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Translated from the original in spanish

Original article

Methodology for conventional gait training in patients with spinal injuries. Preliminary study

Metodología para el entrenamiento de la marcha convencional en pacientes con lesiones medulares. Estudio preliminar

Metodologia para o treinamento de marcha convencional em pacientes com lesões medulares. Estudo preliminar

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ABSTRACT

Spinal cord injury is a complex medical condition that disrupts the lives of people who suffer from it, those affected become dependent due to the multiple sequelae that accompany it, among which the loss of gait stands out, standing as one of priorities in neurorehabilitation. Most international neurorehabilitation programs do not include a defined methodology for gait recovery in spinal cord injured patients. Specialists from the International Center for Neurological Restoration created a methodology for this purpose. The objective of the study was to verify the behavior of the application of the methodology with a sample of 5 patients treated at the institution using content analysis, observation and measurement methods. The patients in the sample were evaluated before and after applying the methodology with the SCIM III, WISCI II scales. Treatment lasted 8 weeks for each patient. The results showed an increase in the functional capacity of walking in the patients, without the presence of complications. It is assumed that the

use of the methodology can guarantee a functional process for gait training, in an organized manner in patients with spinal cord injuries.

Keywords: Neurology; Spinal cord injury; Neurorehabilitation; Gait.

RESUMEN

La lesión de la médula espinal es un estado médico complejo que trastorna la vida de las personas que la padecen, los afectados pasan a ser dependientes por las múltiples secuelas que le acompañan entre las que se destaca la pérdida de la marcha, erigiéndose como una de las prioridades en la neurorrehabilitación. La mayoría de los programas internacionales de neurorrehabilitación no incluyen una metodología definida para la recuperación de la marcha de los pacientes lesionados medulares. Los especialistas del Centro Internacional de Restauración Neurológica crearon una metodología con este fin. El objetivo del estudio fue comprobar el comportamiento de la aplicación de la metodología, con una muestra de cinco pacientes atendidos en la institución y se utilizaron métodos de análisis de contenido, observación y medición. Los pacientes de la muestra se evaluaron antes y después de aplicada la metodología con las escalas SCIM III, WISCI II. El tratamiento duró ocho semanas para cada paciente. Los resultados mostraron un incremento de la capacidad funcional de la marcha en los pacientes, sin la presencia de complicaciones. Se presupone que el empleo de la metodología puede garantizar un proceso funcional para el entrenamiento de la marcha, de forma organizada en pacientes lesionados medulares.

Palabras clave: Neurología; Lesión medular; Neurorrehabilitación; Marcha.

RESUMO

A lesão medular é uma condição médica complexa que perturba a vida das pessoas que sofrem com ela, e os afetados se tornam dependentes devido às múltiplas seqüelas que a acompanham, entre as quais se destaca a perda da caminhada, tornando-a uma das prioridades na neuroreabilitação. A maioria dos programas internacionais de neuroreabilitação não inclui uma metodologia definida para a recuperação de pacientes com lesões da medula espinhal. Os especialistas do Centro Internacional de Restauração Neurológica desenvolveram uma metodologia para este fim. O objetivo do estudo foi testar o comportamento da aplicação da metodologia, com uma amostra de cinco pacientes tratados na instituição, utilizando métodos de análise de conteúdo, observação e medição. Os pacientes da amostra foram avaliados antes e depois da aplicação da metodologia com as escalas SCIM III e WISCI II. O tratamento durou oito semanas para cada paciente. Os resultados mostraram um aumento na capacidade de marcha funcional dos pacientes, sem a presença de complicações. Assume-se que o uso da metodologia pode garantir um processo funcional para o treinamento da marcha de forma organizada em pacientes lesionados pela medula espinhal.

Palavras-chave: Neurologia; lesão medular; Neuroreabilitação; Andamento.

INTRODUCTION

Despite advances in medical science, spinal cord injury continues to be one of the most devastating clinical situations, both because of the functional loss it entails and, consequently, the loss of independence of the individual, and because of the limited

possibilities of spontaneous recovery coupled with the lack of curative treatment. Although in recent decades, knowledge in the care of spinal cord injury has evolved significantly, spinal cord injury continues to pose a serious problem from social, economic and physical points of view (Andrade *et al.,* 2019; Barclay *et al.,* 2019; McDaid *et al.,* 2019; Miller *et al.,* 2016; Sutton *et al.,* 2020).

Currently, research is directed towards regeneration (Babaloo *et al.,* 2019), neuroprotection (Sandrow-Feinberg & Houlé, 2015) and medullary plasticity (Hutson & Di Giovanni, 2019), it is sought, above all, to diminish the neurological sequelae left by the disease.

Spinal cord injury affects a small but significant portion of the population. In reviewing all causes of disability in the U.S. from 1976-1980, the rate of spinal cord injury was found to be 17 per 100,000 populations with an average age of 12-42 years and approximately 10,000 new spinal cord injuries typically occur each year (Hidalgo Martinez, 2017).

Treatment is based on the coordination of a group of specialized professionals: doctors, nurses and health professionals among which physical rehabilitation specialists stand out, headed by Physical Culture Graduates and Rehabilitation Technicians who provide optimal care, thanks to the experience of specialized centers and groups committed and trained to provide continuity of care from the place of the accident and throughout the life of the spinal cord injured person. The elements of this therapeutic approach are based on prevention, pre-hospital care, acute care, rehabilitation and lifelong medical follow-up (Miller et al., 2016). Although in recent years it has been the focus of study with technological advances such as nanotechnology or robotics (Holland *et al.,* 2017; Mekki *et al.,* 2018) and scientific advances, such as the application of stem cells with great results in the reconstruction of nerve tissue (Chasman *et al.,* 2019).

In neurorehabilitation, gait training in spinal cord injuries is adapted to the existing residual musculature, so that the type of gait to be achieved, the orthosis and the technical aids for walking (walker or Canadian canes) depend on the strength present in the different muscle groups. The physical work is aimed at working on or re-educating the most important determinants of walking, i.e. maintaining or releasing joint arches, strengthening the musculature, controlling high tone and re-educating coordination and balance. While specifically working on the gait determinants, compensatory strategies are developed that facilitate movement according to the limitations (Holanda *et al.,* 2017; Mazzoleni *et al.,* 2017).

Depending on the level of injury and the functioning muscle groups, the following phases can be progressed through: passive standing, parallel balancing, parallel walking, walking with a walker, walking with a cane in parallel, off-parallel cane balancing, off-parallel cane walking, stairs, and outdoor walking (Chisholm *et al.,* 2019; Midik *et al.,* 2020; Okawara *et al.,* 2020).

In the world, there are many centers dedicated to the rehabilitation of spinal cord injured patients, some with vast experience in this specialty and with established programs, examples of them are the works of Hidalgo Martínez in which the impact of technologies in spinal cord injury is addressed (Hidalgo Martínez, 2017), the methodological conception for hydrokinesitherapy raised by Dra. Lesbia (Jiménez-Pascual, 2013), or the *Exercises and methodology for teaching walking* by Silverio and Lidia for paraplegics (Silva & Rodríguez, 2004).

All of them have in common that their approach is carried out from the field of Physical Culture and are based on pedagogical conceptions that enrich the rehabilitation process, although in no case is a uniform methodology shown for the functional recovery of walking in these patients. The International Center for Neurological Restoration of Cuba (Ciren in Spanish) recently created a methodology for this purpose to be added to its Physical Rehabilitation Program for spinal cord injured patients. The objective is to evaluate in a preliminary way the behavior in the functional capacity of walking of spinal cord injured patients, when applying the methodology for the training of conventional walking elaborated in Ciren.

MATERIALS AND METHODS

Type of study: longitudinal, prospective, quasi-experimental study. In the present study, a single group was followed.

Population: patients admitted to the Clinic of rachimedullary affections, neuromuscular diseases and multiple sclerosis of the International Center of Neurological Restoration, Havana, Cuba, carriers of spinal cord injuries.

Sample: five patients, three women and two men, with spinal cord injuries at the thoracic level, TS:1; T8:1; T10:2; T12:1. The mean age was 26.6 years, with the youngest age being 18 and the oldest 34 years, with a range of 16 years, and a standard deviation of 6.804.

Methodology

The methods used were:

Qualitative order

- Content analysis.

Quantitative

- The observation.
- Measurement: one of the most widely used methods, as it was used in most of the study to determine aspects related to gait. It was evaluated with the WSCI III scale and the SCMI III (mobility *item*).

The experiment was organized with the following steps.

a) The sample was randomly selected and met the following inclusion criteria:

- Informed patient consent, in accordance with the Ethical Principles for Biomedical and Physical Activity Related Research Involving Human Subjects of the World Medical Association Declaration of Helsinki ("World Medical Association Declaration of Helsinki. Ethical Principles for Medical Research Involving Human Subjects.

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Edinburgh, Scotland: 52nd General Assembly 2000").

- Patients with the possibility of walking.
- Patients with orthoses.
- Patients who confirmed to stay at least 2 months in treatment.

Output criteria:

- Patients who interrupt treatment for more than one week.
- Patients who for any reason wish to stop treatment.

b) Application of the initial evaluation of the selected patients using the instruments:

- Spanish version of the Spinal Cord Independence Measure version III (eSCIM III).
- Walking Index Far Spinal Cord Injury (WISCI II) Descriptors.

From the SCIM III scale, some *items* related to other activities were excluded and only the analyzed mobility *items* were analyzed (indoor and outdoor, on any surface), which evaluate the patient's gait in certain environments with levels of complexity that allow the Physical Culture specialist to foresee the displacement capacity that a patient can achieve, as well as the reduction of barriers that allow his or her social integration.

- Indoor Mobilities: which defines the patient's ability to move around inside the home and is scored from 0 to 8.
- Mobility over moderate distances: this represents the patient's ability to move over distances between 10 and 100 meters and is scored from 0 to 8.
- Outdoor mobility: this represents the patient's capacity to move over distances greater than 100 meters and is scored from 0 to 8.
- Stair Handling: which evaluate the patient's ability to go up and down stairs which is scored between 0 and 3.

The WISCI II scale was used in its entirety since it is a scale created to evaluate the gait of the spinal cord injured patient and its score ranges from 0 to 20.

c) Application of the methodology for gait training: which consisted of the application of the methodology by 2 neurorehabilitation specialists, selected for 8 weeks for each patient, with the following organization by stages:

Stage 1. Stratification

Objective. To determine the functional status of the patient who begins the rehabilitation process.

Procedures

1. Determination of criteria for not starting or stopping gait testing.
2. Awareness of any limitations that the patient may have for the test to be carried out.
3. Definition of the patient's functional group, according to the functional capacity obtained by gait measurement, in accordance with Table 1 below.

Table 1. - Functional group based on gait

Functional Class	WSCI-II	SCIM (Mobility)	State of gait limitation
I - A	>10	+12	Slight
II - B	6-9	7-11	Moderate
III - C	5	6	Serious

RESULTS AND DISCUSSION

Methodological guidelines according to the procedure

To perform this evaluation, the indications and contraindications described for these tests in general (Ditunno *et al.,* 2013) were taken into account. Some of these indications and contraindications are outlined below.

- Patients with spinal cord injury, who are able to stand and walk on the parallel bars, will be eligible for this test. Only reciprocal gait is considered for this scale. Additional inclusion/exclusion criteria may be necessary.
- Most frequent ASIA A below T10 and B below ASIA, C, and D can be measured with the Ditunno scale (14).
- Patients with quadriplegia will require triceps strength of at least grade-3 or that can support body weight.

Stage 2. Intervention

Objective. To implement the contents to be developed in the training session.

Procedures

1. Recording of individual and control data in the physical training session.
2. Establishment according to the functional groups achieved by the patient of the corresponding dosage.

3. Anticipate any modification of the planned content in response to the process of adapting to the loads or any signs or symptoms that the patient presents during the intervention.

4. Organization of the walking session, in such a way as to allow adequate monitoring, control and safety in accordance with the particularities of these patients.

Methodological indications according to the procedure

1. Record the patient's data in the rehabilitation file.

2. Maintain the indications in terms of intensity and dosage for each functional group, as long as there is tolerance and adaptation to the loads:

- Although there is an initial dosage for each functional group, this may vary according to the patient's adaptation.

- Systematically record and specify the periods in which the adaptations are reached in the different exercises in order to increase the stimulus and the corresponding adaptations occur. Otherwise, evaluate the necessary adjustments in the dosage of the load.

- The introduction of a new content must respect the mastery of a previous one, well executed in terms of technique and well tolerated from the adaptive point of view so that there are no signs of inadequate reinstatement and intolerance to it, in its realization.

- Correspondence between the necessary stimulus increases of the workload with the physiological and clinical responses of the patient to achieve, in a progressive way, the improvement of muscular strength and endurance, as well as functional capacity without risks or complications in the session, which could lead to interrupting or terminating it.

1. Establish in the training session the controls established by the proposal regarding the intensity of the load by observing the patient, as well as the criteria established for not starting or suspending the physical rehabilitation session.

Contents and methodological recommendations for the training session

It begins with stretching and joint mobility exercises, which should take approximately five to ten minutes. Before starting the warm-up, the training pulse and respiratory rate should be checked. To start the training session:

- If the patient reports frequent spasms in the standing position, walking activities should not be started until the spasms subside or are under control (to facilitate the subside of the spasms, the hip should be kept tilted back).

- If the patient has any dysautonomic changes, he/she should be sat up and the nurse should be called for assistance.

- It includes walking activities. The distribution of content by functional group.

There must be a correspondence between the necessary increases in the stimulus of the workload, with the physiological and clinical responses of the patient in order to progressively achieve the improvement of muscular strength and endurance, as well as functional capacity without risks or complications that could lead to interrupting or terminating it.

General indications for walking activities

- Training frequency: five times a week.
- Training volume: 60 to 120 minutes.
- The dosage of the training will be established on the basis of the functional group.
- The workloads are designed for 8 weeks, but if this period of time is extended, the work intensities will have to be adjusted according to the functional group that the patient reaches in the new evolutionary assessment.

General data of the activity

- Repetitions: 10, 15, and 20.
- Recovery time: 2 minutes between sets of exercises.
- Frequency: daily from Monday to Saturday.

Stage 3. Functional assessment

- Objective. To assess the evolution of the patient's functional status.

Procedures

1. Organization and assessing of the rehabilitation file data.
2. Analysis and evaluation of the physical rehabilitation process according to the fulfillment of the work objectives and provide recommendations for the continuity of gait recovery.

Methodological indications according to the procedure

1. Check the rehabilitation file for attendance at physical rehabilitation sessions. In case of interruptions, to mention the reasons.

- To make an assessment of the adaptive response to workloads during the intervention stage and to determine whether there were clinical or other elements.

2. Verify that the indications in terms of intensity and dosage for each functional group have been complied with and that there was tolerance and adaptation to the loads.

- Although there is an initial dosage for each functional group, this may vary according to the patient's adaptation.

- Review the systematic record of the periods in which he reached the adaptations in the different exercises to check that the stimulus was the necessary for the corresponding adaptations to occur. If not, evaluate the necessary adjustments in the dosage of the load for the new cycle of the methodology.

- To verify that the introduction of new contents were well established and tolerated from an adaptive point of view and that they did not cause damage to the osteomyoarticular system, incoordination or any other inconvenience.

- Check that there was correspondence between the necessary increases in the workload stimulus, with the physiological and clinical responses of the patient to progressively achieve the improvement of muscular strength and endurance, as well as functional capacity without risks or complications, which could lead to interrupting or terminating it.

3. Carry out the corresponding functional evaluation to assess the results of the stage worked on and decide on the strategy and/or readjustment in order to continue improving the functional walking capacity achieved by the patient.

Indicators for moving between stages

- Indicators that allow the transition from the first stage to the second stage.

- To have carried out the corresponding scales that specify the functional group in which the patient is in order to specify the intensity and dosage of training that corresponds to him/her.

- To know the comprehensive assessment of the patient carried out by the specialists, any limitations that she presents and the recommendations for this, in order to incorporate the patient into rehabilitation, with her particularities well established.

Indicators that allow the transition from the second to the third stage

- Patients who have had a good rehabilitation prior to admission to the centre and have the corresponding physical conditions and functional abilities and have completed at least 4 weeks of walking activities.

- Patients who have not undergone rehabilitation prior to admission should perform 8 weeks of walking activities.

- That the patient improves by at least 2 points on the WSCI II gait scales and on the mobility scale (SCIM III).

- To have had an adequate physiological response to the workloads that allowed the progressive increase of the functional capacity.

d) Final evaluation of the patients, which was carried out under the same conditions as the initial evaluation and by the same evaluators.

e) Collection, processing and analysis of the results. Descriptive statistics was applied, using the median as a measure of central tendency and the standard deviation as a measure of dispersion for each parameter. In addition, for the analysis of qualitative

variables, the Wilconxon test for related samples was used. The significance level used was $p<0.05$.

All the procedures used in the research were approved by the scientific committee of the Rehabilitation Center and Ciren.

The results obtained by patients in the different tests are shown below (Figure 1), the descriptive statistics of the gait and mobility scales at the beginning and end of the experiment (Table 2), the comparison of the initial values with the final values in gait and mobility (Table 3) and the Functional Assessment (Table 4) in which the functional evolution of each patient is observed.

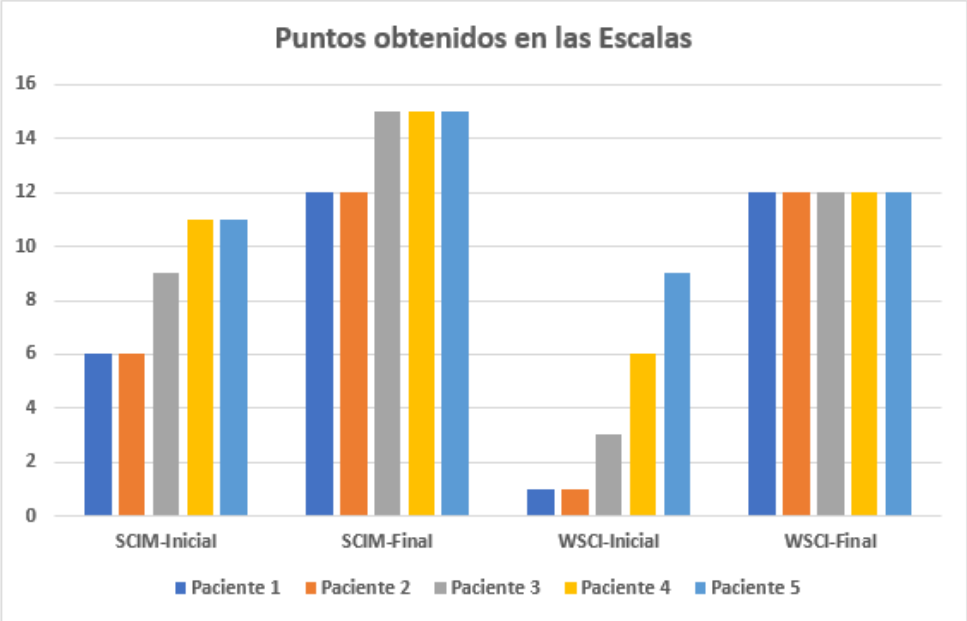

Fig. 1. - Comparison of applied scales

Figure 1 shows the results obtained by the patients in the mobility and gait tests individually.

Table 2 shows the descriptive statistical data of the mobility and gait tests, analyzed as a group, carried out at the beginning and end of the patients' treatment period. The most relevant thing that is observed in both tests is an improvement in the gait parameters of the final values in terms of the median, it is also observed that the dispersion of the data decreases in both tests, also decreasing the range between the maximum and minimum values of the sample (Table 2).

Table 2. - Descriptive statistics

	SCIM_Initial	SCIM_Final	WISCI_Initial	WISCI_Final
Medium	9,00	15,00	3,00	12,00
Typ. deviation	2,510	1,643	3,464	,000
Range	5	3	8	0
Minimum	6	12	1	12
Maximum	11	15	9	12

To verify the hypothesis of the research, the Wilconxon non-parametric test was performed with a significance level of p< 0.5 (Table 3), where it is clearly observed that, in both tests, statistically significant changes are obtained, from which it can be inferred that the improvement obtained by the patients in walking is due to the introduction of the methodology and not to chance.

Table 3. - Contrast statistics[a]

	SCIM_Final - SCIM_Initial	WISCI_Final - WISCI_Initial
Z	-2,032[b]	-2,032[b]
Sig.asymptot. (bilateral)	,042	,042

a. Wilcoxon signed-rank test
b. Based on negative ranges.

Table 4 shows in a functional way how each patient evolved in walking, when applying the instruments, highlighting that all patients, in the scale that evaluates mobility, were able to move with Canadian canes, at least for moderate distances between 10 and 100 meters and in the walking scale itself (WISCI III), all patients were able to move with Canadian canes and orthosis without the help of any person.

Table 4. - Functional assessment of the patients

Patient	SCIM Initial	Final SCIM	Initial WISCI	WISCI final
1	He/she always uses a manual wheelchair for indoor and outdoor mobility.	He was able to move more than 100 meters with Canadian cane with reciprocal gait.	He/she ambles on parallel bars at least 10 meters with a brace with the help of two people.	He/she ambles with orthotics using Canadian canes without assistance.
2	For distances of less than 100 meters he/she uses the walker and for distances of more than 100 metres he needs to be supervised.	He/she was able to move more than 100 meters with Canadian cane with reciprocal gait.	He/she ambles with a walker without assistance for at least 10 metres	He ambles with orthotics using Canadian canes without assistance.
3	He/she always uses a manual wheelchair	He/she was able to move less than 100 meters with Canadian canes with reciprocal gait.	He/she ambles on parallel bars, with orthoses and the physical assistance of a person for at least 10 meters.	He ambles with orthotics using Canadian canes without assistance.
4	Is able to move around with a walker under the supervision of another person.	He/she was able to move less than 100 meters with Canadian canes with reciprocal gait.	He/she ambles with a walker, with orthotics and the physical assistance of a person, 10 metres	He/she ambles with orthotics using Canadian canes without assistance.
5	For distances of less than 100 metres he/she uses the walker and for distances of more than 100 metres he needs to be supervised.	He/she was able to move more than 100 meters with Canadian cane with reciprocal gait.	He/she ambles on parallel bars at least ten meters with orthosis with the help of two persons	He/she ambles with orthotics using Canadian canes without assistance.

The applied methodology guaranteed a logical functional process for gait training, in an organized and structured way, which allowed establishing a common work guide for all the rehabilitators of the International Center of Neurological Restoration that attends spinal cord injured patients. The results of the preliminary study showed an increase in the functional capacity of gait in patients, without the presence of complications.

All patients met the target within 8 weeks. Of the five patients studied, 3 (60 %) were able to walk more than 100 meters using the Canadian canes, according to the final SCIM scale. All five patients, 100 %, were able to amble the distance covered with the Canadian canes and with orthoses, without the assistance of another person, as shown by the final WISCI scale.

With this study, it was possible to prove that when it is had the selected instruments for gait assessment (SCIM III and WISCI II) and it is had an adequate training program, satisfactory results can be obtained as shown by different studies (Calhoun Thielen *et al.,* 2017; Mulcahey *et al.,* 2016). Another achievement of the study is to highlight the positive changes that can be obtained in patients through intensive physical exercise, in patients with spinal cord injury, supported by different studies (Gaspar *et al.,* 2019; Hicks, 2020) and what may represent the achievement of greater independence for the quality of life of patients, obtained by other researchers (Amtmann *et al.,* 2019; Ribeiro Neto *et al.,* 2020). The application of this methodology, with a greater number of patients in different neurorehabilitation contexts and by other specialists in physical neurorehabilitation, presupposes that similar results can be obtained that benefit more patients in less rehabilitation time and facilitate a guide for the work of physical therapists.

The results obtained in the research process showed the importance of the creation and application of the methodology for uniform gait training by specialists, which represents an indispensable methodological contribution in the physical rehabilitation of patients with spinal cord injuries.

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The authors declare not to have any interest conflicts.

Authors' contribution:
Alexander Echemendia del Valle: Conception of the idea, literature search and review, instrument making, instrument application, compilation of information resulting from the instruments applied, statistic análisis, preparation of tables, graphs, and images, database preparation, general advice on the topic addressed, drafting of the original (first version), review and final version of the article, article correction, authorship coordinator, translation of terms or information obtained, review of the application of the applied bibliographic standard