Component	
	1	*2*
Static equilibrium 1	0.649	0.522
Static equilibrium 2	0.784	0.493
Static equilibrium 3	0.784	0.502
Dynamic equilibrium 1	0.807	0.438
Dynamic equilibrium 2	0.745	0.506
Dynamic equilibrium 3	0.305	0.936
Dkinamic equilibrium 4	0.18	0.924
Static equilibrium with upper limbs 1	0.865	0.374
Static equilibrium with upper limbs 2	0.887	0.358
Static equilibrium with upper limbs 3	0.931	0.275
Static equilibrium with upper limbs 4	0.914	0.312
Static equilibrium with upper limbs 5	0.933	0.277
Static equilibrium with upper limbs 6	0.921	0.301

Method of extraction: main component analysis.
Rotation method: varimax with Kaiser normalization.
The rotation has converged at three iterations.

Validity

Content validity, factorial analysis. All of the items were consistent, because they presented high corrected total element correlation. In addition, Cronbach's alpha coefficient, on eliminating the element, remained practically the same; thus, it was decided to maintain all of the items.

The data were analyzed by means of main component analysis by varimax rotation. All of the communalities were high.

Two components were chosen, which explains the 88.94% variance, as shown in Figure 1.

As can be observed in Table 2, the prime factor has a high load for the following variables: static equilibrium, 1, 2 and 3; dynamic equilibrium, 1; and static equilibrium with use of upper limbs, 1–6. For the second factor, it was found that the variables with the highest load were the following: dynamic equilibrium, 2, 3 and 4. Thus, we are able to define factor 1 as static equilibrium and factor II as dynamic equilibrium. It is noteworthy that there are relatively high loads in both factors; therefore, item 1 is composed of 42.1% of static equilibrium (factor I) and 27.2% of dynamic equilibrium (factor II). Static equilibrium item 3 is composed of 61.4% of static equilibrium and 25.2% of dynamic equilibrium, whereas dynamic equilibrium item 2 is composed of 55.5% of static equilibrium and 25.6% of dynamic equilibrium.

Criteria validity. The Mann–Whitney *U*-test demonstrated a statistically significant difference between the scores of patients with adequate and inadequate trunk control with $P=0.001$, with an average score of 20.43 ± 3.87 for individuals with adequate trunk control and an average score of 4.88 ± 5.42 for individuals with inadequate balance.

Logistic regression was conducted to evaluate the relationship between these variables. As can be observed in Table 3, the estimated parameter was 0.613, which is statistically significant ($P=0.001$) according to the Wald test. The estimate of the odds ratio was 1.846 (range, 1.428–2.385), which means that for each increase of one point on the scale there is a 1.846-fold greater probability of having adequate trunk control. The results of the regression show statistical significance by means of the Wald test.

Table 3 Variables in the logistic regression equation

	B	*s.e.*	*Wald*	*df*	*Sig.*	*Exp*(B)	*95% CI for EXP*(B)	
							Lower	*Upper*
Step 1								
Score	0.613	0.131	21.945	1	0.000	1.846	1.428	2.385
Constant	–8.949	1.909	21.987	1	0.000	0.000		

Abbreviation: CI, confidence interval.
B = values for the logistic regression equation for predicting the dependent variable from the independent variable; df = degrees of freedom for the model; Sig. = two-tailed *P*-value for Wald chi-square value; Exp(B) = odds ratios for the predictors;

A receiver operating characteristic curve was plotted to optimize the cutoff point of the instrument, which is shown in Figure 2.

Construct validity

Hypothesis test. The correlations between the score of the proposed scale and the quantitative variables are summarized in Table 4. As can be observed, there is a strong and positive correlation between the proposed scale and SCIM. In relation to time of evolution, the correlation is positive, but weak, although statistically significant. For the hypothesis test with the qualitative variables, the results are presented in Table 5. As can be observed, a statistically significant difference was found among the scores in the scale proposed for each group defined by these variables.

With these results, a power of 86% is obtained for sensitivity and one of 81% for specificity.

DISCUSSION

Trunk control evaluation is a key point in the rehabilitation and follow-up of individuals with SCI. There are two basic methods for evaluating postural capabilities. The first is based on instrumented techniques that provide an objective and measurable evaluation but are time-consuming and expensive; they require specialized personnel and they cannot be used in all types of patients.[16] The second method is based on clinical tests that have the advantage of being applicable to any type of patient; moreover, they are easy to perform and interpret

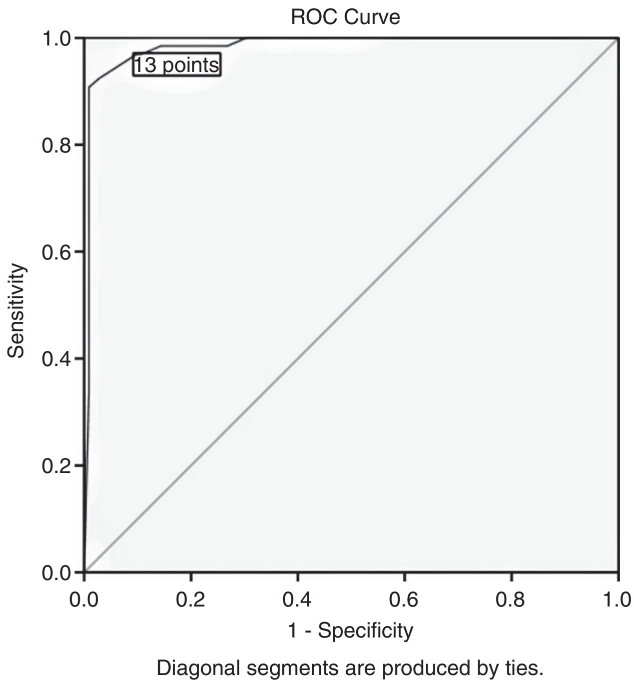

Figure 2 Receiver operating characteristic (ROC) curve for scoring in the proposed scale and assessment by a group of experts. We found an area under the curve of 0.984 and determined that the best cutoff point is 13 points in the test of the study. For this value, we found a sensitivity of 98% and a specificity of 92.2%.

Table 4 Correlation coefficients between the proposed scale and the quantitative variables

	Pearson correlation	*P*-value
Scale/SCIM	0.873	0.000
Scale/time of evolution	0.437	0.001

Abbreviation: SCIM, spinal cord independence measure.

and do not require sophisticated equipment. This is why clinical tests that are reliable, valid and have good feasibility and clinical significance are required for the health-care professionals who provide care for individuals with SCI.

The trunk balance scale proposed in this study appears to be a reliable test. In fact, a high intra- and inter-rater stability was found. For the assessment of the intra-rater stability, the trials were carried out 1 day apart, because in acute stages trunk control can vary drastically within a short period of time. Memory does not play an important role in trunk control assessment;[17] therefore, it is unlikely that the high correlation is due to this short period of time. Also, in order to avoid observation bias in the inter-rater stability, it was ensured that the evaluations of both observers were carried out independently. The tests for balance evaluation in the sitting posture show lower reliability. In effect, the results of the test–retest vary from 0.51 to 0.94 depending on the test and the patient's neurological level.[13–16] The high correlations found in this study are probably due to the way the scale has been designed, with simplified and detailed elaboration of the items, which renders it understandable and easy to apply and interpret for the evaluator as well as for the patient. These results suggest that other clinicians in other places could use this test in their daily practice and research.

Table 5 Contrast between the proposed scale and the qualitative variables

Variable	*Mean (s.d.)*	*Significance*
Neurological level		
Cervical	5.21 (6.93)	0.001
Upper thoracic	9.67 (7.82)	
Lower thoracic	18.42 (6.18)	
Lumbar	21.86 (3.30)	
Lesion type		
A	8.33 (8.38)	0.001
B	9.61 (9.42)	
C	13.33 (7.94)	
D	19.00 (6.73)	
Standing		
No	5.75 (6.38)	0.001
Yes, with stabilizers	19.39 (3.98)	
Yes, independently	22.84 (2.3)	
Walking		0.001
No	8.33 (7.79)	
Yes, with assistance	23.15 (1.61)	
Yes, independently	24	
Chronicity		
Acute (<12 months)	9.14 (8.43)	0.001
Chronic (>12 months)	18.98 (7.38)	

To determine the test's validity, its content, criteria and construct validity were studied. Content validity was evaluated by four experts, who determined that each of the items and the whole test do indeed evaluate the different aspects of trunk balance. In addition, descriptive and exploratory factorial analyses were performed and the results support the content's validity.

There are several tests that evaluate stability during the sitting posture, but there is no gold standard to evaluate trunk control in individuals with SCI to which the proposed test can be compared. That is why the criterion validity was performed between the score of the proposed scale and the clinical evaluation by a group of experts. We achieved determining a cutoff point, which suggests, with a specificity of 92.2% and a sensitivity of 98%, that individuals with a score of 13 or more have adequate trunk control. It was proven that this test is sensitive to change because the risk of having adequate trunk control increases 1.846 times with every point increase in the test.

Construct validity was evaluated by means of a hypothesis test on comparing the proposed scale's score with different variables that form part of the frame of reference behind trunk balance. It has been demonstrated that maintenance of posture in individuals with SCI is associated with neurological level and SCI type, as well as with time of evolution.[18] Some clinical tests for balance in the sitting posture[13–15] show different results according to the neurologic level and elapsed time since the injury. Lynch *et al.*[13] state that the functional reach varies according to the neurologic level. Sprigle *et al.*[14] were able to show a difference in the performance of the functional reach tests, reach area and bilateral reach when comparing individuals with cervical, thoracic and lumbar injuries. Boswell-Ruys *et al.*[15] demonstrated that upper-body balancing, the maximum balance range, the coordinated stability, the alternate reach test, the sitting reach distance and the T-shirt test can discriminate between patients with lower thoracic injuries and those with T7 to C6 injuries. They also encountered differences between individuals at less than a year from the injury with those at 1 year or more. In addition, in other pathologies of the CNS,[9] such as cerebral vascular disease and multiple sclerosis, it has been demonstrated that trunk balance is associated with greater functional independence, as well as with standing and walking. In the present study, it was demonstrated that the score in the proposed scale is associated with the SCIM, the type of SCI and its neurological level, with standing and with walking.

The main limitation of this study is that it deals with a population assigned to a hospital. On the other hand, the work has various strengths, among which the large sample size, greater than that calculated, the high correlations found and the study's originality are noteworthy.

CONCLUSIONS

In this study, we propose a valid and reliable clinical test for the evaluation of trunk control in SCI patients. It is a relevant test because of the importance of trunk control in SCI to achieve better functional performance and independence and diminish complications. On the other hand, because this test is easy and quick to perform, as well as reliable and applicable to every type of patient regardless of their neurologic level and type of injury, it will be of great use for clinicians who treat patients with SCI and for research on the subject. It is important to determine whether this test possesses a prognostic value for functional independence, as well as for standing and walking.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Supplementary Information accompanies this paper on the Spinal Cord website (http://www.nature.com/sc)