Distribution of Spastic Patterns in Upper Limbs, after damage of Upper Motor Neuron

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Background: *evidence of people who have upper motor neuron damage and develop a pattern of upper limbs spasticity (ULS) is limited. This positive dysfunction signal or secondary to upper motor neuron damage is correlated with loss of function and decreasing independence, thus causing life quality deterioration.* ***Objective:*** *to determine frequencies distribution of the ULS patterns, wrist, fingers and thumb after damage of upper motor neuron.* ***Method:*** *descriptive cross sectional prospective design. A sample to 206 subjects belonging to 17 Health Centers was made. These subjects complied with the inclusion criteria and signed a consent. This evaluation included clinical data and ULS Pattern evaluation (Hefter´s Classification), wrist, fingers (Adapted Zancolli) and thumb (House Classification). Results: The analysis considered each of the evaluated ULS patterns taxonomies evaluated (Hefter´s I to V). Frequencies distribution was researched by means of goodness-of-fit χ2 tests, followed by post hoc review of standardized residuals (z) in each cell. Significantly higher frequencies were identified in: pattern III of upper limbs, wrist neutral ulnar pattern, deep flexor/mixed pattern of Adapted Zancolli, and patterns 3, 4 of the thumb. No taxonomy was associated to evolution time and type of CVA.* ***Conclusion:*** *The study provides relevant evidence about the distribution frequency of spastic patterns, after damage of upper motor neuron. The information provided is aimed to support the therapeutical decision process, thus boosting functional recovery of the upper limbs.*

Keywords: *cerebro vascular accident, spasticity, upper limbs, frequencies distribution*

INTRODUCTION

Spasticity is part of the positive clinical signs of Upper motor neuron syndrome (UMN), as a result of a reflex dysfunction causing rheological changes in muscles, thus causing fibrosis, rigidity and musculoskeletal atrophy1. It starts with variable scenarios, it may occur during the first weeks or one year after a cerebro vascular accident (CVA) 2 happens. Its prevalence is estimated within a range of 4% to 43%, with an disability incidence ranging from 2% to 13% 3. The spastic scenario has a variable scope, from focal impact on some muscle groups

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to a generalized scenario. In this way, it typically appears in upper/lower limbs, by means of typical patterns, thus affecting mainly elbow (79%), wrist (66%) and ankle (66%) 4.
From a clinical perspective, two factors have been identified as leading to spastic posture: a neurogenic factor and another biomechanic factor5. All this associated to hyperactivity of the different muscle combinations forces the affected limbs to adopt anomalous postures/movement patterns6. Typical ULS posture is described as adducted shoulder with internal rotation, plus elbow/wrist bent, closed fist and thumb included7, however, this is not the only pattern which may arise.
Starting from a differentiated analysis of ULS posture and movement, in 2012 Hefter´s defined five patterns, based on musculature affected in each joint and segment position. This classification was proposed as a base for a common terminology, thus allowing to potentially increase interventions effectiveness, such as botulinum toxin 6. This scenario must take into account that some studies are designed with a "single size" point of view, which turn them vulnerable depending on heterogeneity of the sample, thus reducing its statistic power and, therefore, limiting generalization of its results 8.
In order to provide new scientific evidence, the study is aimed to determine frequencies distribution of ULS patterns, after damage of upper motor neuron, including wrist, fingers and thumb.

MATERIAL AND METHOD

Design
A descriptive prospective cross-sectional study was made.

Sample
This is a purposive-nonprobability sample, aimed to recruit subjects belonging to 17 Rehabilitation Centers located in different regions, in Chile, complying with the eligibility criteria who voluntarily accepted to participate in this study. Three months after recruitment the sample was finally made up of 206 subjects (Figure # 1).

Eligibility Criteria
Eligibility criteria were evaluated by a trained professional, who works for each of the Rehabilitation Centers.

Inclusion Criteria
- Age between 18 to 80 years old, with no previous motor disability record.
- To have a diagnosis of Ischemic/hemorrhagic CVA or ECT.
- To present spasticity in upper motor neuron, including wrist, fingers and/or thumb.
- To accept voluntary participation in the study, by signing off his/her informed consent, whether it is personal or by means of a relative.
- Exclusion Criteria
- To have a musculoskeletal pathology on the affected arm.
- To have been shot with botulinum toxin or any other local anti-spastic during the last 6 months prior to the evaluation.

Procedure
30 Health Centers from the south of Chile were invited to participate. Out of all the Institutions, 17 of them authorized their professional kinesiologists and occupational therapists to participate in a training about the study approach and their role as evaluators. This process included review of the registration form and postures to be identified. At a further stage, during one month, a testing period was carried out in each Center in order to solve some issues.
The evaluation included a clinic standardized observation aimed to identify demographic/clinical data, plus search for Hefter´s ULS patterns, such as wrist, fingers and thumb. These were observed while seated and, whenever possible, in orthostatic position, with no assistance or stick-aided. This methodology has already been used by previous researchers 6 9 but, unlike them, this study used direct observation, in order to make an objective evaluation. Neither video records nor dynamic tests were added (ambulation with/with no help for walking) in order to detect the natural pattern of upper limbs, without generating synkinetic patterns which could change the position of the segment evaluated when making efforts, which is a common phenomenon in SMNS 10, which has been

Table 1. Socio-demographic characteristics of the sample

		f	%
Genre	Female		
	Male		
Source (origin)	Urban		
	Rural		
Diagnostic	Stroke		
Stroke type	Ischemic		
	Hemorrhagic		
OCSP	TACI		
	PACI		
	LACI		
	POCI		
Evolution time	Acute		
	Subacute		
	Chronic		
Type of tone alteration	Spastic hypertonia		
	Spastic dystonia		
	Normal		
HTA	yes		
	no		
Cardiac alterations	yes		
	no		
DM	Yes		
	No		
Smoking	yes		
	no		

f: frequency; %: percent; OCSP: Oxfordshire Community Stroke Project Classification; TACI: total anterior circulation infarct; PACI: partial anterior circulation infarct; LACI: lacunar infarct; POCI: posterior circulation infarct;
HTA: Hypertension; DM: Diabetes Mellitus.

reported as hindering patterns classification9. That is why, provisional postures caused by a movement or by involuntary responses to motor functions, such as yawn, were not considered. Next characteristics of the evaluated patterns are described.

Upper Limbs Patterns – Hefter´s Classification 6
Pattern I: it is characterized by internal rotation and shoulder adduction, elbow flexion, fore arm supination and wrist flexion, which ends up in arm fixation in a posture on the chest.

Pattern II: it is characterized by internal rotation and shoulder adduction, elbow flexion, forearm supination and wrist extension.

Pattern III: it is characterized by internal rotation, shoulder adduction and elbow flexion, along with a neutral position of the forearm and wrist.

Pattern IV: it is characterized by internal rotation and shoulder adduction, elbow flexion, forearm pronation and wrist flexion.

Pattern V: it is characterized by internal rotation and shoulder retroversion, elbow extension, forearm pronation and wrist flexion, which ends up in the arm fixation, in a position behind the body. The description is shown in Figure # 2.

Wrist Patterns
Classification based on 3 patterns, was defined by the research team, based on neurorehabilitation clinical experience.

Pattern 1-Neutral Decubitus: it is characterized by an ulnar deviation. Fingers may fully extend, with the wrist in a neutral position, or with less than 20° to 30° of active flexion.

Pattern 2-Extended Decubitus: an ulnar deviation is observed. Wrist may fully/partially extend when fingers are bended, as the wrist extensors are active enough as to have voluntary control.

Pattern 3-Bended Decubitus: it is characterized by a fully bended hand, with a slight possibility of an active extension of the wrist, although full flexion is more usual. The description is shown in Figure # 3.

Fingers Patterns
Superficial finger flexor: Pattern characterized by hyperflexion of the proximal interphalangeal joint (PIJ), with no further action of the distal interphalangeal joint (DIJ), which may have variable degrees of flexion in rest position. Spastic hypertonia marked on the Superficial finger flexor and reduced in deep flexion of the fingers.
Deep finger flexor: Pattern characterized by joint hyperflexion (DIJ), with no further action from the PIJ, which may have variable degrees of flexion in rest position. Spastic hypertonia, marked in FPD and reduced in FSD.
Mixed Pattern: It is characterized by joint hyperflexions DIJ and PIJ; generally, this is characterized by a closed hand or 'clenched fist', as it is associated to participation of the thumb; there is strong spasticity of the superficial finger flexor (SFF) and deep finger flexor (DFF). The description is shown in Figure # 4.

Thumb Patterns
It includes four patterns to describe thumb position. Even though this classification was created for children with cerebral palsy, it is possible to use it for adults, as long as the evaluator keeps in mind the differences with the original patterns 11.

Thumb Pattern 1: it is described as "simple metacarpal adduction". The metacarpal bone (MB) remains in adduction, due to hypertonicity in the adductor and the first dorsal interosseous muscles. Some degrees of active flexion and extension of the metacarpophalangeal joint (MCP) and interphalangeal joints (IP) are possible.

Thumb Pattern 2: it is described as "adduction/ metacarpal flexion ". The metacarpal remains in adduction, just as in pattern 1 and, at the same time, the hypertonicity in the short flexor of the thumb promotes MCP joint flexion. The IP joint still may be able to actively bend and extend.

Thumb Pattern 3: it is a mix of metacarpal adduction and MCP in articular hyperextension.

Table 2. Distributions of patients according to the patterns evaluated and results of χ2 tests and standardized residuals (z) analyses.

Taxonomías de patrones	χ^2	%	*n*	*z*
EESS Hefter (*N* = 146)	152,81***			
Patrón I		3,4	5	-3,98***
Patrón II		9,4	14	-2,17*
Patrón III		52,3	78	10,67***
Patrón IV		19,5	29	0,84
Patrón V		3,4	5	-3,98***
Otro		12,1	18	-1,37
Muñeca (*N* = 140)	92,80***			
Cubitalizada neutra		55	77	7,10***
Cubitalizada en extensión		9,3	13	-3,72***
Cubitalizada en flexión		32,1	45	1,69
Otro		3,6	5	-5,07***
Dedos (*N* = 127)	35,55***			
Flexor superficial		20,5	26	-1,02
Flexor profundo		39,4	50	3,24**
Mixto		34,6	44	2,17*
Otro		5,5	7	-4,39***
Pulgar (*N* = 146)	51,33***			
Patrón 1		25,3	37	1,44
Patrón 2		12,3	18	-2,07*
Patrón 3		32,9	48	3,48***
Patrón 4		28,8	42	2,37*
Otro		0,7	1	-5,22***

Figure 3. Classification of spastic wrist patterns.

		
Cubitalized Neutral	Cubitalized Extension	Cubitalized Flexion

Figure 4. Classification of spastic finger patterns.

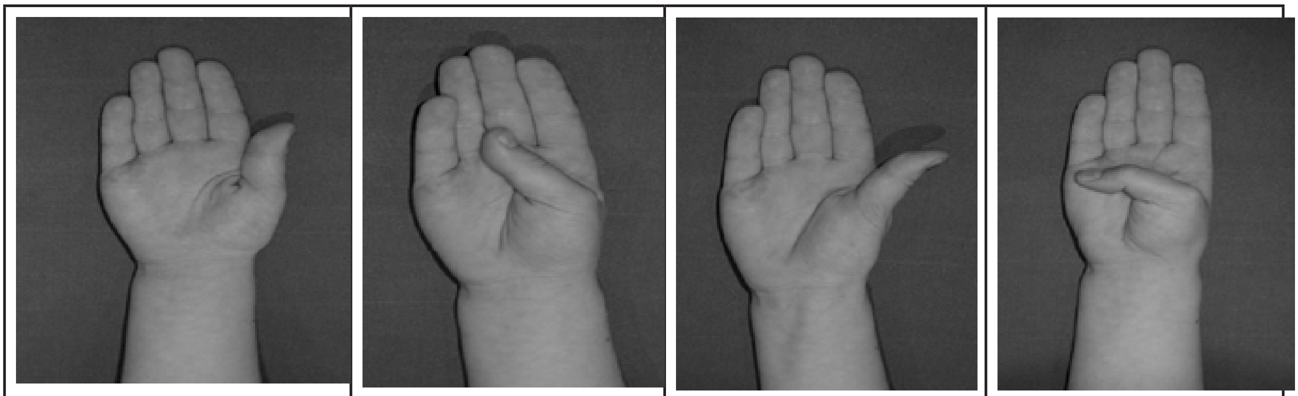
		
Fingers Deep Flexor	Fingers Flexor Superficial	Fingers Mixed

Generally, the MCP joint becomes unstable (a negative functional characteristic) as the metacarpal and the proximal phalange push in different directions, the metacarpal in adduction and the phalange in extension. The difference between thumb Patterns #2 and #3 is the position of the MCP joint, which is bended in Pattern #2 and it is hyperextended, in Pattern #3.

Thumb Pattern 4: it is the typical position of "thumb on the palm", characterized by metacarpal adduction and flexion of the IP joint. This thumb position may be a consequence of hypertonicity and/or contracture in short/long flexors of the thumb. The description is shown in Figure # 5.

Data Analysis
The analysis was made by using software "SPSS 25.0". For each of the patterns taxonomies, the frequencies distribution was found by using the $\chi 2$ tests of goodness-of-fit, followed by post hoc review of standardized residuals (z) in each cell 12. The correlations among each patterns taxonomy and time of evolution variable, measured as acute (1 to 10 days), subacute

Figure 5. House thumb rating.



1	2	3	4

type	description	alteration
1	Metacarpus in adduction	Adductor of the spastic thumb
2	Metacarpus in adduction with phalangeal metacarpus in flexion.	Adductor of the thumb and spastic short flexor
3	Metacarpus in adduction with phalangeal metacarpus with deformity in hyperextension.	Adductor of the spastic thumb with unstable metacarpal phalangeal joint.
4	Metacarpus in adduction with phalangeal and interphalangeal metacarpus in flexion	Adductor thumb and spastic flexor pollicis brevis with spastic flexor pollicis longus.

(10 days to 3 months) and chronic (3 months to 6 months) 13 and type of CVA (ischemic and hemorrhagic CVA, plus ECT) were examined by using the test of independence $\chi 2$, followed by the post hoc review of the corrected standardized residuals. In these two tests, positive/negative residuals with $p \leq 0.05$ were- respectively- interpreted as high frequency (predominant occurrence or above random) and scarce frequency (unusual occurrence or below random). Residuals with $p > 0.05$, i.e. not significant, state the observed frequency is equal to that expectable at random.

RESULTS

The initial sample was made up of 206 subjects; however, when applying taxonomies, 57 patients did not have a spastic pattern in the arm (27.7%), 66 (32.0%) in wrist, 79 (38,3%) in fingers and 60 (29,1%) in thumb. As this study is focused only on patients who suffered spasticity, those who did not have it were excluded of the following analysis.

The analyzed sample finally included 146 subjects. 58.2% of them were men; the average age was 58 years old; 80.8% of them came from urban areas; 95.4% accepted to receive rehabilitation. From a clinical perspective, the main etiology causing spasticity was Ischemic CVA, (70.5%). Its main risk factor was HTA, (65%). Demographic and clinical characteristics are described in Table # 1.

Table # 2 shows distribution of patients, according to 4 taxonomies of spastic patterns, and results of relevant $\chi 2$ tests of a single group, plus the analysis of standardized residuals. All distributions were significantly different from the expected random distribution. For Hefter´s patterns a high frequency of Pattern III and a low frequency of Patterns I, II and V was observed. For wrist, neutral decubitus pattern reported high frequency, while decubitus pattern in extension and the category "another pattern" had a low frequency. For fingers, a high frequency was observed in the patterns of the deep flexor and mixed; low frequency in the category "another pattern". Finally, concerning thumb a high frequency was reported in patterns 3 and 4 and low frequency in pattern 2 and category "another pattern" as well.

No significant correlations ($ps > 0.05$) were found between, on the one hand, taxonomies of evaluated patterns and, on the other hand, variable such as time of evolution and type of CVA; therefore, standardized corrected residuals were not reviewed.

DISCUSSION

This research is aimed to determine the frequencies distribution of 4 taxonomies of spastic patterns after a CVA or a ECT, in a sample of patients in Chile. The joint analysis of these classifications provides a new perspective when including all joints involved in a spastic pattern of upper limbs. The prevailing pattern identified in ULS by means of this study was pattern III, which matches more than half of all cases, which matches prior studies as well 6 9; however, it varies from the classic pattern described in Neurology 14 texts which have to do with pattern IV 6.

In turn, pattern I and V were rather scarce. Both is characterized by depicting extreme postures in joints of the upper limbs. If this information is correlated with the evidence regarding the short time devoted to the upper limbs during a session15, and the approach focused mainly on shoulder and elbow, that would explain the tendency to favor the appearance of complex spastic patterns in wrist, fingers and thumb 16, which lead to complex deformations, mostly affecting functionality and causing problems when performing manual activities 17 18. These approaches require further studies.

Pattern I shows a high spasticity scenario observed in the clinical experience in cases where the patient does not receive an early and periodic rehabilitation therapy. In turn, pattern V involves dystonic extrapyramidal components which may be added to the signs derived from an SMNS.

Regarding patterns involving wrist, fingers and thumb, this research provides evidence about the most frequent postures of such joints. This information may lead the design of therapeutical objectives and decision making by physiatrists, kinesiologists and occupational therapists, regarding usefulness of strategies, such as the use of orthosis and botulinum toxin.

Distribution of spastic patterns frequencies, herein identified, must be carefully interpreted; therefore, as it comes from a sample of patients not selected at random, it cannot be considered, strictly, as indicators of population prevalence.

Even though, clinical experience and scientific evidence consider that spasticity may be beneficial during the rehabilitation process by supporting execution of some functional movements, such as load of some weight in the upper limbs, orthostatism and ambulation 19; it is still a neurologic sign hindering motor functions, after an SMNS. Leading to abnormal patterns of muscle activation and body/joint postures constraining movement of the upper/lower limbs 20. These postures, associated to contractures caused by spasticity, may hinder regular functional performance and induce disability in daily activities 21.

Prevalent pathologies of the central nervous system, such as CVA 22, cause patterns of motor dysfunction in limbs. Its recognition and classification will provide identification of muscle groups responsible, thus orienting and highlighting the importance of interaction between the rehabilitation teams regarding evaluation/intervention strategies aimed to decrease this dysfunction.

Even though there are some recent studies aimed to analyze usefulness and Hefter´s patterns distribution of frequencies, the evidence regarding specific analysis of wrist/finger patterns is limited, thus hindering a comprehensive analysis of upper limbs9.

Findings prove that "clinical manifestations and shoulder/elbow/wrist/fingers patterns of each person after an SMNS, are different". However, understanding patterns, synergies and stereotypical positioning will help the rehabilitation team to interpret the clinical picture and will support setting up objectives and choosing intervention strategies.

For future studies dealing with this topic, it would be interesting to lay down a clinical/radiological correlation regarding spasticity patterns. As well as, depending on the participants´ evolution period it would be necessary to include the Rankin Scale and/or NIHSS Scale, assessing a potential correlation between these scales, patterns classification and spasticity severity.

CONCLUSION

Classification of ULS posture patterns is aimed to be an essential raw material in clinical practice, promoting a common language aimed to foster exchange of information and to support setting up of therapeutical objectives and, as well as to provide orientation for generating future studies in order to define what therapeutical strategies are the best for functional recovery of spastic upper limbs, thus enhancing therapeutical approach of the rehabilitation team.

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This research was approved by the Committee of Ethics of the Health Service, "Araucanía Sur de Chile". The study procedures respected all ethical standards related with the Helsinki Statement (1975), updated in 2008.

This study has been recorded in ClinicalTrials.gov (NCT03588832).

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