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NEUROFUNCTIONAL REHABILITATION IN CHRONIC STROKE

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NEUROFUNCTIONAL REHABILITATION IN CHRONIC STROKE

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"The thoughts of an author should enter our soul like the light in our eyes, with pleasure and without effort; and metaphors should be like a glass that covers the objects, but lets us see them."

Voltaire

DEDICATION

"*Everything which has been achieved in this world, was done thanks to exaggerated hopes*". Jules Verne.

To my family, base of everything.

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SUMMARY

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ABSTRACT

Introduction: The stroke is the major cause of disability worldwide. Currently, ~15 million people suffer from stroke each year. From these ~70-80% of stroke patients present upper limbs functional alterations and the recovery of functional independence with movement patterns as similar as possible to prior the episode, represents an extremely challenging goal. **Objective:** To analyze the effect of a neurofunctional rehabilitation program in the upper limb's functional capacity and motor performance of chronic stroke patients. **Methods:** A randomized controlled clinical trial with chronic participants presenting neuromotor dysfunction after stroke of the middle cerebral artery, randomly assigned to a control (CG) and intervention group (IG) (n=8 and n=15, respectively), was conducted. An eight-week neurofunctional rehabilitation program was delivered to IG, consisting of 16 sessions (of 1h each), and four moments were analyzed: before the intervention (M0), after the first session of neurofunctional rehabilitation (M1), after the 16th program session (M2) and after eight weeks of follow-up for IG (M3). The program was based on different postures experiences, with the adequate facilitation by the therapist. Sensorimotor and proprioceptive stimuli, within typical movement patterns, through functional tasks (reaching for an object, , combing hair, brushing teeth, bathing, dressing a T-shirt, putting on shoes, carrying a plate, a tray, pushing a cart, etc.) were performed, with the necessary repetitions and cognitive stimuli. The Fugl-Meyer Upper Extremity Assessment and the Wolf Motor Function Test were used to assess upper limbs motor impairment and set as sensory-motor impairment, speed, and movement quality variables, respectively. The Modified Ashworth Scale was used to classify muscle resistance to passive movement. The Stroke-Specific Quality of Life Scale was used to assess the quality of life in stroke patients. The International Physical Activity Questionnaire evaluated the moderate-to-vigorous physical activity and the sitting time. Vicon Motion System was used for kinematic evaluation of the two functional tasks: "turning on the light" and "drinking". Relevant variables were analyzed: linear relationship between joint displacements (shoulder-hand and elbow-hand); movement time; mean total movement velocity; peak velocity; movement smoothness (relation between mean velocity and peak velocity). **Results:** The quality of life improved over time in control and intervention groups ($F_{2;42}$ = 5.658; p = 0.019; η^2 = 0.212; Observed power = 0.694). Regarding the speed, differences were found for both groups over time (p = 0.012 vs 0.006 for CG and IG, respectively), but only the intervention group showed improvement in movement quality (CG: p = 0.0001). Concerning the "turning on the light" task, the linear relation of elbow/hand ($F_{3,63}$ = 10.32; p < 0.0001; η^2 = 0.329; observed power = 0.995) improved over time for both groups and of shoulder/hand in the returning phase (IG: p = 0.043). The movement time improved for IG in the "turning on the light" movement (total (s): M0: 3.18 (1.16) and M1: 2.28 (0.66) vs M3: 2.28 (0.60) p = 0.001; "turning on the light" phase: M0: 1.98 (0.77) vs M3: 1.44 (0.47) p = 0.043 and returning phase: M0: 1.19 (0.45) vs M3: 0.83 (0.15) p = 0.001). The peak velocity (anteroposterior: $F_{2,37}$ = 6.37; p < 0.005; η^2 = 0.233; observed power = 0.848); (mediolateral: $F_{2,36}$ = 6.13; p < 0.007; η^2 = 0.226; observed power = 0.820) and movement smoothness (CG: p = 0.012;

IG: p = 0.043) increased after the intervention, regardless the group. In “drinking” task, the movement time at the returning phase decreased over time for IG (p = 0.012) and the forward transportation increased over time for CG (p = 0.06). The smoothness of anteroposterior movement improved over time for IG (p = 0.040). **Conclusions:** There was an improvement in upper limbs function, over time, both in CG and IG. However, only the IG evidenced improvement in movement quality, after the neurofunctional rehabilitation program. This research has contributed to reinforce the need for continuous and specialized physiotherapy assessment and intervention for chronic stroke patients.
Keywords: stroke, physiotherapy intervention, upper extremity, neurological rehabilitation, biomechanics.

RESUMO

Introdução: O acidente vascular cerebral (AVC) é a principal causa de incapacidade em todo o mundo. Atualmente, cerca de 15 milhões de pessoas sofrem um episódio de AVC a cada ano. Destes ~ 70-80% dos pacientes com AVC apresentam alterações funcionais dos membros superiores e a próximas batalha dos pacientes é a recuperação da independência funcional, com padrões de movimento os mais semelhantes possíveis aos anteriores ao episódio. **Objetivo**: Analisar o efeito de um programa de reabilitação neurofuncional na capacidade funcional dos membros superiores e no desempenho motor de pacientes com acidente vascular cerebral crónico. **Métodos**: Foi realizado um ensaio clínico randomizado controlado com participantes crónicos que apresentavam disfunção neuromotora após acidente vascular cerebral da artéria cerebral média, distribuídos aleatoriamente para um grupo controlo (GC) e intervenção (GI) (n=8 e n=15, respectivamente). Foi elaborado um programa de reabilitação neurofuncional de oito semanas, composto por 16 sessões (de 1 hora cada), aplicado ao GI, ocorreram em quatro momentos: antes da intervenção (M0), após a primeira sessão de reabilitação neurofuncional (M1), após a 16ª sessão do programa (M2) e após oito semanas de seguimento para GI (M3).. A terapia baseou-se em diferentes posturas de tratamento, com facilitação e manipulação pelo terapeuta. Estímulos sensório-motores e proprioceptivos, dentro de padrões típicos de movimento, usando tarefas funcionais (bater em um objeto, apoiar e transferir peso corporal sobre os membros superiores, pentear o cabelo, escovar os dentes, tomar banho, vestir uma camiseta, calçar sapatos, carregar um prato, uma bandeja, empurrando um carrinho, etc.) com repetições e estímulos cognitivos. Para a recolha de dados, recorreu-se a escalas Fugl-Meyer Upper Extremity Assessment e Wolf Motor Function Test para avaliar o comprometimento motor dos membros superiores e definidos como comprometimento sensório-motor e variáveis de velocidade e qualidade do movimento, respectivamente. A Escala de Ashworth Modificada foi utilizada para classificar a resistência muscular ao movimento passivo. A Escala de Qualidade de Vida Específica para AVC foi usada para avaliar a qualidade de vida em pacientes com AVC. O International Physical Activity Questionnaire avaliou a atividade física moderada a vigorosa e o tempo sentado. O instrumento de avaliação cinemática 3D foi o Vicon Motion System e foram analisados os movimentos de alcançar e beber, nomeadamente das variáveis: relação linear entre articulações; tempo de movimento; média da velocidade do movimento completo; velocidade máxima atingida; suavidade do movimento. **Resultados:** A qualidade de vida melhorou ao longo do tempo nos grupos controlo e intervenção ($F_{2;42}$ = 5,658; p = 0,019; η2 = 0,212; poder observado = 0,694). Em relação à velocidade, foram encontradas diferenças nos dois grupos (p = 0,012 vs 0,006 para GC e GI, respectivamente), mas apenas o GI apresentou melhoria na qualidade do movimento (GC: p = 0,0001). No que se refere à tarefa de alcançar, a relação linear cotovelo / mão ($F_{3,63}$ = 10,32; p <0,0001; η2 = 0,329; poder observado = 0,995) aumentou ao longo do tempo para os dois grupos e diminuiu para a fase de retorno ao nível do ombro / mão (GI: p = 0,043). O tempo de movimento melhorou para o GI no movimento de alcance (total: M0: 3,18 (1,16) e M1: 2,28 (0,66) vs M3: 2,28 (0,60) p = 0,001; fase de alcance: M0: 1,98 (0,77) vs M3: 1,44 (0,47) p = 0,043; fase de retorno: M0: 1,19 (0,45) vs M3: 0,83 (0,15) p = 0,001). A velocidade máxima (anteroposterior: $F_{2,37} = 6,37$; p <0,005; η2 = 0,233; poder observada = 0,848; mediolateral: $F_{2,36} = 6,13$; p <0,007; η2 = 0,226; poder observado = 0,820) e a suavidade do movimento (GC: p = 0,012; GI: p = 0,043) aumentaram após a intervenção, independentemente do grupo. Em relação à tarefa de beber, o tempo de movimento na fase de retorno diminuiu ao longo do tempo para o GI (p = 0,012) após a intervenção e a fase de transporte para a frente apresentou um nível de significância limítrofe para aumentar ao longo do tempo para o GC (p = 0,06). A suavidade do movimento anteroposterior melhorou ao longo do tempo no GI (p = 0,040). **Conclusões:** O programa de reabilitação neurofuncional foi eficaz para melhorar a o comprometimento sensório-motor, velocidade, qualidade do movimento, velocidade de movimento do membro superior, tempo, suavidade e relação de deslocamento articular. Além disso, a função do membro superior no CG deve ser mais explorada ao longo do tempo. Como perspectivas futuras, esta pesquisa reforça a necessidade da reabilitação contínua e especializada para pacientes com AVE crônico realizada por um fisioterapeuta que compreenda as possibilidades de avaliações (escalas e 3D) da capacidade funcional e motora de seus pacientes com AVE crônico e, assim, contribuindo para seu retorno às atividades da vida diária.

Palavras-chave: acidente vascular cerebral, intervenção em fisioterapia, extremidade superior, reabilitação neurológica, biomecânica.

LIST OF ABREVIATIONS AND ACRONYMS

CG	Control Group
IG	Intervention Group
M0	Pre-intervention
M1	After the first session of intervention
M2	After-intervention
M3	After eight weeks of follow-up

CHAPTER I

GENERAL INTRODUCTION

The scientific community is increasingly expanding the research and knowledge about stroke, pushed by the fact that stroke is the major cause of disability, worldwide[1,2]. Currently, ~15 million people suffer from stroke each year[1,3]. After surviving one stroke episode, the patients' next battles are the recovery of functional independence with movement patterns as similar as possible to prior the episode[4]. However, many stroke survivors remain with complex neurological deficits, leading to poor movement quality, muscle weakness, sensory dysfunction and cognitive impairment[5]. From these ~70-80% of stroke patients present upper limbs functional alterations[2,6].

Accordingly, the upper limbs evaluation and rehabilitation are extremely relevant to the functional capacity, particularly for daily life activities[3,5]. The upper limb movement dysfunction can be mainly related with a single aspect of the motor control (e.g. reduced speed, coordination, range of motion, or force), which directly influences the assessment procedures as well as the clinical reasoning process[2,7]. In this context, proper assessment of motor performance is important for correct decision making in neurofunctional rehabilitation, especially after stroke[3,7-9].

An appropriate assessment is required to well characterize the impairment level and to contribute to a proper decision making by the health professionals to be established underpinning neurofunctional rehabilitation[3,7,8]. Added the importance of evaluation, there is also a need of randomized controlled trials studies in this area, specifically in chronic stroke patients, that are often described as having no potential for change after chronicity [5,10,11]. Subjective clinical scales such as the Fugl-Meyer Upper Extremity Assessment and the Wolf Motor Function Test are essentials for clinical and scientific purposes and are used to assess general and/or patient-specific functionality[7,12-14].

The Fugl-Meyer Upper Extremity Assessment scale is a well-designed, feasible and efficient clinical measurement tool for post stroke motor function, containing five domains, where the motor domain has the primary value for motor recovery monitoring in a 100-point score[15]. The Wolf Motor Function Test evaluates the upper limb motor skills through time and quality of functional tasks movement[7]. In addition to these scales, the three-dimensional kinematics analysis appears as an important tool to express objectively the clinically outcomes and changes in functional status after stroke[7,8,16]. Indeed, as a gold standard assessment of the motor control parameters[10,16-18], it allows sight into movement patterns, quality and strategies[16-18], through spatial and temporal information about the movement performed by the individual[17,18] and contributes to continuously looking forward the best decision-making in clinical practice.

Therefore, regarding the three-dimensional kinematics analysis, assessing two simple upper limbs movements, such as "drinking" and turning off the switch, allows the possibility to address changes in motor control and might provide a better image of the patient recovery[4,19]. Indeed, the combination of the analysis of smoothness, peak velocity, movement time, and joint coordination during "turning on the light" and drinking tasks can contribute to explain upper limbs motor functions[19]. Moreover, movement time and smoothness allow a reproducible description of the minimum motor changes and rehabilitation responses[4,19].

Regarding rehabilitation, health professionals, namely physiotherapists, should integrate the principles of motor learning theories, such as repetitive training and guided activities[3,9,20], in the neurofunctional rehabilitation programs. These principles must be applied intensively by the physiotherapist based on the central nervous system plasticity[13], and focused on maximizing the functional motor sensory ability[9], with movements within the so-called typical patterns. Increased or reduced movement velocity, longer time to accomplish functional tasks and reduced smoothness are characteristics of an impaired upper limb[7,8]. To overcome these deficits and the consequent functional limitations, the neurofunctional rehabilitation program is a response aimed to the individual needs as the basis for skill acquisition and recovery[21-23].

The present thesis is the result of a broad concern of health professional and researchers in the area, about the importance of having a functional independence to carry out daily living activities in all stages of life, especially among the elderly and individuals who have had a stroke. This reflects on the quality of life for all of us. Thus, after these personal and scientific considerations, the present thesis general objective is:

- To analyze the effect of an eight-week program of neurofunctional rehabilitation in the upper limbs of chronic stroke patients.

And the specifics objectives are:

- To analyze upper limbs functional capacity of chronic stroke patients after neurofunctional rehabilitation.
- To evaluate upper limb motor performance of chronic stroke patients after neurofunctional rehabilitation.
- To evaluate upper limb movement time and smoothness in chronic stroke patients after neurofunctional rehabilitation.

The present thesis is organized into four chapters. The general introduction to the theme and the main aims of the thesis are presented in chapter 1. The methods, with all the instruments and protocols used, are described in chapter 2. Regarding chapter 2, details about studies design, sampling, data collection procedures and intervention procedures are presented. Also, details about the instruments used for the evaluations and their specifications are described. The fieldwork is presented into three original studies, in chapter 3. Based on a methodological neurofunctional rehabilitation and the assessment order applied, the first study brings clinical assessments and obtaining scores using only the assessment scales. The proposal for this study was to compare the scales since it is the most accessible method for physiotherapists and clinics to assess and compare the patients’ evolution.

The second study used the kinematic analysis of “turning on the light”, to assess neuromotor behavior of both groups. The choice of the task “turning on the light” allowed to cover the entire sample, including participants that presented lower functional capacity, since the demands of this task in terms of complexity are lower than other upper limbs functional tasks, like drinking. The third study used kinematic analysis with the “drinking” task movement, covering stroke survivors who managed to complete this task. The choice of the “drinking” task was to specifically assess patients who have motor control to perform a daily activity with a higher level of demand and greater complexity in terms of intersegmental and muscular organization than the task of “turning on the light”. In addition, it is one of the functional tasks most frequently analyzed in terms of research in this area.

The general discussion, encompassing the overall results, limitations and main conclusions of the thesis are outlined in chapter 4.

REFERENCES

1. Wang Z, Hu S, Sang S, Luo L, Yu C. Age-Period-Cohort Analysis of Stroke Mortality in China: Data From the Global Burden of Disease Study 2013. *Stroke.* 2017;48(2):271-275.
2. Mandehgary Najafabadi M, Azad A, Mehdizadeh H, et al. Improvement of Upper Limb Motor Control and Function After Competitive and Noncompetitive Volleyball Exercises in Chronic Stroke Survivors: A Randomized Clinical Trial. *Archives of Physical Medicine and Rehabilitation.* 2019;100(3):401-411.
3. Valkenborghs SR, Callister R, Visser MM, Nilsson M, van Vliet P. Interventions combined with task-specific training to improve upper limb motor recovery following stroke: a systematic review with meta-analyses. *Physical Therapy Reviews.* 2019:1-18.
4. Mesquita IA, Pinheiro ARV, Velhote Correia MFP, Silva CICd. Methodological considerations for kinematic analysis of upper limbs in healthy and poststroke adults. Part I: A systematic review of sampling and motor tasks. *Topics in stroke rehabilitation.* 2019;26(2):142-152.
5. Pollock A, Farmer SE, Brady MC, et al. Interventions for improving upper limb function after stroke. *Cochrane database of systematic reviews.* 2014(11):CD010820.
6. Wolf SL, Kwakkel G, Bayley M, McDonnell MN, Upper Extremity Stroke Algorithm Working G. Best practice for arm recovery post stroke: an international application. *Physiotherapy.* 2016;102(1):1-4.
7. Thompson-Butel AG, Lin G, Shiner CT, McNulty PA. Comparison of three tools to measure improvements in upper-limb function with poststroke therapy. *Neurorehab Neural Re.* 2015;29(4):341-348.
8. Mandehgary Najafabadi M, Azad A, Mehdizadeh H, et al. Improvement of Upper Limb Motor Control and Function After Competitive and Noncompetitive Volleyball Exercises in Chronic Stroke Survivors: A Randomized Clinical Trial. *Arch Phys Med Rehabil.* 2019;100(3):401-411.
9. Pollock A, Farmer SE, Brady MC, et al. Interventions for improving upper limb function after stroke. *Cochrane Database Syst Rev.* 2014(11):CD010820.
10. Murphy MA, Resteghini C, Feys P, Lamers I. An overview of systematic reviews on upper extremity outcome measures after stroke. *Bmc Neurol.* 2015;15.
11. Mesquita IA, Fonseca P, Pinheiro ARV, Velhote Correia MFP, Silva C. Methodological considerations for kinematic analysis of upper limbs in healthy and poststroke adults Part II: a systematic review of motion capture systems and kinematic metrics. *Topics in Stroke Rehabilitation.* 2019;26(6):464-472.
12. Chen HF, Wu CY, Lin KC, et al. Measurement Properties of Streamlined Wolf Motor Function Test in Patients at Subacute to Chronic Stages After Stroke. *Neurorehab Neural Re.* 2014;28(9):839-846.
13. Bernhardt J, Hayward KS, Kwakkel G, et al. Agreed definitions and a shared vision for new standards in stroke recovery research: the stroke recovery and rehabilitation roundtable taskforce. *International Journal of Stroke.* 2017;12(5):444-450.
14. Adhikari SP, Tretriluxana J, Chaiyawat P. Reliability and Validity of the Nepali Wolf Motor Function Test following Cross-cultural Adaptation. *Kathmandu Univ Med J (KUMJ).* 2016;14(53):3-8.
15. Kim WS, Cho S, Baek D, Bang H, Paik NJ. Upper Extremity Functional Evaluation by Fugl-Meyer Assessment Scoring Using Depth-Sensing Camera in Hemiplegic Stroke Patients. *Plos One.* 2016;11(7).

16. Lopez-Nava IH, Arnrich B, Munoz-Melendez A, Guneysu A. Variability Analysis of Therapeutic Movements using Wearable Inertial Sensors. *J Med Syst.* 2017;41(1).
17. Wu CY, Yang CL, Chen MD, Lin KC, Wu LL. Unilateral versus bilateral robot-assisted rehabilitation on arm-trunk control and functions post stroke: a randomized controlled trial. *J Neuroeng Rehabil.* 2013;10:35.
18. Li KY, Lin KC, Chen CK, Liing RJ, Wu CY, Chang WY. Concurrent and Predictive Validity of Arm Kinematics With and Without a Trunk Restraint During a Reaching Task in Individuals With Stroke. *Arch Phys Med Rehab.* 2015;96(9):1666-1675.
19. van Dokkum L, Hauret I, Mottet D, Froger J, Métrot J, Laffont I. The contribution of kinematics in the assessment of upper limb motor recovery early after stroke. *Neurorehab Neural Re.* 2014;28(1):4-12.
20. Schneider EJ, Lannin NA, Ada L, Schmidt J. Increasing the amount of usual rehabilitation improves activity after stroke: a systematic review. *J Physiother.* 2016;62(4):182-187.
21. Michielsen M, Vaughan-Graham J, Holland A, Magri A, Suzuki M. The Bobath concept–a model to illustrate clinical practice. *Disabil Rehabil.* 2019;41(17):2080-2092.
22. Díaz-Arribas MJ, Martín-Casas P, Cano-de-la-Cuerda R, Plaza-Manzano G. Effectiveness of the Bobath concept in the treatment of stroke: a systematic review. *Disabil Rehabil.* 2019:1-14.
23. Pumprasart T, Pramodhyakul N, Piriyaprasarth P. The effect of the Bobath therapy programme on upper limb and hand function in chronic stroke individuals with moderate to severe deficits. *International Journal of Therapy And Rehabilitation.* 2019;26(10):1-12.

CHAPTER II

METHODS

Original studies

To accomplish the above-mentioned aims, the objective of each study was designed considering a methodological sequence for the upper limbs neurofunctional rehabilitation in chronic stroke patients. First, analyzing the data collected from the motor assessment scales (n=15), secondly, analyzing the data collected from the kinematic analysis of the “turning on the light” task (n=15) and, lastly, the kinematic analysis of a “drinking” task because not all patients were able to take the glass grabbing action (n=8).

Study design, sampling, and randomization

A randomized controlled clinical trial was conducted with chronic stroke patients with neuromotor dysfunction of the middle cerebral artery in a biomechanics laboratory and followed the CONSORT guidelines. Recruitment was carried out by radio communication, internet, and television. The inclusion and exclusion criteria were selected to minimize the heterogeneity of the stroke sample as much as possible, considering the great variability of movement patterns, clinical conditions and biological individualities associated with the stroke. The choice to study individuals with stroke in the chronic state was for the purpose of reaffirming the need to continue rehabilitation and make progress at this stage. Another important exclusion criterion chosen, individuals should have a minimum of upper limb function to complete “drinking” and/or “turning on the light” tasks[1], and so, the lack of both were important exclusion criteria.

The inclusion criteria were: (i) to have clinical diagnosis of a single stroke affecting the middle cerebral artery; (ii) to have a time evolution superior to six months; (iii) to present upper limbs neuromotor dysfunction resulting from the stroke, with at least minimal initiation of shoulder flexion and elbow extension, allowing the accomplishing of the selected tasks (Fugl-Meyer Upper Extremity Assessment)[1]; (iv) to score over 18 points on the Mini-Mental Test and (v) to sign the voluntary participation consent form (annex B)[2,3]. The exclusion criteria were: (i) to have a neurological or cardiovascular instability and/or exercise contraindication; and (ii) to have severe neuropsychological alterations interfering with the ability to follow instructions or understand the performed tasks. Fifteen volunteers were selected according to the criteria, with the sample size being estimated *a priori* by the G*Power software (version 3.1.9.2). All volunteers who did not meet the criteria were referred to other physiotherapy services free of charge.

From the 107 individuals attending the screening evaluation, 36 subjects had a clinical diagnosis of stroke affecting other cerebral arteries than the middle cerebral artery and 12 were diagnosed with another neurological lesion. Of the remaining 59 subjects, 29 had a time evolution lower than six months, 11 had an upper limb plegia sequelae and four scored below 18 on the Mini-Mental Test (annex A)[2,3]. The recruitment was conducted between August 1st and September 10th, 2018. The request for clinical trial retrospective registration 15 was sent to clinicaltrials.gov on September 17, 2019, and the trial last updated was on November 19, 2019, because of an administrative error, lack of awareness and error of omission by the research team.

The total physical activity level of the recruited subjects was computed using the equation [(walk: min/week*frequency) + (moderate physical activity: min/week*frequency) + (vigorous physical activity: min/week*frequency)], allowing to categorize them as physically inactive or active (< and ≥ 150 min/week, respectively)[4-6]. Complementarily, it was assessed the sedentary behavior after stroke through the sitting time module of the International Physical Activity Questionnaire (annex C)[5] (considered as non-sedentary and sedentary, respectively, if < and ≥ 7.0 hours/day, a cut-off value associated with the risk of death from different causes)[7,8]. These two confounding variables were evaluated to control the possible influence of rehabilitation[8,9]. The 15 participants, physically inactive and sedentary, were simple randomized using the online platform *www.randomizer.org*[10] and allocated to control and intervention groups (n = 8 and n = 7, respectively). The CG participants were invited to participate in the IG after the controlled period, totaling 15 individuals receiving the neurofunctional rehabilitation program.

Instruments and data collection procedures

The instruments and protocols used were designed to cover both clinical scales and 3D kinematics for motor evaluation. Firstly, an anamnesis was performed with each participant to collect socio-demographic and anthropometric variables (age, gender, body mass, height, ethnicity, date of birth, marital status and profession before and after stroke), as well as data on patient admission (when the stroke occurred, how was the care length of stay, hospitalization interventions, other types of treatment, prior physical therapy and/or stroke) and clinical diagnosis (current disease history, type and location of stroke, symptoms, other diagnosed diseases, and associated medications, drugs used and in use and complications during treatment, lifestyle, main complaint) with an author evaluation form and semi-structured interview.

The functional assessment (skin inspection, respiratory and heart rate, blood pressure, muscle tone, reflexes, sensitivity, range of motion, involuntary and voluntary motor control, functional activities, daily living, and locomotion) was performed and documented in the same form (annex D). Then, the motor scales and kinematic data collection were performed. The Fugl-Meyer Upper Extremity Assessment (annex E)[11,12] and the Wolf Motor Function Test (time and score) (annex F)[3,13] were used to assess upper limbs motor impairment and set as sensory-motor impairment and speed and movement quality variables, respectively. The Modified Ashworth Scale (annex G)[14,15] was used to classify muscle resistance to passive movement[3,13,16]. The Stroke-Specific Quality of Life Scale was used to assess the quality of life in stroke patients (annex H)[17,18] and the International Physical Activity Questionnaire evaluated the moderate-to-vigorous physical activity and the sitting time[4-6].

The instrument for kinematic evaluation were the Vicon Motion System[13,19-21]. After calibration, three-dimensional kinematical analysis was performed with six MX T-series – T10 cameras with capture frequency of 100 Hz and one Bonita camera[13,20,21]. The three-dimensional coordinate positions of the markers were calculated instantly in camera units with high spatial resolution, with the admitted error for each camera below 0.2 mm, throughout the measured movement. The data were collected automatically by Nexus Track Manager (Vicon®), which enabled image capture, camera synchronization and biomechanical model marker coordinates three-dimensional reconstruction. Joint kinematics were obtained by Euler angles and the capture data were transferred to MATLAB (The MathWorks Inc) software for custom-made analysis. A total of 19 spherical 12 mm retroreflective clusters were positioned in landmarks, following the International Society Biomechanics recommendations[22] that is shown in the Figure 1.

Figure 1. Positions of the retroreflective clusters in landmarks studied. (i) head – frontolateral (1) –, occipitolateral (2) –; (ii) thorax – processus spinosus of the 7th cervical vertebra (3) –, processus spinosus of the 10th thoracic vertebra (4) –, right posterior thorax – region between right scapula and spine (5) –, deepest point of incisura jugularis (suprasternal notch) (6) – and processus xiphoideus – most caudal point on the sternum (7) –; (iii) scapula – angulus acromialis – most laterodorsal point of the scapula (8) –; (iv) humerus – most caudal point on lateral epicondyle (9) –, at the upper limb between the elbow and shoulder markers (10) –; (v) forearm – most caudal-lateral point on the radial styloid (11) –, most caudal-medial point on the ulnar styloid (12) –, at the forearm between the wrist and elbow markers (13) – and (vi) hand – head of 3rd metacarpal (14).

The volunteers performed two basic movements for data collection. The choice of tasks for three-dimensional kinematic analysis was to assess motor skill, functional range and quality of movement based on two daily life activities that are apparently simple, but very demanding for individuals with chronic stroke. In addition, the two tasks present different complexities, one of the tasks is feasible even in the absence of hand function, while the other presupposes functional capacity at the hand level, which is therefore more demanding. Thus, data of different complexities and requirements were obtained with both tasks. The movement of “turning on the light” and the movement of grabbing a glass and “drinking”.

For motion capture, after verbal command, the volunteer performed the “turning on the light” and the “drinking” tasks[23], three times, returning to the starting position in each attempt. The initial and final position and the phases of each movement are shown in Figure 2. The evaluation protocol was formulated to consider, as much as possible, a standardization of the experimental set up, considering the anthropometric characteristics of the participants, thinking about the greater validity of the data presented. So, kinematic collections were performed with participants seated in a hydraulic chair, adjustable to a height of 100% of each subject’s leg length[24]. The standardized initial posture: three-quarter support of the femur in the seat and feet parallel to the width of the hips, with the hands resting on the respective ipsilateral thighs, facing downwards[24]. The switch and the drinking glass were on a table, adjustable in height, at the volunteer’s olecranon level, at a distance corresponding to the upper limb length. A 7 cm diameter and 9.5 cm high (240 mL volume) drinking glass was filled with 120 mL of water (half full)[25-27].

The selection of kinematic variables and data analysis calculations were based on the literature[23,28,29]. The kinematic variables analyzed for the current research were linear relationship between joint displacements (shoulder-hand and elbow-hand); movement time; mean total movement velocity; peak velocity; movement smoothness (relation between mean velocity and peak velocity)[23]. The variables chosen, in addition to being the most used in the literature[23,28,29], are variables in which their results are considered easier to be interpreted by professionals who are not used to the terms of three-dimensional kinematics, increasing the reach of the results.

Among the chosen variables, the relationship between joint displacements was used to determine the different linear joint movements, resulting in coordinated movement[23,28,29]. A metric with high validity, reproducibility and sensitivity to the clinical changes obtained[23,28,29]. Regarding the variables that evaluate the movement speed, the metrics movement time, mean total movement velocity and peak velocity represent the time spent to perform a certain motor function [23,30,31]. Those variables are extremely sensitive and valid for translating functional clinical changes and improving motor control[23,30,31]. Also, the movement smoothness variable, through the relation between mean velocity and peak velocity, describes the quality of the movement under analysis. This metric can reproduce the presence, even if minimal, of movement disorder, which can cause loss or functional minimization[23,30,31].

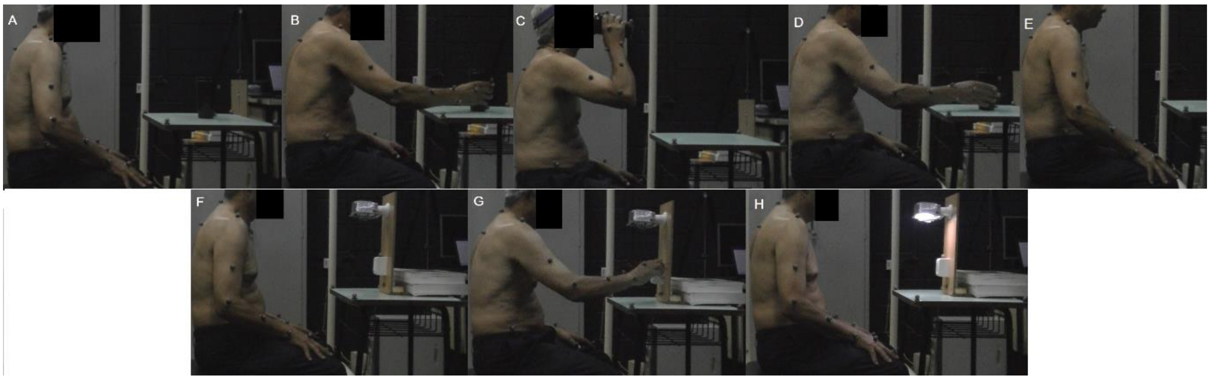

Figure 2. Initial and final position and phases of the "drinking" (A, B, C, D and E) and "turning on the light" (F, G and H) tasks. The "drinking" task was broken down into five logical phases: (A) reaching for the glass, (B) forward transport of the glass to the mouth; (C) drinking, (D) back transport of the glass to the table and (E) returning the hand to the initial position. The "turning on the light" task was broken down into two logical phases: (F) the reaching phase (movement onset until minimal distance at the switch and hand markers) and (G) the returning phase (touch the switch until the movement offset) (H)[26].

Intervention protocol

A single clinician specialized in neurofunctional physiotherapy conducted the evaluations and the neurofunctional rehabilitation program between August/2018 and January/2019, along the following moments: before the intervention (M0), after the first session of neurofunctional rehabilitation (M1), after the 16th program session (M2) and after eight weeks of follow-up for IG (M3)[6,32,33]. Both groups were assessed concomitantly at the four moments[6,33] and, after the controlled period, the CG was merged in the IG, receiving the same neurofunctional rehabilitation program, and the same intervals between evaluations and follow-up. The Figure 3 presents the diagram of sample randomization and data collection procedures.

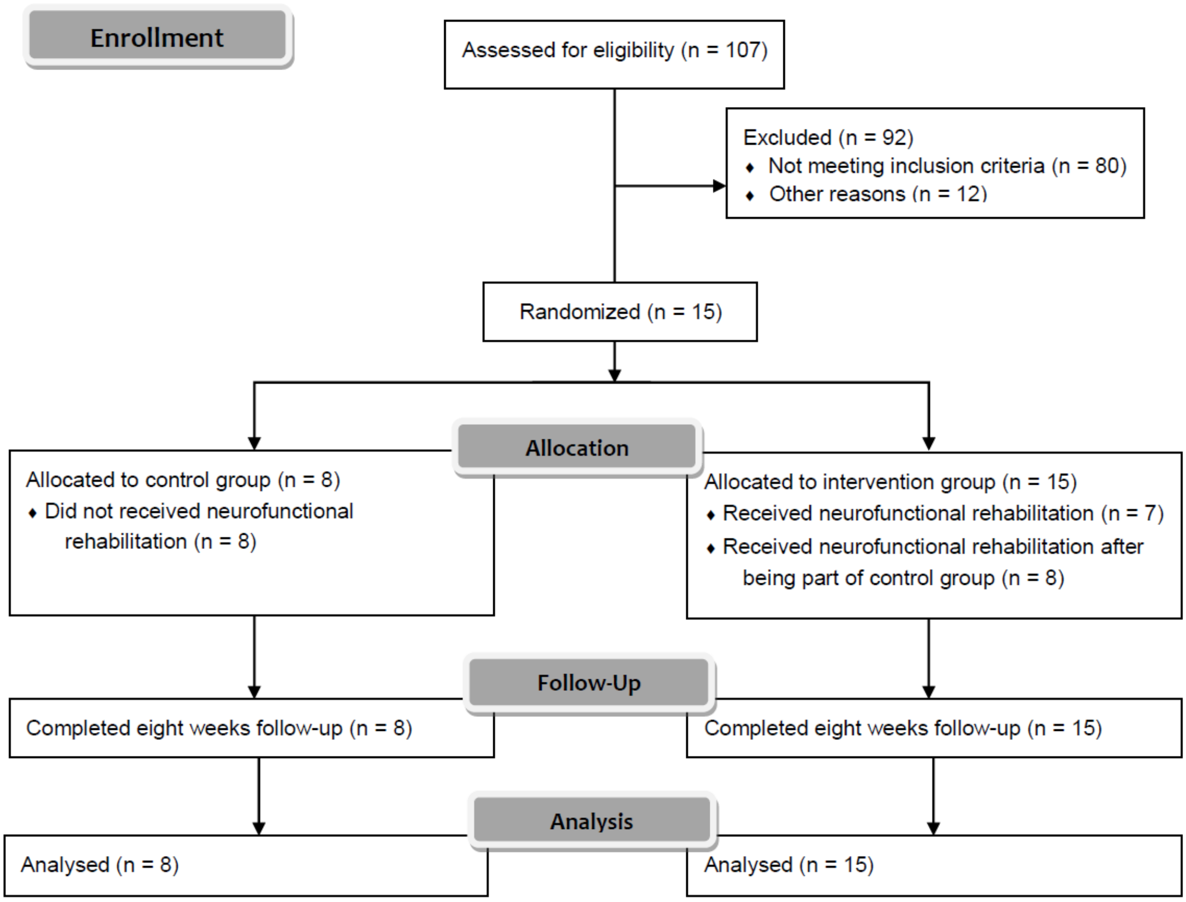

Figure 3. Randomization and allocation.

The intervention program consisted of 16 sessions (of 1 h each) of neurofunctional rehabilitation, lasting eight weeks (twice a week, but not on consecutive days)[6,32,34]. This program intended to provide adequate movement experiences, with components of sensory re-education, tactile orientation and repetitive sensory practice, respecting individual needs[3,32,35,36]. The intervention followed a worksheet with accompanying guidelines used on rehabilitation[32,36,37] and the exercises are described in Table 1. All tasks and activities selected for the rehabilitation program were focused on minimizing the sequelae of neurological disorders, providing a greater degree of independence for people in their activities[38-40]. Also stimulating the central nervous system and neuroplasticity, preventing musculoskeletal deformities, improving postural control responses, to prepare the patient for functional movements, where typical patterns of movements were facilitated[38-40].

The neurofunctional rehabilitation program[36,41,42] respected the individuality and the need checked in the individual evaluation[3,43-46]. The therapy was based on different treatment postures, with a facilitation and manipulation by therapist. Sensorimotor and proprioceptive stimuli, within typical movement patterns, using functional tasks (hitting an object, supporting, and transferring body weight on the upper limbs, combing hair, brushing teeth, bathing, wearing a T-shirt, putting on shoes, carrying a plate, a tray, pushing a cart, etc.) with repetitions and cognitive stimuli[6,32,33].

Table 1. Exercises series used on the neurofunctional rehabilitation program.

Decubitus Material	**Exercises**	**Exercise Evolution**
Dorsal Rigid roll, empty and full water bottle	Mobilization of the shoulder girdle; Active stretching of shortened muscles; Extension, abduction, external rotation and shoulder reach, and selective flexion, adduction, and internal rotation of the shoulder; Elbow, wrist and finger extension and selective flexion of the elbow, wrist, and fingers; Forearm supination and selective forearm pronation; Flexion, bilateral upper trunk rotation, flexion, bilateral lower trunk rotation and dissociation of the shoulder and pelvic girdle; Facilitating functional tasks such as rolling and sitting.	Associate the exercises with selective control, involving trunk movements, during the execution of the movement
Lateral (contralesional) Rigid roll, empty and full water bottle	Functional reach with weight transfer on the contralesional side (positioned at 90 ° of shoulder flexion and with slight scapular protraction); Seated training with weight transfer to the contralesional side, with selective elbow and shoulder control.	Associate the exercises with selective control during the execution of the movement and dissociation of the shoulder and pelvic girdle during the execution of the movement
Lateral (ipsilesional) Rigid roll, empty and full water bottle	Functional reach associated with selective flexion, extension, external rotation, internal rotation, abduction, and shoulder adduction; Seated training with weight transfer to the contralesional side, with selective elbow and shoulder control; Active Stretching of shortened muscles.	
Seated Rigid roll, empty and full water bottle, and a light table.	Flexion, extension, and rotation of the trunk with shoulder flexion and scapular protraction, pushing the table; Lateral flexion of the trunk with weight transfer to the upper limb, bilateral and with trunk corrections; Anterior trunk flexion, associated with lateral flexion and trunk rotation, keeping the upper limbs at 90º of shoulder flexion and elbow extension; Sit to stand with the weight transfer to the lower limbs pushing the table; Pick up and release the rigid roll, full and empty water bottle, positioned on the table; Bilateral handling of water bottle and rigid roller.	Associate the exercises with selective control and stops during the execution of the movement; Combining two or more of the previous exercises: increasing the difficulty of handling the rigid roll and water bottle
Four support position	Weight transfer to the upper limbs; Remove the contralesional upper limb from the support and reach the rigid roller; Remove the ipsilesional upper limb from the support and reach the rigid roll; Neck flexion, extension, and rotation; Bilateral protraction and retraction of the scapulae.	
Orthostatic Rigid roll, empty and full water bottle, and a light table.	Anterior trunk flexion, associated with lateral trunk flexion and trunk rotation, keeping the upper limbs at 90° shoulder flexion and elbow extension (with slight bilateral knee flexion); Pick up and release the rigid roll, full and empty water bottle, positioned on the table; Bilateral handling of water bottle and rigid roller.	

Statistical Procedures

The current study aimed to analyze the effect of an eight-week program of neurofunctional rehabilitation in the upper limb's functional capacity, motor performance and movement time and smoothness of chronic stroke patients. To answer these objectives, the following statistical procedures were used: all data were checked for normality by the Shapiro-Wilk test that best fit due to the small sample size. Descriptive data were in mean, standard deviation and percentage to characterize the sample of all variables included in the study, i.e. quality of life, sensory-motor impairment, speed, and movement quality in study 1, the linear relationship between joint displacements (shoulder-hand and elbow-hand), movement time, mean total movement velocity, peak velocity, and movement smoothness (relation between mean velocity and peak velocity) in study 2 and movement time and smoothness in study 3.

Statistical analysis allows different types of null hypothesis tests. Each test has assumptions for better adequacy and reliability of the results. Knowing this, at baseline, parametric (Students t-test for continuous variables and Chi-square for categorical variables) and non-parametric tests (Mann-Whitney test) were used for comparison between groups and one way repeated-measures ANOVA was conducted to analyze the intervention effects over time and between CG and IG. The comparison of two or more population averages based on paired samples can be performed using an ANOVA of repeated measures[47], to analyze the data collection for the same sample over time, verifying the sample longitudinal/temporal modifications. The intervention was the two levels factor between-subject to analyze the effect of an eight-week program of neurofunctional rehabilitation in the upper limbs of chronic stroke patients (CG and IG) and time was the three or four repeated measure levels factor (M0, M1, M2 and M3) within-subject, i.e. comparing the volunteer at baseline (M0) with another moment of intervention. Subsequently, Bonferroni correction for multiple comparisons was used to verify the main effects of time and the interaction time*group was assessed by the Greenhouse-Geisser test. Friedman tests were used to test variables with non-normal distribution (followed by Mann-Whitney test for comparisons between moments and groups) and the Cochran Test was performed for categorical variables. The statistical analysis was performed using the version 26.0 Statistical Package for the Social Sciences software, with the significance level being set at $p < 0.05$.

REFERENCES

1. Winstein CJ, Wolf SL, Dromerick AW, et al. Effect of a task-oriented rehabilitation program on upper extremity recovery following motor stroke: the ICARE randomized clinical trial. *Jama.* 2016;315(6):571-581.
2. Van Kordelaar J, Van Wegen E, Kwakkel G. Impact of Time on Quality of Motor Control of the Paretic Upper Limb After Stroke. *Arch Phys Med Rehab.* 2014;95(2):338-344.
3. Dogru Huzmeli E, Yildirim SA, Kilinc M. Effect of sensory training of the posterior thigh on trunk control and upper extremity functions in stroke patients. *Neurol Sci.* 2017.
4. Craig CL, Marshall AL, Sjorstrom M, et al. International physical activity questionnaire: 12-country reliability and validity. *Medicine and science in sports and exercise.* 2003;35(8):1381-1395.
5. Matsudo S, Araújo T, Marsudo V, Andrade D, Andrade E, Braggion G. Questinário internacional de atividade f1sica (IPAQ): estudo de validade e reprodutibilidade no Brasil. *Rev bras ativ fís saúde.* 2001:05-18.
6. Valkenborghs SR, Callister R, Visser MM, Nilsson M, van Vliet P. Interventions combined with task-specific training to improve upper limb motor recovery following stroke: a systematic review with meta-analyses. *Physical Therapy Reviews.* 2019:1-18.
7. Chau JY, Grunseit AC, Chey T, et al. Daily sitting time and all-cause mortality: a meta-analysis. *Plos One.* 2013;8(11):e80000.
8. Ku P-W, Steptoe A, Liao Y, Hsueh M-C, Chen L-J. A cut-off of daily sedentary time and all-cause mortality in adults: a meta-regression analysis involving more than 1 million participants. *BMC medicine.* 2018;16(1):74.
9. Ezeugwu VE, Manns PJ. Sleep Duration, Sedentary Behavior, Physical Activity, and Quality of Life after Inpatient Stroke Rehabilitation. *J Stroke Cerebrovasc.* 2017;26(9):2004-2012.
10. Bo W, Lei M, Tao S, et al. Effects of combined intervention of physical exercise and cognitive training on cognitive function in stroke survivors with vascular cognitive impairment: a randomized controlled trial. *Clinical rehabilitation.* 2019;33(1):54-63.
11. Fugl-Meyer AR, Jääskö L, Leyman I, Olsson S, Steglind S. The post-stroke hemiplegic patient. 1. a method for evaluation of physical performance. *Scandinavian journal of rehabilitation medicine.* 1975;7(1):13-31.

12. Michaelsen SM, Rocha AS, Knabben RJ, Rodrigues LP, Fernandes CG. Translation, adaptation and inter-rater reliability of the administration manual for the Fugl-Meyer assessment. *Brazilian Journal of Physical Therapy.* 2011;15(1):80-88.
13. Murphy MA, Resteghini C, Feys P, Lamers I. An overview of systematic reviews on upper extremity outcome measures after stroke. *Bmc Neurol.* 2015;15.
14. ASHWORTH B. Preliminary trial of carisoprodol in multiple sclerosis. *Practitioner.* 1964;192:540-542.
15. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. *Physical Therapy.* 1987;67(2):206-207.
16. Thompson-Butel AG, Lin G, Shiner CT, McNulty PA. Comparison of three tools to measure improvements in upper-limb function with poststroke therapy. *Neurorehab Neural Re.* 2015;29(4):341-348.
17. Muus I, Williams LS, Ringsberg KC. Validation of the Stroke Specific Quality of Life Scale (SS-QOL): test of reliability and validity of the Danish version (SS-QOL-DK). *Clinical Rehabilitation.* 2007;21(7):620-627.
18. Williams LS, Weinberger M, Harris LE, Clark DO, Biller J. Development of a stroke-specific quality of life scale. *Stroke.* 1999;30(7):1362-1369.
19. Gulde P, Hughes CM, Hermsdorfer J. Effects of Stroke on Ipsilesional End-Effector Kinematics in a Multi-Step Activity of Daily Living. *Front Hum Neurosci.* 2017;11:42.
20. Li KY, Lin KC, Chen CK, Liing RJ, Wu CY, Chang WY. Concurrent and Predictive Validity of Arm Kinematics With and Without a Trunk Restraint During a Reaching Task in Individuals With Stroke. *Arch Phys Med Rehab.* 2015;96(9):1666-1675.
21. Wu CY, Yang CL, Chen MD, Lin KC, Wu LL. Unilateral versus bilateral robot-assisted rehabilitation on arm-trunk control and functions post stroke: a randomized controlled trial. *J Neuroeng Rehabil.* 2013;10:35.
22. Wu G, van der Helm FC, Veeger HE, et al. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion--Part II: shoulder, elbow, wrist and hand. *J Biomech.* 2005;38(5):981-992.
23. de los Reyes-Guzman A, Dimbwadyo-Terrer I, Trincado-Alonso F, Monasterio-Huelin F, Torricelli D, Gil-Agudo A. Quantitative assessment based on kinematic measures of functional impairments during upper extremity movements: A review. *Clin Biomech (Bristol, Avon).* 2014;29(7):719-727.
24. Pereira S, Silva CC, Ferreira S, et al. Anticipatory postural adjustments during sitting reach movement in post-stroke subjects. *J Electromyogr Kinesiol.* 2014;24(1):165-171.
25. Alt Murphy M, Sunnerhagen KS, Johnels B, Willen C. Three-dimensional kinematic motion analysis of a daily activity drinking from a glass: a pilot study. *J Neuroeng Rehabil.* 2006;3:18.
26. Alt Murphy M, Willen C, Sunnerhagen KS. Kinematic variables quantifying upper-extremity performance after stroke during reaching and drinking from a glass. *Neurorehabil Neural Repair.* 2011;25(1):71-80.
27. Aizawa J, Masuda T, Koyama T, et al. Three-dimensional motion of the upper extremity joints during various activities of daily living. *Journal of Biomechanics.* 2010;43(15):2915-2922.
28. van Dokkum L, Hauret I, Mottet D, Froger J, Métrot J, Laffont I. The contribution of kinematics in the assessment of upper limb motor recovery early after stroke. *Neurorehab Neural Re.* 2014;28(1):4-12.
29. Mesquita IA, Fonseca P, Pinheiro ARV, Velhote Correia MFP, Silva C. Methodological considerations for kinematic analysis of upper limbs in healthy and poststroke adults Part II: a systematic review of motion capture systems and kinematic metrics. *Top Stroke Rehabil.* 2019;26(6):464-472.

30. Adans-Dester C, Fasoli SE, Fabara E, et al. Can kinematic parameters of 3D reach-to-target movements be used as a proxy for clinical outcome measures in chronic stroke rehabilitation? An exploratory study. *Journal of NeuroEngineering and Rehabilitation.* 2020;17(1):1-13.
31. Collins KC, Kennedy NC, Clark A, Pomeroy VM. Kinematic components of the reach-to-target movement after stroke for focused rehabilitation interventions: systematic review and meta-analysis. *Frontiers in neurology.* 2018;9.
32. Pollock A, Farmer SE, Brady MC, et al. Interventions for improving upper limb function after stroke. *Cochrane database of systematic reviews.* 2014(11):CD010820.
33. Schneider EJ, Lannin NA, Ada L, Schmidt J. Increasing the amount of usual rehabilitation improves activity after stroke: a systematic review. *J Physiother.* 2016;62(4):182-187.
34. van Peppen RP, Hendriks HJ, van Meeteren NL, Helders PJ, Kwakkel G. The development of a clinical practice stroke guideline for physiotherapists in The Netherlands: a systematic review of available evidence. *Disability and Rehabilitation.* 2007;29(10):767-783.
35. Wolf SL, Kwakkel G, Bayley M, McDonnell MN, Upper Extremity Stroke Algorithm Working G. Best practice for arm recovery post stroke: an international application. *Physiotherapy.* 2016;102(1):1-4.
36. Michielsen M, Vaughan-Graham J, Holland A, Magri A, Suzuki M. The Bobath concept–a model to illustrate clinical practice. *Disabil Rehabil.* 2019;41(17):2080-2092.
37. Royal Dutch Society for Physical Therapy. KNGF Clinical Practice Guideline for Physical Therapy in patients with stroke. In: Koninklijk Nederlands Genootschap voor Fysiotherapie K, ed2014.
38. Normann B. Facilitation of movement: New perspectives provide expanded insights to guide clinical practice. *Physiotherapy theory and practice.* 2018:1-10.
39. Vaughan-Graham J, Patterson K, Zabjek K, Cott CA. Important Movement Concepts: Clinical Versus Neuroscience Perspectives. *Motor control.* 2019;23(3):273-293.
40. Vaughan-Graham J, Cheryl C, Holland A, et al. Developing a revised definition of the Bobath concept: Phase three. *Physiotherapy Research International.* 2020;25(3):e1832.
41. Platz T, Eickhof C, van Kaick S, et al. Impairment-oriented training or Bobath therapy for severe arm paresis after stroke: a single-blind, multicentre randomized controlled trial. *Clin Rehabil.* 2005;19(7):714-724.
42. Pumprasart T, Pramodhyakul N, Piriyaprasarth P. The effect of the Bobath therapy programme on upper limb and hand function in chronic stroke individuals with moderate to severe deficits. *International Journal of Therapy And Rehabilitation.* 2019;26(10):1-12.
43. Lopez-Nava IH, Arnrich B, Munoz-Melendez A, Guneysu A. Variability Analysis of Therapeutic Movements using Wearable Inertial Sensors. *J Med Syst.* 2017;41(1).
44. Wolf SL, Kwakkel G, Bayley M, McDonnell MN, W UESA. Best practice for arm recovery post stroke: an international application. *Physiotherapy.* 2016;102(1):1-4.
45. Pollock A, Farmer SE, Brady MC, et al. Interventions for improving upper limb function after stroke. *Cochrane Database Syst Rev.* 2014(11):CD010820.
46. Klimkiewicz P, Kubsik A, Jankowska A, Woldanska-Okonska M. [The effect of neurorehabilitation on the functional state and muscle tone of upper limb in patients after ischaemic stroke]. *Pol Merkur Lekarski.* 2014;36(213):191-194.
47. Maroco J. Análise Estatística com ultização do SPSS. *Lisboa: Edições Silabo.* 2010:199.

CHAPTER III

ORIGINAL STUDIES

1. UPPER LIMBS NEUROFUNCTIONAL REHABILITATION IN CHRONIC STROKE PATIENTS: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Introduction: Stroke leads to ~70-80% of patients presenting upper limbs dysfunction with huge implications on activities of daily living. Objective: To analyze the effect of an eight-week neurofunctional rehabilitation program in the upper limb's functional capacity of chronic stroke patients. Methods: A randomized controlled clinical trial with 15 chronic stroke patients with neuromotor dysfunction of the middle cerebral artery chronic stroke was conducted. The Fugl-Meyer Upper Extremity Assessment and the Wolf Motor Function Test were used to assess upper limbs motor impairment and set as sensory-motor impairment and speed and movement quality variables, respectively. The Modified Ashworth Scale was used to classify muscle resistance to passive movement. The Stroke-Specific Quality of Life Scale was used to assess the quality of life in stroke patients. The International Physical Activity Questionnaire evaluated the moderate-to-vigorous physical activity and the sitting time. The eight-week neurofunctional rehabilitation program was based on motor function and quality of life scales were used in data collection. Results: The quality of life improved over time in control and intervention groups ($F_{2;42} = 5.658$; $p = 0.019$; $\eta 2 = 0.212$; Observed power = 0.694), no differences were found in sensory-motor impairment ($F_{3;63} = 0.328$; $p = 0.741$; $\eta 2 = 0.015$; Observed power = 0.101). Regarding the speed, differences were found for both groups over time ($p = 0.012$ vs 0.006 for CG and IG respectively). But only the intervention group showed improvement in movement quality (CG: $p = 0.0001$). Interpretation: The selected neurofunctional rehabilitation program was effective in improving upper limbs function, expressed by sensory-motor impairment, speed and movement quality.

Clinicaltrials.gov identifier Retrospective Clinical Trial Registration: RBR-2hth8p Brazilian Registry of Clinical Trials (ReBEC) http://www.ensaiosclinicos.gov.br/rg/RBR-2hth8p/.

Keywords: stroke, upper extremity, neurological rehabilitation.

INTRODUCTION

Stroke is the most common cause of disability worldwide[1,2], with 15 million people suffering from this cerebrovascular accident each year[1,3]. A large proportion of survivors present long-term disabilities with complex neurological deficits[4], leading to poor movement quality, muscle weakness, sensory dysfunction and cognitive impairment[2]. In fact, ~70-80% of stroke patients present upper limbs functional alterations[2,5], with its evaluation and rehabilitation being extremely relevant to their functional capacity and daily life activities[3,4]. The upper limbs movement dysfunction is mainly related with a single aspect of the motor control (e.g. reduced speed, coordination, range of motion or force) or can result from the combination of some. Different patterns of neuromotor behaviour presented by stroke patients are not only dependent on the affected brain area, but also on the movement opportunities and experiences after lesion[4,6,7]. This directly influences the clinical reasoning and decision-making process in neurofunctional rehabilitation programs (especially after stroke)[2,3,6].

The lack of randomized controlled trials in this area, specifically in chronic stroke patients (that are often described as having no potential for change after chronicity) remains a barrier to overcome[4,8,9]. The movement performance would contribute to a better understanding of clinical condition and indicate the neurofunctional rehabilitation program effectiveness[6,10]. The neurofunctional rehabilitation principles derive from motor learning theories[3,4,11] and the repetitive training and guided activities[3] should be applied intensively. Physiotherapists should focus on the central nervous system plasticity[12], aiming maximizing the functional sensory motor ability[4] through variable movement experiences.

Complementarily, assessing the patient status properly (using appropriate instruments and protocols) is fundamental to guide the clinical reasoning process within rehabilitation and to monitor the neuromotor evolution of chronic stroke individuals. Thus, a proper assessment is essential for clinical practice, enhancing the intervention results. The current study aimed to analyze the effect of an eight-week program of neurofunctional rehabilitation in the upper limbs functional capacity of chronic stroke patients. It was expected that participants engaged in such a program would present an overall rising of their functionality.

SUBJECTS/MATERIALS AND METHODS

Ethics statement, study design, sampling and randomization

The current study obtained ethics approvals from the host universities (10.2018 and 2.759.798) and participants gave their informed consent. A randomized controlled clinical trial was conducted with chronic stroke patients with neuromotor dysfunction of the middle cerebral artery in a biomechanics laboratory. Recruitment was carried out by radio communication, internet, and television. The inclusion criteria were: (i) to have clinical diagnosis of a single stroke affecting the middle cerebral artery; (ii) to have a time evolution superior to six months; (iii) to present upper limbs neuromotor dysfunction resulting from the stroke, with at least minimal initiation of shoulder flexion and elbow extension (Fugl-Meyer Upper Extremity Assessment)[16]; (iv) to score over 18 points on the Mini-Mental Test; and (v) to sign the voluntary participation consent form[13,14].

The exclusion criteria were: (i) to have a neurological or cardiovascular instability and/or exercise contraindication; (ii) to have severe neuropsychological alterations interfering with the ability to follow instructions or understand the performed tasks and (iii) to have an upper limb articular disability and/or plegia preventing accomplishing both tasks (Fugl-Meyer Upper Extremity Assessment)[16]. Fifteen volunteers were selected according to the criteria, with the sample size being estimated *a priori* by the G*Power software (version 3.1.9.2). All volunteers who did not meet the criteria were referred to other physiotherapy services free of charge.

From the 107 individuals attending the screening evaluation, 36 subjects had a clinical diagnosis of stroke affecting other cerebral arteries than the middle cerebral artery and 12 were diagnosed with another neurological lesion. Of the 59 subjects that met the inclusion criterion, 29 had a time evolution lower than six months, 11 had an upper limb plegia sequelae and four scored below 18 on the Mini-Mental Test[13,14]. The recruitment was conducted between August 1st and September 10, 2018; The request for clinical trial retrospective registration[15] was sent to clinicaltrials.gov on September 17, 2019, and the trial last updated was on November 19, 2019, because of an administrative error, lack of awareness and error of omission by the research team.

The total physical activity level of the recruited subjects was computed using the equation [(walk: min/week*frequency) + (moderate physical activity: min/week*frequency) + (vigorous physical activity: min/week*frequency)], allowing to categorize them as physically inactive or active (< and ≥ 150 min/week, respectively)[20]. Complementarily, it was assessed the sedentary behavior after stroke through the sitting time module of the International Physical Activity Questionnaire[3,19,20] (considered as non-sedentary and sedentary, respectively, if < and ≥ 7.0 hours/day, a cut-off value associated with the risk of death from different causes)[18,22]. These two confounding variables were evaluated to control the possible influence of rehabilitation[17,18], with the 15 participants classified as physically inactive and sedentary at baseline.

Patients were simple randomized using the online platform www.randomizer.org[23] and allocated to control (CG, n = 8) and intervention groups (IG, n = 7). The CG participants were invited to participate in the IG after the controlled period, totaling 15 individuals receiving the neurofunctional rehabilitation program. Therefore, the sample consisted of 23 individuals aged

61.8 ± 17.0 and 62.7 ± 12.8 years old (CG vs. IG; $p = 0.877$). The groups were composed of five and nine (62.5 and 60.0%) male participants, respectively.

Data collection procedures and intervention protocol

A single clinician specialized in neurofunctional physiotherapy conducted the evaluations and the neurofunctional rehabilitation program along the following moments: before the intervention (M0), after the first session of neurofunctional rehabilitation (M1), after the 16th program session (M2) and after eight weeks of follow-up for IG (M3)[3,4,11]. Both groups were assessed concomitantly at the four moments[3,10] and, after the controlled period, the CG was merged in the IG, receiving the same neurofunctional rehabilitation program, intervals between evaluations and follow-up. Figure 1 presents the diagram of sample randomization and data collection procedures.

An anamnesis was also conducted to collect participants socio-demographic and anthropometric variables (age, gender, body mass, height, ethnicity, date of birth, marital status and profession), as well as their admission data (stroke occurrence date, time spent in hospital, hospitalization interventions, other types of treatment and prior physical therapy) and clinical diagnosis (current disease history, stroke type and location, symptoms, other diagnosed diseases, medications used and in use, complications during treatment, lifestyle and main complaint). Then, a functional assessment (skin inspection, respiratory and heart rate, blood pressure, muscle tone, reflexes, sensitivity, range of motion, involuntary and voluntary motor control, functional activities, daily living, and locomotion) was performed and documented.

Most CG and IG participants were married (62.5 and 60%), had altered cholesterol (87.5 and 73.3%), diabetes (62.5 and 66.7%) and high blood pressure (87.5 and 86.7%). Regarding the educational level, 37.5 and 33.3% completed the elementary and high school levels and

33.3% had a university graduation. About the body mass index, CG and IG were categorized as: 50.0 and 40% normal weigh, 25 and 40% overweigh and 25 and 20% obesity (respectively).

The Fugl-Meyer Upper Extremity Assessment[24,25] and the Wolf Motor Function Test (time and score)[25,26] were used to assess upper limbs motor impairment (primary outcome) and set as sensory-motor impairment, speed and movement quality, respectively[8,14]. The Modified Ashworth Scale[28,29] helped classifying muscle resistance to passive movement (secondary outcome)[6,8,14]. The Stroke-Specific Quality of Life Scale was used to assess the quality of life in stroke patients (secondary outcome)[30,31] and the International Physical Activity Questionnaire evaluated the moderate-to-vigorous physical activity and the sitting time (secondary outcome)[3,19,20].

Participants did not previously undergo neurological physiotherapy, although 13% underwent neurosurgery and 50% had thrombolysis protocol. For CG and IG (respectively), the time since stroke episode was 61.8 ± 44.9 and 62.5 ± 54.4 months, the ischemic was the most frequent stroke type (87.5 and 80.0%), the lesioned hemisphere was the left one (62.5 and 60.0%) and they were without aphasia (62.5 and 66.7%). The kinetic functional diagnosis was 25.0 and 33.3%, 37.5 and 40.0%, and 37.5 and 26.7% with light, moderate and severe hemiparesis at the sensory-motor impairment score (The Fugl-Meyer Upper Extremity Assessment)[24,25] in CG and IG (respectively). The modified Ashworth scale classified the individuals as 25.0% with slight increase in tone with minimal resistance and 25% with remarkable increase in tone in the CG and IG as 26.7% with remarkable increase in tone and 25.0% with considerable increase in tone.

Regarding the CG and IG functional capacity, most individuals presented semi-dependence regarding the supine to lateral position transition (70.0 and 66.7%), from supine to seated position (75.0 and 66.7%) and from lateral to prone position (62.5 and 53.3%), dependence from prone to four supports positions (62.5 and 60.0%) and four supports to seated position (62.5 and 53.3%) in CG and IG (respectively). In addition, CG and IG individuals presented semi-independence for daily living activities (62.5 and 53.3%) and independence for locomotion (62.5 and 66.7%), respectively. No differences were found between groups at M0 for the studied variables.

The intervention program consisted of 16 sessions (of 1 h each) of neurofunctional rehabilitation, lasting eight weeks (twice a week but not on consecutive days)[3,4,32]. This program was based on neurofunctional rehabilitation with components of sensory re-education, tactile orientation and repetitive sensory practice, respecting individual needs[4,5,14,33]. The therapy involved facilitation procedures within different treatment postures, integrating proprioceptive stimuli within typical movement patterns. Performance of functional tasks (to reach an object, to brush the hair and teeth, to put on a t-shirt, to put on shoes, to carry a plate or a tray and to push a table or a chair) with repetitions and dual task cognitive stimulation were facilitated[3,4,11]. The intervention followed a worksheet with accompanying guidelines used on rehabilitation[4,33,34.]

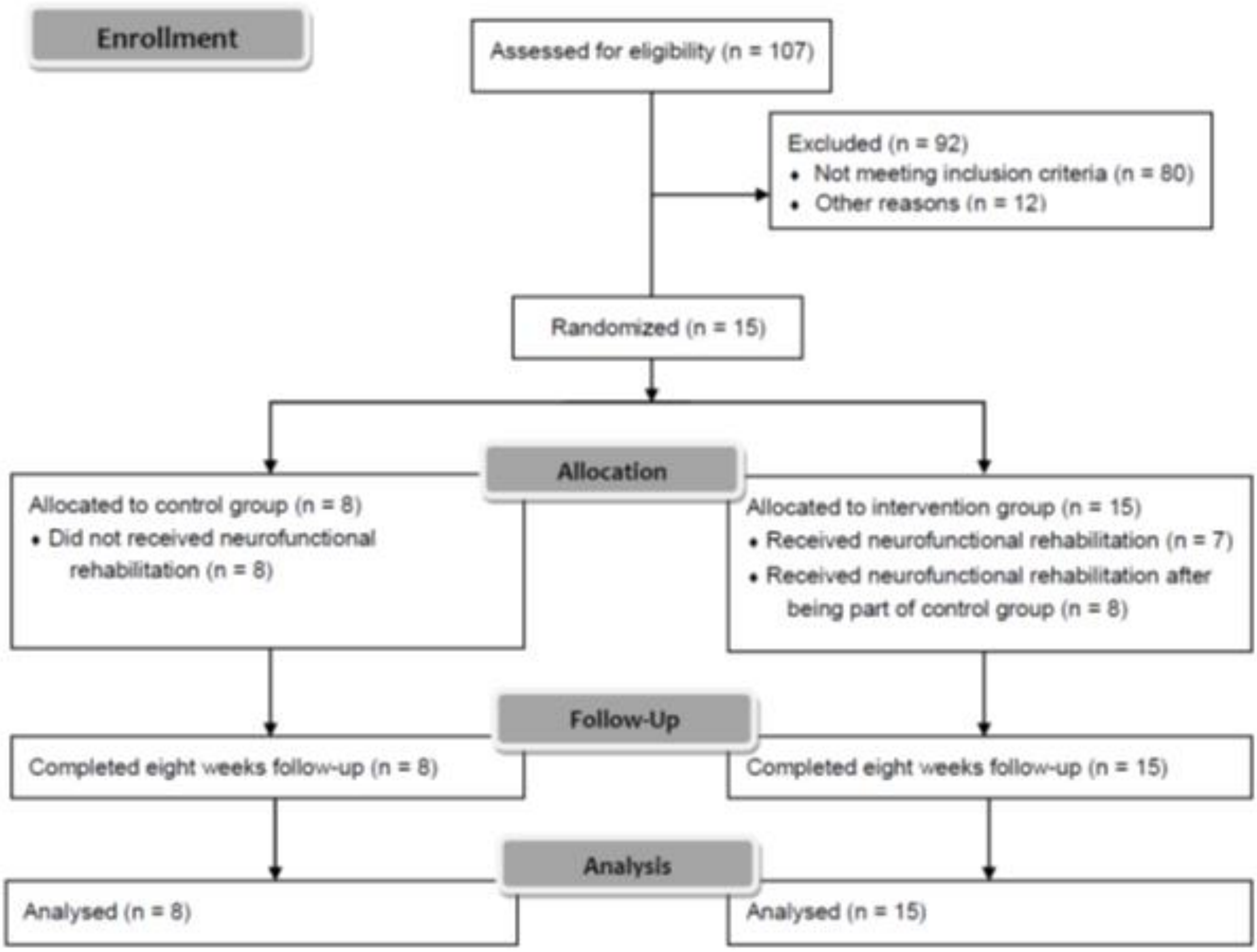

Figure 1. Samples randomization and allocation.

Statistical Procedures

All data were checked for normality by the Shapiro-Wilk test. Descriptive data were in mean, standard deviation and percentage to characterize the sample. At baseline, parametric (Students t-test for continuous variables and Chi-square for categorical variables) and non-parametric tests (Mann-Whitney test) were used for comparison between groups. A one way repeated-measures ANOVA was conducted to analyze the intervention effects over time. The intervention was the two levels factor between-subject (CG and IG) and time was the three or four repeated measure levels factor (M0, M1, M2 and M3) within-subject. Subsequently, Bonferroni correction for multiple comparisons was used to verify the main effects of time and the interaction time*group was assessed by the Greenhouse-Geisser test. Friedman tests were used to test variables with non-normal distribution (followed by Mann-Whitney test for comparisons between moments and groups) and the Cochran Test was performed for categorical variables. The statistical analysis was performed using the version 26.0 Statistical Package for the Social Sciences software, with the significance level being set at $p < 0.05$.

RESULTS

In Figure 2 it is possible to verify that the quality of life score improved over time regardless of the group ($F_{2;42} = 5.658$; $p = 0.019$; $\eta^2 = 0.212$; Observed power = 0.694), but no interaction was found when considering time and group ($F_{2;42} = 0.342$; $p = 0.615$; $\eta^2 = 0.016$; Observed power = 0.091). In the same direction, no differences were found in the sensory-motor impairment over time ($F_{3;63} = 0.328$; $p = 0.741$; $\eta^2 = 0.015$; Observed power = 0.101), as well as for speed and group interaction ($F_{3;63} = 1.031$; $p = 0.370$; $\eta^2 = 0.047$; Observed power = 0.227).

Over time, differences were found for both groups regarding the speed ($p = 0.012$ vs $p = 0.006$ for CG and IG respectively), yet only IG showed improvement in movement quality ($p = 0.375$ vs $p = 0.0001$ for CG and IG respectively). Complementarily, no differences were found between groups within each evaluation moment (Figure 2). Considering the categories of total physical activity level and sedentary behavior, only IG individuals migrated from 100% inactive and sedentary to 33 and 26.4% active ($p = 0.368$ vs $p = 0.042$) and non-sedentary respectively ($p = 0.368$ vs $p = 0.049$), for CG and IG respectively. IG individuals were better ranked than the CG in the M2 and M3 for the functional activities evaluated, from dependent or semi-dependent to independent category ($p < 0.05$).

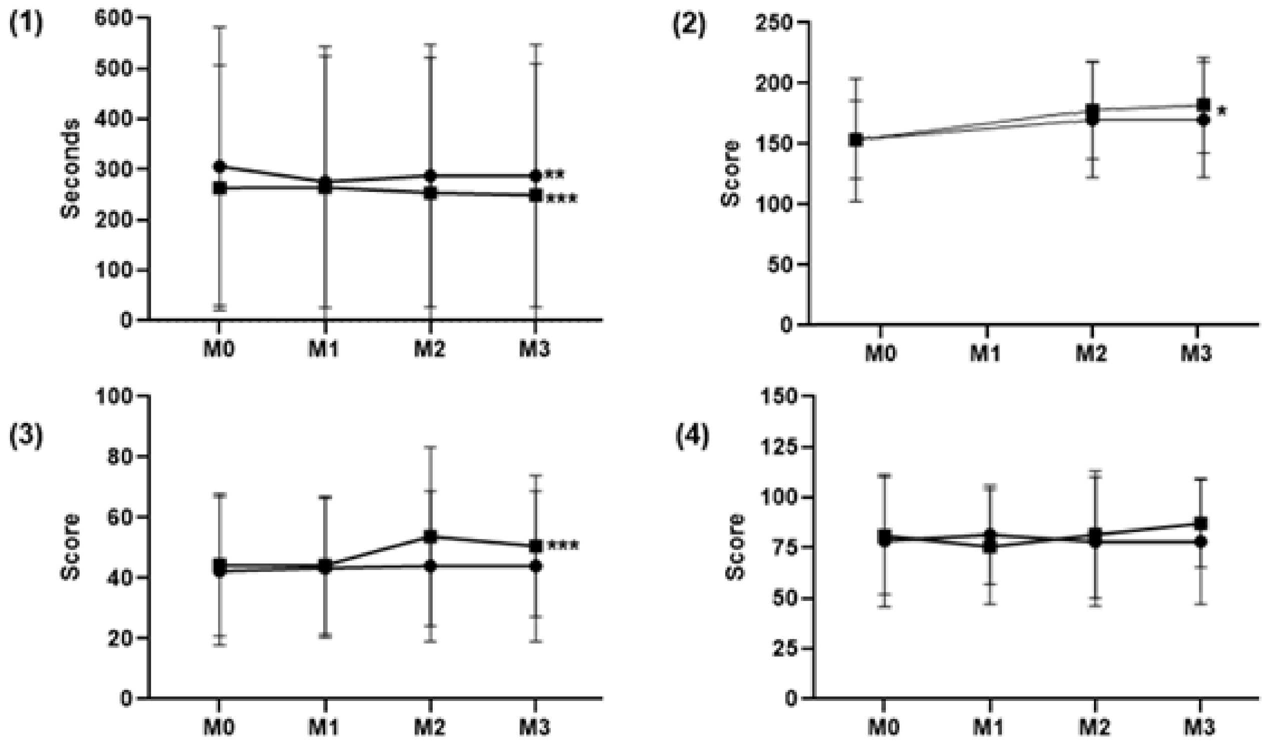

Figure 2. Comparisons between control and intervention groups (circles and squares, respectively) for the variables of quality of life and motor function throughout the intervention: Time in upper extremity function activities (1), Quality of Life (2), Score in upper extremity function activities (3) and upper extremity function (4). M0, M1, M2 and M3: Baseline and, after a rehabilitation session, eight weeks of rehabilitation and eight weeks of follow-up. $p < 0.05$ for repeated measures ANOVA* and Friedman test**;***.

DISCUSSION

The current study aimed to compare upper limbs functional capacity before and after an eight-week program of neurofunctional rehabilitation, with changes in lifestyle and physical condition improvements as secondary outcomes. No differences were found between CG and IG at M0 for the studied variables (such as the general sample characterization, stroke data and comorbidities, motor function, quality of life and functional capacity), which made the two groups comparable. Main outcomes of this study showed that while the quality of life improved over time in both groups, the sensory-motor impairment remained stable over time. However, differences were found for both groups regarding the speed, yet only IG showed improvement on the movement quality.

At M0, the total sample was classified as sedentary and physically inactive, with no differences for characteristics such as hypertension, diabetes, heart disease, cholesterol, and stroke time, between the CG and the IG. Considering the multifactor character that influences the motor function of individuals with chronic stroke sequelae, it was important to control these confounding variables, to allow the discussion of the effects of the intervention[1,2]. It is known that stroke is responsible for the individual functional decline. In fact, in a recent study, it was found that more than one-fifth of stroke survivors showed a decline in physical activity level[2]. The functional decline and the subsequent change in lifestyle can be explained by the lack of knowledge by stroke patients that exercise is viable and also extremely beneficial. Another factor that can influence functional decline is the lack of access to resources and guidance after a stroke[2]. In the current study, there was an improvement between the total physical activity at the baseline and at the M3, for the IG, where some individuals were reclassified as physically active, as well as non-sedentary. Thus, it seems that the intervention was effective regarding changes in lifestyle and possible improvement in the physical condition of the volunteers.

Regarding the outcomes related with upper limb function, individuals from the CG and GI showed improvement over time in speed and movement quality, i.e. there was an improve in speed requested to perform the 15 pre-established tasks, with a greater power in the IG. The improvement in both groups may be related to the learning effect due to repetition of the test tasks[4,16], which had better power in the IG because there were more training and functional repetitions inherent to the task. However, when considering the score attributed to movement quality, only the IG showed improvement over time due to intervention itself. This category refers to the quantification of movement quality in each test task[6,8]. On the other hand, the sensory-motor impairment results showed no differences over time and between groups, despite the improvement over time shown by IG.

Regarding these results it is important to highlight that the motor outcomes related to the assessment provided by the Wolf Motor Functional Test were the most expressive about the influence of the intervention program, and in fact there is evidence that this scale seems to be the most appropriate to assess movement function and quality, especially in cases of moderate impairment, as it demonstrates a high level of quality of motion measurement and clinical utility[6,8]. On the other hand, the results about sensory-motor impairment may be supported by previous findings[8,35] that considered the scale that assesses this outcome as ideal for individuals in acute and subacute phases, but has failed sensitivity to assess changes in individuals at chronic phase. The sensory-motor impairment has been considered essential for the motor function classification in stroke individuals, very efficiently in the acute and subacute periods[36] and for its characteristic of identifying major functional changes[35].

Individuals with chronic stroke sequelae have a 37 to 55% impairment in the ability to perform daily and functional activities, such as postural transitions, locomotion and related to personal hygiene, food and wearing clothes, due to the planning and sequencing actions being impaired[14]. In the current study, regarding the functional activities and body positions transitions, there were differences between groups at moments 2 and 3 (supine to lateral position; supine to seated position; prone to four supports positions; four supports to seated position), in which the IG presented more subjects classified as independent than the CG. The same results occurred with respect to activities of daily living. Although IG improved over time, no differences were found in the locomotion category between groups. Positive results related to functional changes can be found in the literature, with the application of specific task training and the repetition of movements aiming at relearning the movement, apparently bringing the best results of therapies for stroke patients[3,4,16,32].

A meta-analysis suggested that specialized rehabilitation ensures an improvement in stroke patients and that a longer amount of rehabilitation time may further benefit the individual, especially in terms of their quality of life[11]. The stroke specific quality of life scale is considered a specific and ideal assessment tool for stroke patients[37,38], however, individuals with stroke are considered a heterogeneous group in relation to their functional dimension[4,16]. The term health-related quality of life refers to individuals perceptions of their disease and its effects on their lives, including personal satisfaction associated with physical, functional, emotional and social well-being[37,38]. The quality of life variation showed increased scores over time, but there was no difference between groups. Despite the statistical analysis, the improvement over time in the perception of quality of life of all study participants was well received because it is an evaluation of a construct with complex and multifactor characteristics in a group of individuals who needs this improvement.

This study is not without limitations. Although it was not underpowered, the small sample size may not be representative of the whole stroke population. The small and unequal sizes of the groups also warrant caution in the interpretation of results. For instance, chi-square statistical test results should not be extrapolated because some categories do not meet test assumptions (n=0). Therefore, we conclude that a neurofunctional rehabilitation in chronic stroke patients was effective in improving upper limbs function, expressed by sensory-motor impairment, speed and movement quality, in daily life functional activities, in the participants' physical activity level and sedentary behavior.

REFERENCES

1. Wang Z, Hu S, Sang S, Luo L, Yu C. Age-Period-Cohort Analysis of Stroke Mortality in China: Data From the Global Burden of Disease Study 2013. Stroke. 2017;48(2):271-275.
2. Mandehgary Najafabadi M, Azad A, Mehdizadeh H, et al. Improvement of Upper Limb Motor Control and Function After Competitive and Noncompetitive Volleyball Exercises in Chronic Stroke Survivors: A Randomized Clinical Trial. Archives of Physical Medicine and Rehabilitation. 2019;100(3):401-411.
3. Valkenborghs SR, Callister R, Visser MM, Nilsson M, van Vliet P. Interventions combined with task-specific training to improve upper limb motor recovery following stroke: a systematic review with meta-analyses. Physical Therapy Reviews. 2019:1-18.
4. Pollock A, Farmer SE, Brady MC, et al. Interventions for improving upper limb function after stroke. Cochrane database of systematic reviews. 2014(11):CD010820.
5. Wolf SL, Kwakkel G, Bayley M, McDonnell MN, Upper Extremity Stroke Algorithm Working G. Best practice for arm recovery post stroke: an international application. Physiotherapy. 2016;102(1):1-4.
6. Thompson-Butel AG, Lin G, Shiner CT, McNulty PA. Comparison of three tools to measure improvements in upper-limb function with poststroke therapy. Neurorehabilitation and Neural Repair. 2015;29(4):341-348.
7. Yadolahi, F. and M. Mehrpour (2019). "Neuroplasticity and neuromotor synergies in context of rehabilitation after stroke: a systematic review." Tehran University Medical Journal TUMS Publications 77(7): 415-422.
8. Murphy MA, Resteghini C, Feys P, Lamers I. An overview of systematic reviews on upper extremity outcome measures after stroke. Bmc Neurology. 2015;15.
9. Mesquita IA, Fonseca P, Pinheiro ARV, Velhote Correia MFP, Silva C. Methodological considerations for kinematic analysis of upper limbs in healthy and poststroke adults Part II: a systematic review of motion capture systems and kinematic metrics. Topics in Stroke Rehabilitation. 2019;26(6):464-472.
10. Kim WS, Cho S, Baek D, Bang H, Paik NJ. Upper Extremity Functional Evaluation by Fugl-Meyer Assessment Scoring Using Depth-Sensing Camera in Hemiplegic Stroke Patients. Plos One. 2016;11(7).
11. Schneider EJ, Lannin NA, Ada L, Schmidt J. Increasing the amount of usual rehabilitation improves activity after stroke: a systematic review. Journal of Physiotherapy. 2016;62(4):182-187.
12. Bernhardt J, Hayward KS, Kwakkel G, et al. Agreed definitions and a shared vision for new standards in stroke recovery research: the stroke recovery and rehabilitation roundtable taskforce. International Journal of Stroke. 2017;12(5):444-450.

13. van Kordelaar J, van Wegen E, Kwakkel G. Impact of time on quality of motor control of the paretic upper limb after stroke. Archives of Physical Medicine and Rehabilitation. 2014;95(2):338-344.
14. Dogru Huzmeli E, Yildirim SA, Kilinc M. Effect of sensory training of the posterior thigh on trunk control and upper extremity functions in stroke patients. Neurological Sciences. 2017;38(4):651-657.
15. Al-Durra M, Nolan RP, Seto E, Cafazzo JA. Prospective registration and reporting of trial number in randomised clinical trials: global cross sectional study of the adoption of ICMJE and Declaration of Helsinki recommendations. bmj. 2020;369.
16. Winstein CJ, Wolf SL, Dromerick AW, et al. Effect of a task-oriented rehabilitation program on upper extremity recovery following motor stroke: the ICARE randomized clinical trial. Jama. 2016;315(6):571-581.
17. Ezeugwu VE, Manns PJ. Sleep Duration, Sedentary Behavior, Physical Activity, and Quality of Life after Inpatient Stroke Rehabilitation. Journal of Stroke & Cerebrovascular Diseases. 2017;26(9):2004-2012.
18. Ku P-W, Steptoe A, Liao Y, Hsueh M-C, Chen L-J. A cut-off of daily sedentary time and all-cause mortality in adults: a meta-regression analysis involving more than 1 million participants. BMC medicine. 2018;16(1):74.
19. Craig CL, Marshall AL, Sjorstrom M, et al. International physical activity questionnaire: 12-country reliability and validity. Medicine and science in sports and exercise. 2003;35(8):1381-1395.
20. Matsudo S, Araújo T, Marsudo V, Andrade D, Andrade E, Braggion G. Questinário internacional de atividade f1sica (IPAQ): estudo de validade e reprodutibilidade no Brasil. Revista Brasileira de Atividade Física & Saúde. 2001:05-18.
21. World Health Organization. World Health Organization Global recommendations on physical activity for health. Geneva, Switzerland: WHO. 2010.
22. Chau JY, Grunseit AC, Chey T, et al. Daily sitting time and all-cause mortality: a meta-analysis. Plos One. 2013;8(11):e80000.
23. Bo W, Lei M, Tao S, et al. Effects of combined intervention of physical exercise and cognitive training on cognitive function in stroke survivors with vascular cognitive impairment: a randomized controlled trial. Clinical rehabilitation. 2019;33(1):54-63.
24. Fugl-Meyer AR, Jääskö L, Leyman I, Olsson S, Steglind S. The post-stroke hemiplegic patient. 1. a method for evaluation of physical performance. Scandinavian journal of rehabilitation medicine. 1975;7(1):13-31.
25. Michaelsen SM, Rocha AS, Knabben RJ, Rodrigues LP, Fernandes CG. Translation, adaptation and inter-rater reliability of the administration manual for the Fugl-Meyer assessment. Brazilian Journal of Physical Therapy. 2011;15(1):80-88.
26. Pereira ND, Michaelsen SM, Menezes IS, Ovando AC, Lima R, Teixeira-Salmela LF. Reliability of the Brazilian version of the Wolf Motor Function Test in adults with hemiparesis. Brazilian Journal of Physical Therapy. 2011;15(3):257-265.
27. Wolf SL, Lecraw DE, Barton LA, Jann BB. Forced use of hemiplegic upper extremities to reverse the effect of learned nonuse among chronic stroke and head-injured patients. Experimental neurology. 1989;104(2):125-132.
28. Ashworth B. Preliminary trial of carisoprodol in multiple sclerosis. Practitioner. 1964;192:540-542.
29. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. Physical Therapy. 1987;67(2):206-207.
30. Muus I, Williams LS, Ringsberg KC. Validation of the Stroke Specific Quality of Life Scale (SS-QOL): test of reliability and validity of the Danish version (SS-QOL-DK). Clinical Rehabilitation. 2007;21(7):620-627.

31. Williams LS, Weinberger M, Harris LE, Clark DO, Biller J. Development of a stroke-specific quality of life scale. Stroke. 1999;30(7):1362-1369.
32. van Peppen RP, Hendriks HJ, van Meeteren NL, Helders PJ, Kwakkel G. The development of a clinical practice stroke guideline for physiotherapists in The Netherlands: a systematic review of available evidence. Disability and Rehabilitation. 2007;29(10):767-783.
33. Michielsen M, Vaughan-Graham J, Holland A, Magri A, Suzuki M. The Bobath concept–a model to illustrate clinical practice. Disability and Rehabilitation. 2019;41(17):2080-2092.
34. Royal Dutch Society for Physical Therapy. KNGF Clinical Practice Guideline for Physical Therapy in patients with stroke. In: Koninklijk Nederlands Genootschap voor Fysiotherapie K, ed 2014.
35. Lewthwaite R, Winstein CJ, Lane CJ, et al. Accelerating stroke recovery: body structures and functions, activities, participation, and quality of life outcomes from a large rehabilitation trial. Neurorehabilitation and Neural Repair. 2018;32(2):150-165.
36. van Kordelaar J, van Wegen EE, Nijland RH, Daffertshofer A, Kwakkel G. Understanding adaptive motor control of the paretic upper limb early poststroke: the EXPLICIT-stroke program. Neurorehabilitation and Neural Repair. 2013;27(9):854-863.
37. Silva SM, Correa FI, Pereira GS, Faria CDCdM, Corrêa JCF. Construct validity of the items on the Stroke Specific Quality of Life (SS-QOL) questionnaire that evaluate the participation component of the International Classification of Functioning, Disability and Health. Disability and Rehabilitation. 2018;40(2):225-231.
38. Pedersen SG, Heiberg GA, Nielsen JF, et al. Validity, reliability and Norwegian adaptation of the stroke-specific quality of life (SS-QOL) scale. SAGE open medicine. 2018;6:2050312117752031.

2. UPPER LIMB NEUROFUNCTONAL REHABILITATION IMPROVES MOTOR PERFORMANCE IN CHRONIC STROKE

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ABSTRACT

Introduction: Upper limb function assessment in post-stroke subjects is extremely relevant to characterize motor strategies used, following central nervous system damage. Three-dimensional kinematics appears as the gold standard option to express important outcomes through spatial and temporal information about movement performance

Objective: To evaluate the effect of an eight-week program of upper limb neurofunctional rehabilitation on chronic stroke patients motor performance through the use of three-dimensional kinematics. Methods: A randomized controlled clinical trial at a general community and ambulatory care was conducted. Fifteen subjects presenting clinical diagnosis of chronic middle cerebral artery stroke allocated to a control group (CG = 8) and an intervention group (IG = 15). IG was engaged in an eight weeks program of neurofunctional rehabilitation. The assessment was through a “turning on the light” task (turning on the light) three-dimensional motion analysis, using the variables linear relationship between joint displacement, movement time, mean velocity, peak velocity and smoothness. Results: The linear relation of elbow/hand ($F_{3,63} = 10.32$; $p < 0.0001$; square partial eta 0.329; observed power = 0.995) decreased over time for both groups and shoulder/hand increased in the returning phase (IG: p = 0.043). The movement time of the task improved for IG (total: M0: 3.18(1.16) and M1: 2.28(0.66) vs M3: 2.28(0.60) p = 0.001; reaching phase: M0: 1.98(0.77) vs M3: 1.44(0.47) p = 0.043; returning phase: M0: 1.19(0.45) vs M3: 0.83(0.15) p = 0.001). The peak velocity (anteroposterior: $F_{2,37} = 6.37$; $p < 0.005$; square partial eta = 0.233; observed power = 0.848), (mediolateral: $F_{2,36} = 6.13$; $p < 0.007$; square partial eta = 0.226; observed power = 0.820) and movement smoothness (CG: p = 0.012; IG: p = 0.043) increased after the intervention, regardless the group. Conclusions: An eight-week neurofunctional rehabilitation using specific training, oriented and repeated tasks in chronic stroke patients was effective in improving upper limb movement velocity, time and joint displacement relation.

Keywords: Stroke; Upper Extremity; Neurological Rehabilitation; Biomechanical assessment.

INTRODUCTION

Stroke survivors struggle to achieve functional independence and full recovery of their lives patterns prior to the episode[1]. Health professionals pursue for the best stroke-specific rehabilitation, requiring proper assessment of motor function and performance[2-4]. Regarding functional status, 70-80% of stroke patients present upper limbs dysfunction and 40% remain with it chronically[5,6]. A single upper limb movement aspect could be impaired, such as reduced velocity, coordination, smoothness, or a combination of these components, requiring different strategies to measure induced deficits[5,7]. Moreover, health professionals, namely physiotherapists, should integrate the principles of motor learning theories, such as repetitive training and guided activities on the neurofunctional rehabilitation programs[2,3,8]. These principles should be applied intensively by the physiotherapist based on the central nervous system plasticity[9] and focused on maximizing the functional motor sensory ability[2], with movements within the so-called typical patterns.

An appropriate assessment is required to well characterize the impairment level and to contribute to a proper decision making, underpinning neurofunctional rehabilitation[3,5,7]. Clinical assessment by scales is essential and widely used to assess general and/or patient-specific functionality[9-11]. However, the observational or ordinal rating scales present the disadvantage of scoring subjectivity[4] and lack of sensitivity to detect small changes in motor performance[12], eventually not having the desired sensitivity for clinical practice and specially for research purposes[13,14]. Thus, kinematic analysis based on quantitative motion capture procedures appears as an option to express important outcomes and changes in functional status after stroke[14]. Among the biomechanical assessments, the three-dimensional stand out, allowing a detailed gold standard assessment of the motor control parameters, providing insight into movement variables, quality and strategies through spatial and temporal information about the individual performed movements[13-16].

Reaching kinematics contribute to an objective, quantitative and reproducible assessment of sensorimotor impairments[1,12]. Addressing changes in motor control might provide a complete image of the recovery related to functional gestures assessment[1,12]. In fact, this gesture is one of the most common movements studied at the kinematical assessment field, with properties that allows the movement performance analysis[4]. Therefore, assessing tasks that integrate this gesture could provide important knowledge about the performance of post stroke subjects. In fact, the combination of smoothness, peak velocity, movement time and joint coordination within functional tasks performance could explain upper limbs motor functions[12]. These variables detect small variations in motor performance and provide important information on recovery and therapy response after stroke[12]. The current study aimed to evaluate the effect of an eight-week program of upper limb neurofunctional rehabilitation, on the motor performance of chronic stroke patients, through the use of three-dimensional kinematics.

SUBJECTS/MATERIAL AND METHODS

Ethics statement, study design, sampling and randomization

This study, a randomized controlled clinical trial[17], obtained ethics approval (registered protocols 10.2018 and 2.759.798). The target sample size consisted of at least 12 individuals with clinical diagnosis of chronic middle cerebral artery stroke[18], estimated *a priori* by the G*Power software version 3.1.9.2, with α level set at 0.05 and statistical power of 80%. To have clinical diagnosis of a single stroke affecting the middle cerebral artery superior to six months and an upper limb neuro motor dysfunction resulting from the stroke were established as inclusion criteria. The volunteer needed to score over 18 points on the Mini-Mental Test (test that assesses the cognitive state of patients) and to agree and sign the voluntary participation consent form[18,19]. Furthermore, to have diagnosis of a neurological or cardiovascular instability and/or exercise contraindication, severe neuropsychological dysfunction were established as exclusion criteria. The request for clinical trial retrospective registration[20] was performed.

A total of 107 individuals attended the screening assessment. Of these, 36 had a stroke affecting other cerebral arteries (28 at the anterior cerebral artery, six at the posterior cerebral artery, two at the basilar artery) and 12 were diagnosed with another neurological lesion. Of the remaining 59 subjects, 29 had a time evolution inferior to six months, 11 had an upper limb plegia sequelae and four scored below 18 on the Mini-Mental Test. All volunteers who did not meet the inclusion criteria were referred to other physiotherapy services, free of charge. Finally, the total of 15 volunteers were selected according to the inclusion and exclusion criteria of the research and allocated to an intervention group and a control group (n = 7 and 8, respectively). CG members participated at the IG after the controlled period, totaling 15 individuals engaged at the rehabilitation program. Subjects included in the study did not previously undergo neurological physiotherapy. The mean age for the CG was 61.8 (17.0) years old and 62.7 (12.8) for the IG. The time of stroke was 61.8 (44.9) months for the CG and 62.5 (54.4) for the IG ($p > 0.05$). At baseline, all variables included in the current study were similar ($p > 0.05$).

To verify the sedentary behavior and physical activity level after stroke and control the potential confounding effect of these behaviors[21,22], the volunteers answered the International Physical Activity Questionnaire short version[23,24] before the randomization of the groups. The total physical activity level was categorized as physically inactive and physically active (< 150 and ≥ 150 min/week respectively)[25] and the sedentary behavior regarding sitting time was categorized as non-sedentary and sedentary (< 7.0 and ≥ 7.0 h/day respectively) because this cut-off have been associated with the risk of death from different causes[22,26]. All subjects were classified as physically inactive and sedentary.

Data collection procedures and rehabilitation protocol

A single physiotherapist specialized in Neurofunctional Physiotherapy performed the assessments and the neurofunctional rehabilitation within a time-window of five months. The assessments were performed at the baseline (M0), after the first session of neurofunctional physical therapy (M1), after the 16th session of neurofunctional rehabilitation (M2) and after eight weeks of follow-up (M3)[2,3,8]. Both groups were assessed concomitantly at the four moments[3,8] and, after the controlled period, the CG volunteers were included in the IG, receiving the same neurofunctional rehabilitation program and follow-up (with the same intervals between evaluations). Figure 1 presents the randomization and data collection procedures diagram.

After calibration, three-dimensional kinematical analysis was performed with a Vicon Motion System six MX T-series – T10 cameras with capture frequency of 100 Hz and one Bonita camera (primary outcome)[13,15,16]. The three-dimensional coordinate positions of the markers were calculated instantly in camera units with high spatial resolution, with the admitted error for each camera below 0.2 mm, throughout the measured movement. The data were collected automatically by Nexus Track Manager (Vicon®) that enabled image capture, camera synchronization and biomechanical model marker coordinates three-dimensional reconstruction. Joint kinematics is obtained by Euler angles and the capture data were transferred to MATLAB (The MathWorks Inc) software for custom made analysis.

A total of 19 spherical 12 mm retroreflective clusters were positioned in landmarks[27]: (i) thorax – Processus Spinosus of the 7th cervical vertebra –, Processus Spinosus of the 10th thoracic vertebra –, right posterior thorax – region between scapula and right spine –, deepest point of Incisura Jugularis (suprasternal notch) – and Processus Xiphoideus – most caudal point on the sternum –; (ii) scapula – Angulus Acromialis – most laterodorsal point of the scapula – ; (iii) humerus – most caudal point on lateral epicondyle –, at the upper limb between the elbow and shoulder markers –; (iv) forearm – most caudal-lateral point on the radial styloid –, most caudal-medial point on the ulnar styloid –, at the forearm between the wrist and elbow markers – and (v) hand – head of 3rd metacarpal.

For motion capture, after verbal command, the volunteer performed a functional "turning on the light" task[28], with the contralesional upper limb (turning the switch on, which was attached to a lamp, over the table), three times, returning to the starting position in each attempt. Kinematic collections were performed with participants seated in a hydraulic chair, adjustable to a height of 100% of each subjects leg length[29]. The standardized initial posture was: three-quarter support of the femur in the seat and feet parallel to the width of the hips, with the hands resting on the respective ipsilateral thighs, facing downwards[29]. The switch was on a table, adjustable in height, at the volunteers olecranon level, at a distance corresponding to the upper limb length.

The selection of kinematic variables and data analysis calculations were based on the literature[12,28,30]. The movement was divided into two logical phases, the reaching phase (movement onset until the hand touches the switch) and the returning phase (after the hand touches the switch and until the movement offset)[1]. Movement onset was defined as the time when the tangential velocity of the hand marker exceeded 2% of the maximum velocity in the reaching phase[31]. Movement offset was detected when the velocity of the hand was less than 2% of the maximum velocity in the returning phase[31]. The kinematic variables analyzed were: (i) linear relationship between joint displacements (shoulder-hand and elbow-hand); (ii) movement time; (iii) mean total movement velocity; (iv) peak velocity; (v) movement smoothness (relation between mean velocity and peak velocity)[28].

The intervention program consisted of 16 sessions of the neurofunctional rehabilitation program (eight weeks), lasting 1 h each, twice a week, not on consecutive days[2,3,32]. The program was based on neurofunctional rehabilitation with components of sensory re-education, tactile orientation and repetitive sensory practice, respecting individual needs[2,6,19,33]. The therapy involved facilitation procedures within different treatment postures, integrating proprioceptive stimuli within typical movement patterns. Performance of functional tasks (to reach an object, to brush the hair and teeth, to put on a t-shirt, to put on shoes, to carry a plate or a tray, to push a table or a chair) with repetitions and dual task cognitive stimulation were facilitated[2,3,8]. The intervention followed a worksheet with accompanying guidelines used on rehabilitation[2,33,34].

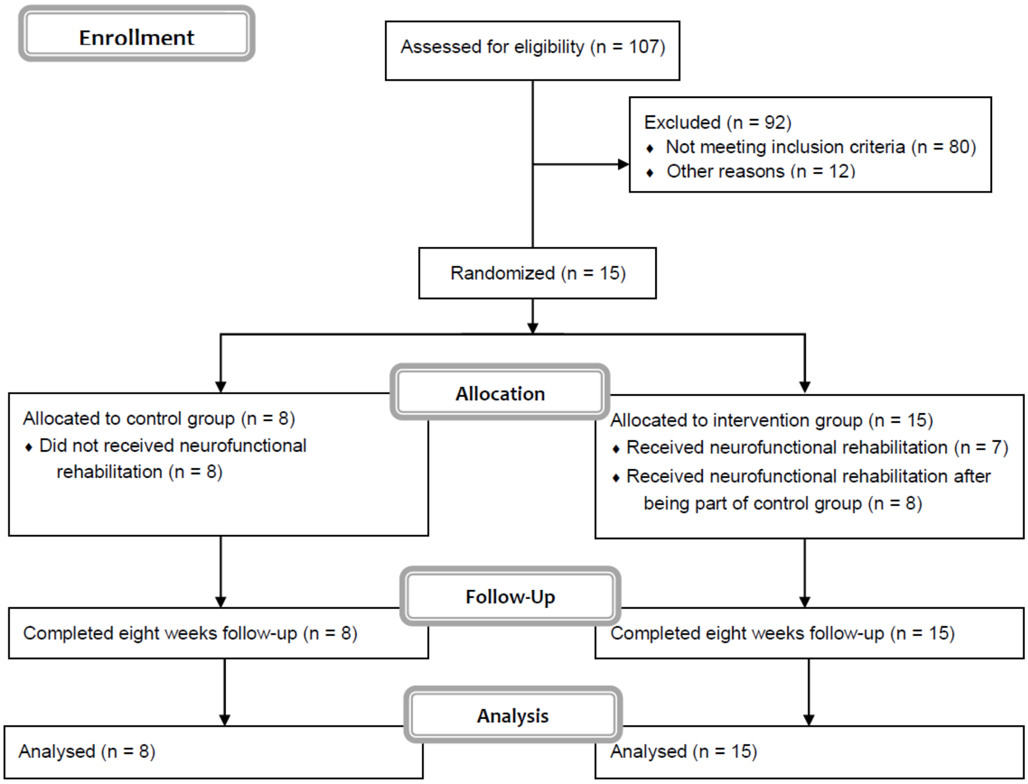

Figure 1. The randomization and data collection procedures.

Statistical Procedures

The kinematics data were checked for normality by the Shapiro-Wilk test and described with mean and standard deviation for parametric variables and median and interquartile range for nonparametric variables. The repeated-measures analysis of variances (RM-ANOVA) were conducted between groups and within subjects at the different experimental moments. For variables with non-normal distribution, Friedman tests were performed, followed by Bonferroni adjustment to verify the main effects within groups. All statistics analyses were performed using the Statistical Package for the Social Sciences – SPSS software, version 26.0. The significance level was set at $p < 0.05$.

RESULTS

In Table 1 it is possible to observe the linear relation of shoulder/hand (returning phase) decreased and the elbow/hand (total and returning phase) increased over time for the IG. Meantime, the linear relation of elbow/hand (reaching phase) and the movement smoothness increased over time, regardless the group. In Figure 2 it is possible to observe that the movement time for total, reaching and returning phases improved for the IG after the rehabilitation program. As well, in Table 2 it is possible to observe that the peak velocity decreased over time on the anteroposterior and mediolateral movements (total and reaching phase), whereas the IG presented lower descriptive means although without differences between groups. Also, in Table 2 the mean velocity presented no differences between and within groups.

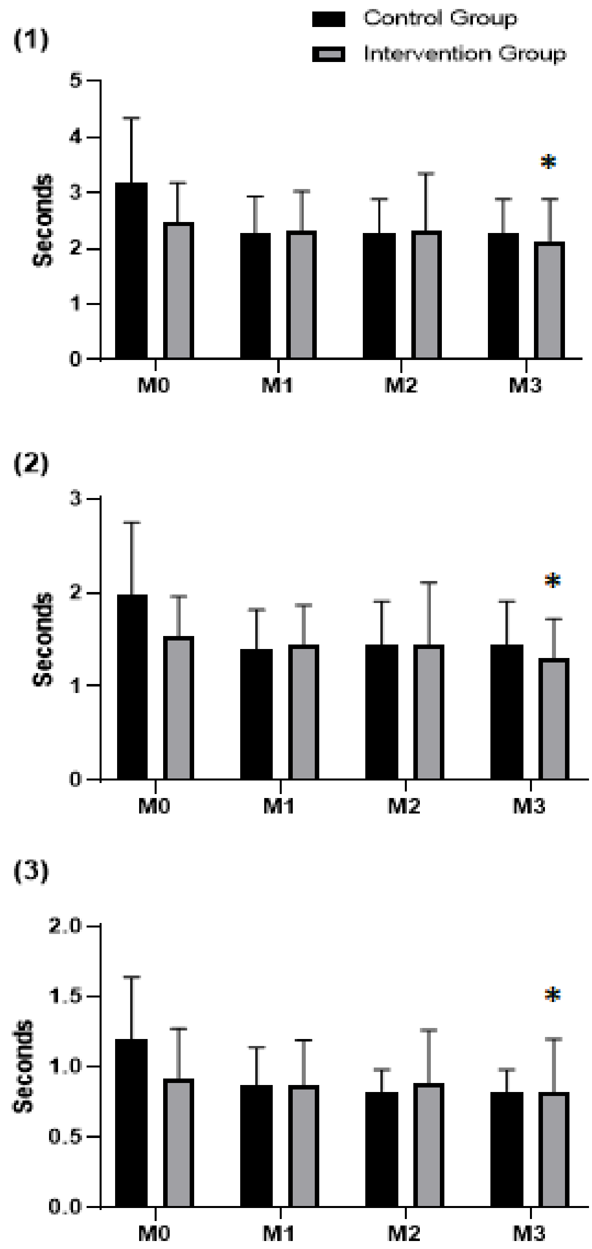

Figure 2. Mean (standard deviation) of the "turning on the light" task movement. M0 at the baseline. M1: after the first session of neurofunctional physical therapy; M2: after the 16^{th} session of neurofunctional rehabilitation. M3: after eight weeks of follow-up. *Friedman test, within intervention group: (1) Time - total task M3 < M0 (Test = 0.001; p = 0.001); M1 (p = 0.043); (2) Time - Reaching phase M3 < M0 (Test = 0.039; p = 0.043); (3) Time - Returning phase M3 < M0 (Test = 0.002; p = 0.001).

Table 1. Comparisons between and within groups for the linear relation and movement smoothness variables of three-dimensional kinetics throughout the intervention.

Variables		Control Group (n=8)				Intervention Group (n=15)			
		M0	**M1**	**M2**	**M3**	**M0**	**M1**	**M2**	**M3**
Linear Relation	Shoulder/hand	0.832 (0.636)	0.740 (0.562)	0.591 (1.018)	0.559 (0.506)	0.475 (0.900)	0.452 (0.676)	0.682 (1.081)	0.504 (0.793)
	Reaching phase	0.103 (0.166)	0.072 (0.080)	0.072 (0.106)	0.086 (0.063)	0.093 (0.088)	0.083 (0.097)	0.090 (0.071)	0.089 (0.063)
	Returning phase	0.083 (0.133)	0.068 (0.059)	0.074 (0.089)	0.072 (0.048)	0.095 (0.062)[#2]	0.075 (0.070)	0.067 (0.071)	0.073 (0.067)
	Elbow/hand	1.115 (0.811)	1.139 (0.627)	0.916 (0.504)	0.933 (0.444)	0.953 (0.542)[#2]	1.183 (0.392)	1.541 (1.136)	1.130 (0.708)
	Reaching phase	0.709 (0.187)	0.641 (0.166)	0.626 (0.177)	0.609 (0.187)	0.668 (0.139)	0.627 (0.138)	0.599 (0.112)	0.589 (0.144)*
	Returning phase	0.710 (0.245)	0.692 (0.178)	0.629 (0.173)	0.679 (0.132)	0.707 (0.133)	0.663 (0.134)	0.636 (0.154)	0.660 (0.121)
Movement Smoothness	Anteroposterior	0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)	0.011 (0.007)	0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)
	Reaching phase	0.003 (0.001)	0.003 (0.001)	0.003 (0.001)	0.091 (0.080)	0.003 (0.001)	0.003 (0.001)	0.003 (0.001)	0.003 (0.001)
	Returning phase	0.005 (0.001)	0.005 (0.003)	0.004 (0.002)	0.002 (0.125)	0.005 (0.002)	0.005 (0.002)	0.005 (0.003)	0.006 (0.003)
	Cephalocaudal	0.0001 (0.0001)	0.0001 (0.0002)	0.0002 (0.0001)	0.0006 (0.008)	0.0002 (0.0002)	0.0001 (0.0001)	0.0001 (0.0002)	0.0001 (0.0002)
	Reaching phase	0.003 (0.001)	0.003 (0.001)	0.003 (0.001)	0.012 (0.089)	0.003 (0.002)	0.003 (0.001)	0.003 (0.001)	0.004 (0.001)
	Returning phase	0.004 (0.001)	0.005 (0.002)	0.005 (0.002)	0.012 (0.108)	0.005 (0.001)	0.005 (0.002)	0.005 (0.002)	0.005 (0.002)
	Mediolateral	0.00003 (0.00002)	0.00002 (0.0001)	0.00004 (0.0001)	0.0002 (0.004)	0.00003 (0.00004)	0.00003 (0.00004)	0.00002 (0.00002)	0.00002 (0.00005)
	Reaching phase	0.002 (0.001)[#1]	0.002 (0.001)	0.002 (0.001)	0.001 (0.072)	0.002 (0.001)[#3]	0.002 (0.001)	0.002 (0.0004)	0.002 (0.001)
	Returning phase	0.004 (0.0004)	0.004 (0.0005)	0.004 (0.001)	0.009 (0.072)	0.004 (0.001)	0.005 (0.001)	0.004 (0.001)	0.005 (0.001)

M0 at the baseline. M1: after the first session of neurofunctional physical therapy; M2: after the 16^{th} session of neurofunctional rehabilitation. M3: after eight weeks of follow-up. Mean values (standard deviation) for *RM ANOVA. over time ($F_{3.63} = 10.32$; $p < 0.0001$; square partial eta 0.329; observed power = 0.995); linear relation – elbow/hand – reaching phase M3 > M0 (p = 0.003); M1 (p = 0.002) and M2 (p = 0.015). Median (interquartile range) for #Friedman test. within group. Linear relation: Intervention group: shoulder/hand – returning phase M0 > M2 (Test = 8.84; p = 0.043); elbow/hand M0 < M2 (Test = 11.96; p = 0.004). Movement Smoothness – reaching phase: Control group M0 < M1 (Test = 11.00; p = 0.012) and intervention group: M0 < M3 (Test = 8.68; p = 0.043).

Table 2. Comparisons between and within groups for the mean and peak velocity variables of three-dimensional kinetics throughout the intervention.

Variables		Control Group (n=8)				Intervention Group (n=15)			
		M0	**M1**	**M2**	**M3**	**M0**	**M1**	**M2**	**M3**
Mean Velocity	Anteroposterior	-0.16 (1.22)	-0.84 (0.76)	-0.40 (1.03)	-0.38 (0.97)	-0.31 (0.87)	-1.12 (1.12)	-0.69 (0.77)	-0.65 (1.27)
	Reaching phase	57.90 (13.38)	55.68 (13.09)	48.16 (17.33)	48.78 (12.38)	53.07 (14.61)	48.39 (11.88)	49.23 (12.46)	47.77 (10.77)
	Returning phase	-58.46 (13.09)	-58.20 (14.22)	-49.34 (17.86)	-47.01 (13.05)	-54.00 (14.71)	-51.78 (12.96)	-51.28 (11.98)	-49.72 (9.82)
	Cephalocaudal	-0.01 (0.70)	0.08 (0.59)	-0.03 (0.86)	-0.02 (1.46)	0.03 (1.22)	-0.02 (0.60)	-0.03 (0.68)	0.20 (0.95)
	Reaching phase	-0.87 (26.65)	4.69 (26.07)	8.39 (30.50)	6.29 (45.05)	5.65 (30.70)	3.38 (24.54)	3.31 (25.15)	3.85 (24.21)
	Returning phase	0.87 (27.20)	-4.47 (25.17)	-8.48 (29.32)	-7.48 (16,31)	-5.59 (29.05)	-3.41 (25.40)	-3.38 (25.17)	-3.27 (23.50)
	Mediolateral	0.14 (0.52)	0.31 (0.56)	-0.03 (0.63)	-0.04 (0.53)	0.08 (0.74)	0.26 (0.69)	0.14 (0.36)	0.17 (0.45)
	Reaching phase	58.95 (7.78)	61.38 (11.90)	56.41 (9.47)	57.41 (8.01)	57.75 (10.12)	59.28 (9.23)	57.05 (9.28)	57.99 (8.32)
	Returning phase	-58.50 (8.46)	-60.47 (12.76)	-56.50 (10.20)	-58.50 (09.50)	-57.55 (9.95)	-58.48 (9.04)	-56.68 (9.07)	-57.44 (7.82)
Peak Velocity	Anteroposterior	111.74 (25.34)	92.87 (12.04)	94.05 (21.21)	91.09 (19.31)	96.84 (18.89)	83.21 (15.44)	92.74 (19.64)	76.42 (16.11)*
	Reaching phase	203.44 (42.19)	167.47 (31.20)	166.09 (39.05)	152.49 (79.03)	174.31 (36.54)	151.41 (34.37)	167.85 (37.68)	147.23 (33.68)*
	Returning phase	3.87 (14.78)	2.49 (15.66)	6.96 (14.31)	7.01 (14.01)	3.59 (12.70)	0.22 (10.80)	5.70 (16.66)	-3.45 (14.58)
	Cephalocaudal	54.69 (32.93)	41.19 (9.68)	53.12 (21.04)	50.19 (17.09)	50.42 (23.47)	40.37 (19.11)	41.68 (17.67)	40.30 (15.38)
	Reaching phase	77.66 (79.92)	46.40 (33.07)	66.95 (60.20)	62.90 (40.74)	58.88 (51.03)	47.41 (44.98)	46.35 (39.16)	49.38 (34.08)
	Returning phase	37.56 (27.07)	26.08 (22.54)	21.10 (27.84)	19.18 (20.48)	23.29 (28.14)	21.70 (25.58)	23.21 (26.75)	19.74 (23.65)
	Mediolateral	186.28 (58.23)	142.58 (45.48)	140.78 (34.87)	142.38 (31.09)	146.56 (31.73)	141.93 (34.95)	139.56 (32.49)	121.52 (30.30)*
	Reaching phase	335.90 (91.47)	256.94 (76.97)	257.93 (63.47)	234.77 (73.98)	266.19 (55.10)	264.15 (72.51)	256.80 (55.55)	230.20 (61.54)*
	Returning phase	13.44 (10.61)	8.56 (10.60)	7.41 (7.14)	6.91 (12.94)	8.59 (6.99)	8.94 (7.80)	8.17 (7.18)	6.87 (10.56)

Mean values (standard deviation). M0: baseline; M1: After a rehabilitation session; M2: After eight weeks of rehabilitation; M3: Follow-up. *RM ANOVA. over time; Anteroposterior Peak Velocity ($F_{2.37} = 6.37$; $p < 0.005$; square partial eta = 0.233; observed power = 0.848); M0 > M1 (p = 0.015) and M3 (p = 0.032); M2 > M3 (p = 0.016); Anteroposterior – Reaching phase ($F_{2.42} = 6.34$; $p < 0.004$; square partial eta = 0.232; observed power = 0.880); M0 > M1 (p = 0.009) and M3 (p = 0.028); Mediolateral ($F_{2.36} = 6.13$; $p < 0.007$; square partial eta = 0.226; observed power = 0.820); M0 > M3 (p = 0.021); Reaching phase ($F_{2.39} = 6.65$; $p < 0.002$; square partial eta = 0.212; observed power = 0.816); M0 > M3 (p = 0.021).

DISCUSSION

The current study aimed to evaluate the effect of an eight-week program of upper limb neurofunctional rehabilitation on the motor performance of chronic stroke patients through the use of three-dimensional kinematics. Therefore. considering the proper assessment importance stated in a recent systematic review on this topic. which documented that the most commonly assessed stroke physiological constructs and metrics were. task/movement time and peak velocity[35]. the current study found improvements in IG for the “turning on the light” variables. linear relation. movement time and peak velocity.

The shoulder/hand and elbow/hand linear relation are metrics used to analyze the coordination between joints during “turning on the light” movements, since there is a linear relation between upper limbs joints displacement[28]. At the current study, the linear relation of elbow/hand increased over time, indicating a more balanced use, without compensations of the middle and distal segments of the upper limb during the task[12,28]. While the linear relation of shoulder/hand decreased, which at the beginning had a large participation in the movement, due to the compensation with the trunk[12]. after rehabilitation, the relation between the joint displacements became more organized[12,28] and translated into a better motor function[28,30]. Thus, the observed kinematic changes at the “turning on the light” movement and the relationship between the joints may indicate a new optimal movement coordination[12,28] and decrease the elicit pathological synergy patterns and compensatory movements[35]. The evolution found at the current study could be due to the functional, repetitive training and sensory motor stimuli and should be used as an ally for the rehabilitation of chronic stroke individuals[2,3,8].

The neurofunctional rehabilitation program led to the movement improvement of the patients in the current study[2,3,8]. The optimization in motor planning and sequencing due to better inter-hemispheric communication that translates to better contralesional upper limb control[5,9]. The interaction between movement and sensory perception is a key to improving motor performance[2,3,8]. The neurofunctional rehabilitation program works with problem solving, which when applied to the training of repetitive and functional tasks, enhances the components of skill acquisition[5,9,33]. The rehabilitation of the upper limb of chronic stroke is complex, multifactorial and requires the integration of different neurofunctional therapeutic techniques, allowing the optimization of results for patients[15,33]. Associating biological individuality to the therapeutic program is essential to achieve the best result[3,8,33].

Furthermore, the “turning on the light” movement time is a quantitative variable often used in clinical research assessments and is frequently described as longer in stroke patients[12]. In the current study, the movement time decreased over time for total, “turning on the light” and returning phase after the neurofunctional rehabilitation program. A meta-analysis showed that there is a big difference between the time of “turning on the light” movement between individuals with and without stroke[36]. Stroke survivors had better movement times after neurofunctional reabilithation[36], due to the information processing which may increase with the task complexity[28,37]. Likewise, the stroke may also imply impairment of the parametrization capacity, which an individual may add specific values to the motor program to meet the specific environmental demands and stroke survivors have less movement variability, thus showing less ability to choose the best movement / parameter to achieve normal motor control[37]. Movement time metric has high quality of evidence to chronic stroke survivours[35]. Besides that, movement time provide insight that ineffective functional tasks are characterized by poor velocity profile in stroke patients[12].

Thereby, velocity profiles are assumed to reflect efficiency of motor control[35] and the chronic stage improvements are generally reliant on intense task repetition[38]. Stroke survivors with lower speed movements could be related of a greater percentage of maximum voluntary contraction and decreased coherence between muscle pairs[36]. The findings at the current study showed that the peak velocity decreased on both groups. On the other hand, another study shows that the peak velocity has increased after rehabilitation[39]. that indicates motor recovery over time after the initial insult[38]. An important possibility raised in a previous study is that middle cerebral artery stroke survivors are able to form and run a motor program, but with limitation in parameterizing it which explain the barrier to be overcome by survivors and their therapists[37]. For the purpose of facilitating coordination and motor learning, therapies that aim to reorganize the cortical representations may result in an easier control of the muscles[5].

In the same sense, it is possible to state that the "turning on the light" movement acquires a greater control during its trajectory or it is smoother when the peak velocity of the movement approaches the mean velocity[5,7,36]. This relationship would describe movement smoothness, that indicates differences between a functional upper limb and an impaired one[12,30,35], even as a meta-analysis showed that people after stroke exhibit less accurate reaches[36]. The movement smoothness increased for both groups that could be explained by the learning factor[2, 40] and movement rehabilitation for IG. As seen at the current study, the kinematics movement smoothness provides an evolution of the recovery on multiple levels for upper extremity chronic stroke rehabilitation[12,36]. A smoothness improvement was able to be related with a better movement performance after rehabilitation[12]. Attention, planning, problem solving, integration of sensory information, retention and transfer are some of the in structural and functional damage after stroke and could affect directly and indirectly the movement quality[37], hence the importance of applying the neurofunctional rehabilitation program in stroke survivors. The neurofunctional rehabilitation program improves task performance, facilitates the integration of sensory information during movement and improves perception and motor control of daily tasks[33,41,42].

Study Limitations

The sample size may be a limitation to extrapolate the findings in the population of other locations. The use of the physical activity and sedentary behavior questionnaire may have a bias in the respondent's memory.

CONCLUSIONS

An eight-week neurofunctional rehabilitation in chronic stroke patients was effective in improving upper limb peak velocity, movement time and joint displacement relationships. The need to extrapolate the findings of the upper limbs with a larger sample could be a way to understand the motor control processes and compensations.

REFERENCES

1. Mesquita IA. Pinheiro ARV. Velhote Correia MFP. Silva CICd. Methodological considerations for kinematic analysis of upper limbs in healthy and poststroke adults. Part I: A systematic review of sampling and motor tasks. *Topics in stroke rehabilitation.* 2019;26(2):142-152.
2. Pollock A. Farmer SE. Brady MC. et al. Interventions for improving upper limb function after stroke. *Cochrane Database Syst Rev.* 2014(11):CD010820.
3. Valkenborghs SR. Callister R. Visser MM. Nilsson M. van Vliet P. Interventions combined with task-specific training to improve upper limb motor recovery following stroke: a systematic review with meta-analyses. *Physical Therapy Reviews.* 2019:1-18.
4. Alt Murphy M. Willén C. Sunnerhagen KS. Movement kinematics during a drinking task are associated with the activity capacity level after stroke. *Neurorehab Neural Re.* 2012;26(9):1106-1115.
5. Mandehgary Najafabadi M. Azad A. Mehdizadeh H. et al. Improvement of Upper Limb Motor Control and Function After Competitive and Noncompetitive Volleyball Exercises in Chronic Stroke Survivors: A Randomized Clinical Trial. *Arch Phys Med Rehabil.* 2019;100(3):401-411.
6. Wolf SL. Kwakkel G. Bayley M. McDonnell MN. Upper Extremity Stroke Algorithm Working G. Best practice for arm recovery post stroke: an international application. *Physiotherapy.* 2016;102(1):1-4.
7. Thompson-Butel AG. Lin G. Shiner CT. McNulty PA. Comparison of three tools to measure improvements in upper-limb function with poststroke therapy. *Neurorehab Neural Re.* 2015;29(4):341-348.

8. Schneider EJ. Lannin NA. Ada L. Schmidt J. Increasing the amount of usual rehabilitation improves activity after stroke: a systematic review. *J Physiother.* 2016;62(4):182-187.
9. Bernhardt J. Hayward KS. Kwakkel G. et al. Agreed definitions and a shared vision for new standards in stroke recovery research: the stroke recovery and rehabilitation roundtable taskforce. *International Journal of Stroke.* 2017;12(5):444-450.
10. Chen HF. Wu CY. Lin KC. et al. Measurement Properties of Streamlined Wolf Motor Function Test in Patients at Subacute to Chronic Stages After Stroke. *Neurorehab Neural Re.* 2014;28(9):839-846.
11. Adhikari SP. Tretriluxana J. Chaiyawat P. Reliability and Validity of the Nepali Wolf Motor Function Test following Cross-cultural Adaptation. *Kathmandu Univ Med J (KUMJ).* 2016;14(53):3-8.
12. van Dokkum L. Hauret I. Mottet D. Froger J. Métrot J. Laffont I. The contribution of kinematics in the assessment of upper limb motor recovery early after stroke. *Neurorehab Neural Re.* 2014;28(1):4-12.
13. Li KY. Lin KC. Chen CK. Liing RJ. Wu CY. Chang WY. Concurrent and Predictive Validity of Arm Kinematics With and Without a Trunk Restraint During a Reaching Task in Individuals With Stroke. *Arch Phys Med Rehab.* 2015;96(9):1666-1675.
14. Lopez-Nava IH. Arnrich B. Munoz-Melendez A. Guneysu A. Variability Analysis of Therapeutic Movements using Wearable Inertial Sensors. *J Med Syst.* 2017;41(1).
15. Murphy MA. Resteghini C. Feys P. Lamers I. An overview of systematic reviews on upper extremity outcome measures after stroke. *Bmc Neurol.* 2015;15.
16. Wu CY. Yang CL. Chen MD. Lin KC. Wu LL. Unilateral versus bilateral robot-assisted rehabilitation on arm-trunk control and functions post stroke: a randomized controlled trial. *J Neuroeng Rehabil.* 2013;10:35.
17. Bo W. Lei M. Tao S. et al. Effects of combined intervention of physical exercise and cognitive training on cognitive function in stroke survivors with vascular cognitive impairment: a randomized controlled trial. *Clinical rehabilitation.* 2019;33(1):54-63.
18. Van Kordelaar J. Van Wegen E. Kwakkel G. Impact of Time on Quality of Motor Control of the Paretic Upper Limb After Stroke. *Arch Phys Med Rehab.* 2014;95(2):338-344.
19. Dogru Huzmeli E. Yildirim SA. Kilinc M. Effect of sensory training of the posterior thigh on trunk control and upper extremity functions in stroke patients. *Neurol Sci.* 2017.
20. Al-Durra M. Nolan RP. Seto E. Cafazzo JA. Prospective registration and reporting of trial number in randomised clinical trials: global cross sectional study of the adoption of ICMJE and Declaration of Helsinki recommendations. *bmj.* 2020;369.
21. Ezeugwu VE. Manns PJ. Sleep Duration. Sedentary Behavior. Physical Activity. and Quality of Life after Inpatient Stroke Rehabilitation. *J Stroke Cerebrovasc.* 2017;26(9):2004-2012.
22. Ku P-W. Steptoe A. Liao Y. Hsueh M-C. Chen L-J. A cut-off of daily sedentary time and all-cause mortality in adults: a meta-regression analysis involving more than 1 million participants. *BMC medicine.* 2018;16(1):74.
23. Craig CL. Marshall AL. Sjorstrom M. et al. International physical activity questionnaire: 12-country reliability and validity. *Medicine and science in sports and exercise.* 2003;35(8):1381-1395.
24. Matsudo S. Araújo T. Marsudo V. Andrade D. Andrade E. Braggion G. Questinário internacional de atividade f1sica (IPAQ): estudo de validade e reprodutibilidade no Brasil. *Rev bras ativ fís saúde.* 2001:05-18.

25. World Health Organization. World Health Organization Global recommendations on physical activity for health. *Geneva. Switzerland: WHO.* 2010.
26. Chau JY. Grunseit AC. Chey T. et al. Daily sitting time and all-cause mortality: a meta-analysis. *Plos One.* 2013;8(11):e80000.
27. Wu G. van der Helm FC. Veeger HE. et al. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion--Part II: shoulder. elbow. wrist and hand. *J Biomech.* 2005;38(5):981-992.
28. de los Reyes-Guzman A. Dimbwadyo-Terrer I. Trincado-Alonso F. Monasterio-Huelin F. Torricelli D. Gil-Agudo A. Quantitative assessment based on kinematic measures of functional impairments during upper extremity movements: A review. *Clin Biomech (Bristol. Avon).* 2014;29(7):719-727.
29. Pereira S. Silva CC. Ferreira S. et al. Anticipatory postural adjustments during sitting reach movement in post-stroke subjects. *J Electromyogr Kinesiol.* 2014;24(1):165-171.
30. Mesquita IA. Fonseca P. Pinheiro ARV. Velhote Correia MFP. Silva C. Methodological considerations for kinematic analysis of upper limbs in healthy and poststroke adults Part II: a systematic review of motion capture systems and kinematic metrics. *Top Stroke Rehabil.* 2019;26(6):464-472.
31. Murphy MA. Willén C. Sunnerhagen KS. Kinematic variables quantifying upper-extremity performance after stroke during reaching and drinking from a glass. *Neurorehab Neural Re.* 2011;25(1):71-80.
32. Van Peppen RP. Hendriks HJ. van Meeteren NL. Helders PJ. Kwakkel G. The development of a clinical practice stroke guideline for physiotherapists in The Netherlands: a systematic review of available evidence. *Disabil Rehabil.* 2007;29(10):767-783.
33. Michielsen M. Vaughan-Graham J. Holland A. Magri A. Suzuki M. The Bobath concept–a model to illustrate clinical practice. *Disabil Rehabil.* 2019;41(17):2080-2092.
34. Royal Dutch Society for Physical Therapy. KNGF Clinical Practice Guideline for Physical Therapy in patients with stroke. In: Koninklijk Nederlands Genootschap voor Fysiotherapie K. ed2014.
35. Schwarz A. Kanzler CM. Lambercy O. Luft AR. Veerbeek JM. Systematic Review on Kinematic Assessments of Upper Limb Movements After Stroke. *Stroke.* 2019;50(3):718-727.
36. Collins KC. Kennedy NC. Clark A. Pomeroy VM. Kinematic components of the reach-to-target movement after stroke for focused rehabilitation interventions: systematic review and meta-analysis. *Frontiers in neurology.* 2018;9.
37. dos Santos Palma GC. Corrêa UC. Torriani-Pasin C. The differentiated effect of the task complexity on retention and transfer of stroke survivors. *Human movement science.* 2020;69:102545.
38. Harcum S. Conroy SS. Boos A. et al. Methods for an Investigation of Neurophysiological and Kinematic Predictors of Response to Upper Extremity Repetitive Task Practice in Chronic Stroke. *Archives of Rehabilitation Research and Clinical Translation.* 2019;1(3-4):100024.
39. Wu C-y. Chuang L-l. Lin K-c. Chen H-c. Tsay P-k. Randomized trial of distributed constraint-induced therapy versus bilateral arm training for the rehabilitation of upper-limb motor control and function after stroke. *Neurorehab Neural Re.* 2011;25(2):130-139.
40. Winstein CJ. Wolf SL. Dromerick AW. et al. Effect of a task-oriented rehabilitation program on upper extremity recovery following motor stroke: the ICARE randomized clinical trial. *Jama.* 2016;315(6):571-581.

41. Pumprasart T. Pramodhyakul N. Piriyaprasarth P. The effect of the Bobath therapy programme on upper limb and hand function in chronic stroke individuals with moderate to severe deficits. *International Journal of Therapy And Rehabilitation.* 2019;26(10):1-12.
42. Díaz-Arribas MJ. Martín-Casas P. Cano-de-la-Cuerda R. Plaza-Manzano G. Effectiveness of the Bobath concept in the treatment of stroke: a systematic review. *Disabil Rehabil*. 2019:1-14.

3. DRINKING TASK AND NEUROFUNCTIONAL REHABILITATION IN CHRONIC STROKE

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ABSTRACT

Introduction: The functional independence is the aim of all stroke patients and health professionals, even with all obstacles. Within the process of clinical reasoning and decision making, the kinematical analysis is an essential tool to allow the expression of important clinical outcomes and changes in functional status after stroke. Therefore, the current study aimed to verify the effect of an eight-week neurofunctional rehabilitation program on upper limb movement time and smoothness in chronic stroke patients during the drinking task. Methods: This is a randomized controlled clinical trial assessing the effect of a neurofunctional rehabilitation program, with eight chronic stroke patients with neuromotor dysfunction resulting of the middle cerebral artery lesion. Three-dimensional motion capture of "drinking" was performed, and the variables movement time and smoothness were analyzed during five logical phases of the task. Results: The movement time at the returning phase decreased over time for IG ($p = 0.012$) after the intervention and the forward transportation phase presented a borderline significance level to increase over time for CG ($p = 0.06$). The smoothness of anteroposterior movement improved over time for IG ($p = 0.040$). Conclusion: The neurofunctional rehabilitation program in chronic stroke patients was effective to improve movement time and smoothness of the upper limb function.

Retrospective Clinical Trial Registration: RBR-2hth8p Brazilian Registry of Clinical Trials (ReBEC)

http://www.ensaiosclinicos.gov.br/rg/RBR-2hth8p/

Keywords: Stroke; Physiotherapy; Upper Extremity; Neurological Rehabilitation; Kinematics.

INTRODUCTION

The functional independence is the aim of all stroke patients and health professionals, even with all the obstacles usually faced[1,3,4]. To achieve this goal, adequate rehabilitation based on a gold standard assessment is essential[2-4]. Dysfunction of upper limb movement is present in 40% of all stroke survivors, which persists chronically[5,6]. Within the process of clinical reasoning and decision making in clinical practice, the kinematical analysis is essential to express important outcomes and changes in functional status after stroke[5,7,14]. Three-dimensional kinematics allows sight into movement patterns, quality and strategies[13,14,16], through spatial and temporal information about the movement performed by the individual[13,16].

Movement time and smoothness allows a reproducible description of changes in motor control and might provide a more complete recovery image[1,12]. “Turning on the light” to drink is one of the most common movements studied at the kinematical assessment with properties of natural and purposeful movement performance[4]. Small variations in motor performance could provide important information on recovery and therapy response after stroke[12]. Increased or reduced movement velocity, longer time to accomplish functional tasks and reduced smoothness are characteristics of an impaired upper limb[5,7].

Thus, the neurofunctional rehabilitation program is a response based to the individual needs as the basis for skill acquisition and recovery[33,41,42]. The neurofunctional rehabilitation program must be applied by the physiotherapist based on the central nervous system plasticity[9,41,43]. Therefore, the current study aimed to verify the effect of an eight-week neurofunctional rehabilitation program on upper limb movement time and smoothness in chronic stroke patients.

SUBJECTS/MATERIAL AND METHODS

Ethics Statement, study design, sampling and randomization

The current study obtained ethics approval by 10.2018 and 2.759.798 registered protocols. Before study enrolment, participants gave their informed consent. This is a randomized controlled clinical trial. The target population consisted of patients with clinical diagnosis of a single middle cerebral artery stroke with chronic neuromotor dysfunction sequelae[18], from community centers, patient registration centers and support groups for stroke patients. The sample size was estimated by the G*Power software, version 3.1.9.2. The *a priori* calculations, with α level set at 0.05 and statistical power of 80% indicated the minimum sample size of 12 individuals. The request for clinical trial retrospective registration[20] was sent to clinicaltrials.gov on September 17. 2019. and the trial last updated was on November 19. 2019. because of an administrative error, lack of awareness and error of omission by the research team.

The inclusion criteria for patients in research were to: (i) have diagnosis of a single middle cerebral artery stroke; (ii) agree and sign the voluntary participation consent form; (iii) have a time evolution greater than six months; (iv) have contralesional upper limb movement dysfunction resulting from stroke and (v) score over 18 points on the Mini-Mental Test (that assesses the cognitive state of patients)[18,19]. The exclusion criteria were to have: (i) a diagnosis of neurological or cardiovascular instability and/or exercise contraindication; (ii) severe neuropsychological problems, that interfere with the ability to follow instructions or understand the demanded tasks; (iii) an upper limb articular dysfunction and/or complete plegia that prevents the “drinking” task accomplishment (no hand function).

The volunteer’s recruitment for the research was carried out by print and digital media (radio, internet and television) without costs. A total of 107 individuals attended the screening assessment. Of these, 28 subjects had a clinical diagnosis of anterior cerebral artery, six posterior cerebral artery, two basilar artery and 12 were diagnosed with another neurological lesion. Of the remaining 59 subjects, 29 had less than six months of diagnosis time, 11 had an upper limb plegia sequelae, seven did not have the hand function needed to complete the “drinking” task and four scored below 18 on the Mini-Mental Test. All volunteers who did not meet the inclusion criteria were referred to other physiotherapy services, free of charge. Finally, the total of eight volunteers were selected according to the inclusion and exclusion criteria of the research.

Subjects included in the study did not previously undergo neurological physiotherapy, were right-handed and were classified as inactive and sedentary at baseline. The most frequent type of stroke was the ischemic and the most affected hemisphere was the left, in 75% of the subjects. For the sample characterization at M0, all variables included in the current study, did not showed difference between CG and IG (i.e. age, gender, body mass, type and quantity of the stroke and sensory-motor impairment score) ($p > 0.05$).

Before the randomization, it was important to verify the physical activity levels and sedentary behavior after stroke, to control the possible influence of these two confounding variables on rehabilitation[21,22]. Thus, the volunteers were evaluated with the International Physical Activity Questionnaire short version[3,23,24]. The total physical activity level (total PAL: minutes/week) was computed by the equation: [(walk: min/week*frequency) + (moderate physical activity: min/week*frequency) + (vigorous physical activity: min/week*frequency)]. The total physical activity level was categorized as physically inactive and physically active (<150 and ≥150 min/week, respectively[25].

The sedentary behavior was assessed with the sitting time module of the International Physical Activity Questionnaire[24]. The sitting time (h/day) was computed by the equation: [(sitting time hours during the week*5) + (sitting time hours during the weekend*2)]/7. The sitting time was categorized as non-sedentary and sedentary (< 7.0 and ≥ 7.0 h/day, respectively) because this cut-off has been associated with the risk of death from different causes[22,26]. The eight subjects were classified as physically inactive and sedentary. Then the volunteers were randomized by the online platform *www.randomizer.org*[17] and allocated to a control group (CG=4) and an intervention group (IG=4). The volunteers allocated to the CG participated in the IG after the end of the controlled period. The sample consisted of 12 individuals (CG=4; IG=8) and the mean age was 64.0 (20.3) years old for CG and 63.8 (14.0) for IG.

Data collection procedures and intervention protocol

One physiotherapist, specialized in Neurofunctional Physiotherapy, performed the neurofunctional rehabilitation program and the evaluations along the baseline (M0), after the first session of neurofunctional rehabilitation program (M1), after the 16th session (M2) and after eight weeks of follow-up (M3)[2,3,8]. The CG was assessed concomitantly with the IG, at M0, M1, M2 and M3[3,8]. After the controlled period ended, the CG volunteers were included in the IG and received the same neurofunctional rehabilitation program and follow-up, with the same intervals between assessments. Figure 1 presents the randomization and data collection procedures diagram.

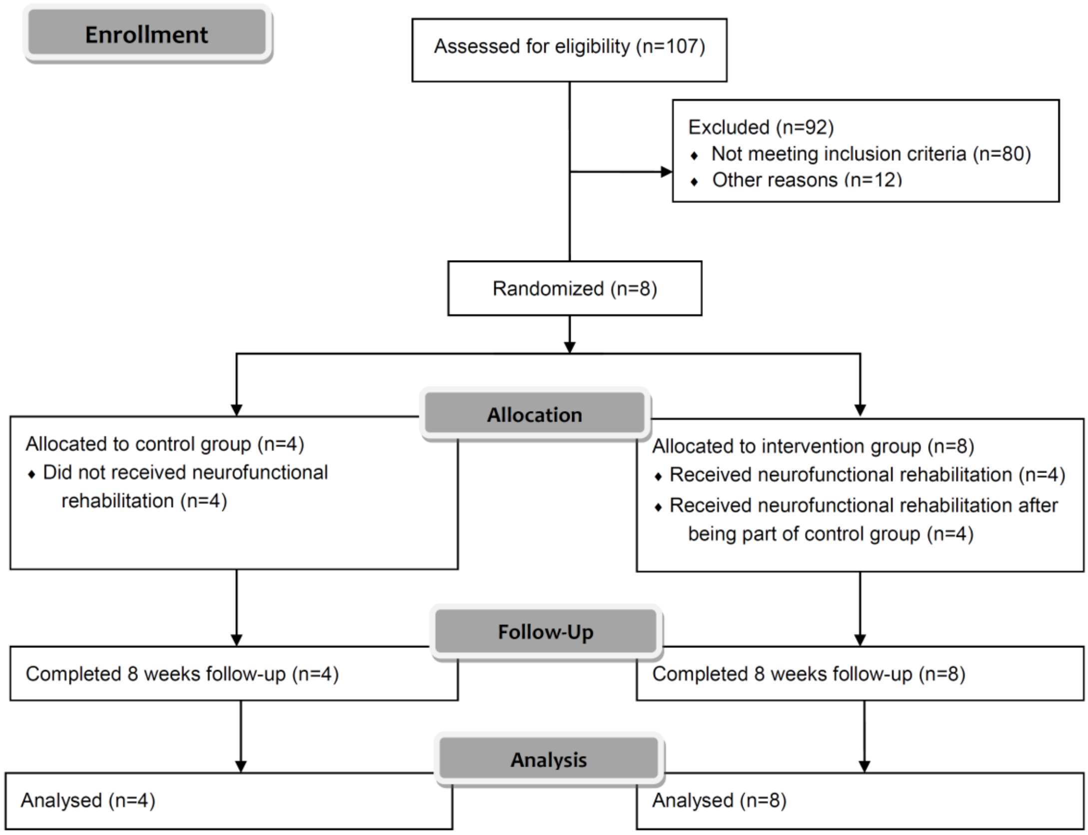


Figure 1. The randomization and allocation.

An anamnesis was performed with each participant to collect demographic and anthropometric variables (age, gender, body mass, height, ethnicity, date of birth, marital status and profession before and after stroke), as well as data on patient admission (when the stroke occurred, how was the care length of stay, hospitalization interventions, other types of treatment, prior physical therapy) and clinical diagnosis (current disease history, type and location of stroke, symptoms, other diagnosed diseases and associated medications, drugs used and in use and complications during treatment, lifestyle, main complaint) as well the functional assessment (skin inspection, respiratory and heart rate, blood pressure, muscle tone, reflexes, sensitivity, range of motion, involuntary and voluntary motor control, functional activities, daily living and locomotion).

Three-dimensional motion capture analysis was performed with a Vicon Motion System six MX T-series – T10 cameras with capture frequency of 100 Hz and one Bonita camera[13,15,16]. The three-dimensional coordinate positions of the markers were calculated instantly in camera units with high spatial resolution, with the admitted error for each camera below 0.2mm. throughout the measured movement. The system was calibrated prior to every measurement session. The data were collected automatically by Nexus Track Manager (Vicon®) that enabled image capture, camera synchronization and biomechanical three-dimensional Reconstruction with model marker coordinates. Joint kinematics were obtained by Euler angles. The capture data were transferred to MATLAB (The MathWorks Inc) software for custom-made analysis,

A total of 23 spherical 12 mm retroreflective clusters were positioned in landmarks, following the International Society Biomechanics recommendations[27]: (i) head – frontolateral region – occipitolateral region; (ii) thorax – processus spinosus of the 7th cervical vertebra – processus spinosus of the 10th thoracic vertebra – right posterior thorax – region between right scapula and spine – deepest point of incisura jugularis (suprasternal notch) – and processus xiphoideus – most caudal point on the sternum; (iii) scapula – angulus acromialis – most laterodorsal point of the scapula; (iv) humerus – most caudal point on lateral epicondyle –, at the upper limb between the elbow and shoulder markers; (v) forearm – most caudal-lateral point on the radial styloid, most caudal-medial point on the ulnar styloid, at the forearm between the wrist and elbow markers – and (vi) hand – head of 3rd metacarpal.

For motion capture, after verbal command, the volunteer performed the functional task of “drinking”[28] with contralesional upper limb, returning to the starting position after each attempt. Three valid repetitions were recorded. Kinematic collections were performed with participants seated in a hydraulic chair, adjustable to a height of 100% of each subjects leg length[29]. The standardized initial posture: three-quarter of the femur supported in the seat with feet parallel to the width of the hips, with the hands resting on the respective ipsilateral thighs, with palms facing downwards[29]. The glass of drink was placed on the table that was adjustable in height, at the volunteer's olecranon level, at a distance from this joint equal to the upper limb length. A 7 cm diameter and 9.5 cm high (240 mL volume) drinking glass was filled with 120 mL of water (half full)[44-46]. The selection of kinematic variables and data analysis calculations were based on the literature[12,28,30].

The "drinking" task was broken down into five logical phases: (i) reaching for the glass, (ii) forward transport of the glass to the mouth, (iii) drinking, (vi) back transport of the glass to the table and (v) returning the hand to the initial position[45]. Movement onset was defined as the time when the tangential velocity of the hand marker exceeded 2% of the maximum velocity in the reaching phase[31,47]. Movement offset was detected when the velocity of the hand was less than 2% of the maximum velocity in the returning phase[31,47]. Forward transport phase onset was defined when the tangential velocity of the glass exceeded 15 mm/s[31,47]. The drinking phase was defined when 15% increase or decrease of the steady-state distance between the head and hand marker[31,48]. Backward transport phase onset was defined when the tangential velocity of the hand exceeded 15 mm/s[4,31,47]. Returning phase onset was defined the tangential velocity of the glass was under 10 mm/s[31,47]. The kinematic variables analyzed for the current study were: (i) Movement time and (ii) Movement Smoothness (mean velocity/peak velocity)[28].

The intervention program consisted of 16 sessions of the neurofunctional rehabilitation program (eight weeks), lasting one hour each, twice a week, not on consecutive days[2,3,32]. It was based on tactile orientation and repetitive sensory practice, respecting individual needs[2,6,19,33]. The therapy involved facilitation procedures within different treatment postures, integrating proprioceptive stimuli within typical movement patterns. Performance of functional tasks with repetitions and dual task cognitive stimulation were facilitated[2,3,8]. The intervention followed a worksheet with accompanying guidelines used on rehabilitation[33,34,42].

Statistical Procedures

All data were checked for normality by the Shapiro-Wilk test. Descriptive data were shown in median and interquartile range (calculated as the difference between the upper and lower quartiles) to characterize the sample. For variables with non-normal distribution, Friedman tests were performed for multiple comparisons for moments, followed by Mann-Whitney test for comparisons between one moment assessment and groups. For categorical variables, the Cochran Test was performed. All statistics analyses were performed using the Statistical Package for the Social Sciences – SPSS software, version 26.0 and the significance level was set at $p < 0.05$.

RESULTS

In Figure 2 it is possible to observe the comparisons between groups for the "drinking" movement time and its phases throughout the intervention. Movement time in returning phase decreased over time for the IG (M0 > M3; $p = 0.012$), and in forward transporting phase presented a borderline significance level to increase over time for CG ($p = 0.06$). In Table 1 it is possible to observe the comparisons between groups for the movement smoothness, considering the X, Y and Z axis (anteroposterior, cephalocaudal and mediolateral movements respectively) and the "drinking" movement phases throughout the intervention. The movement smoothness (anteroposterior movement) in forward transport phase improved over time for IG (M0 > M2; $p = 0.040$). The movement smoothness (mediolateral movement) in backward transport phase decrease over time for CG with no significance level ($p = 0.09$), Table 2. For all other kinematic variables assessed in the current study, no differences were found over time ($p > 0.05$).

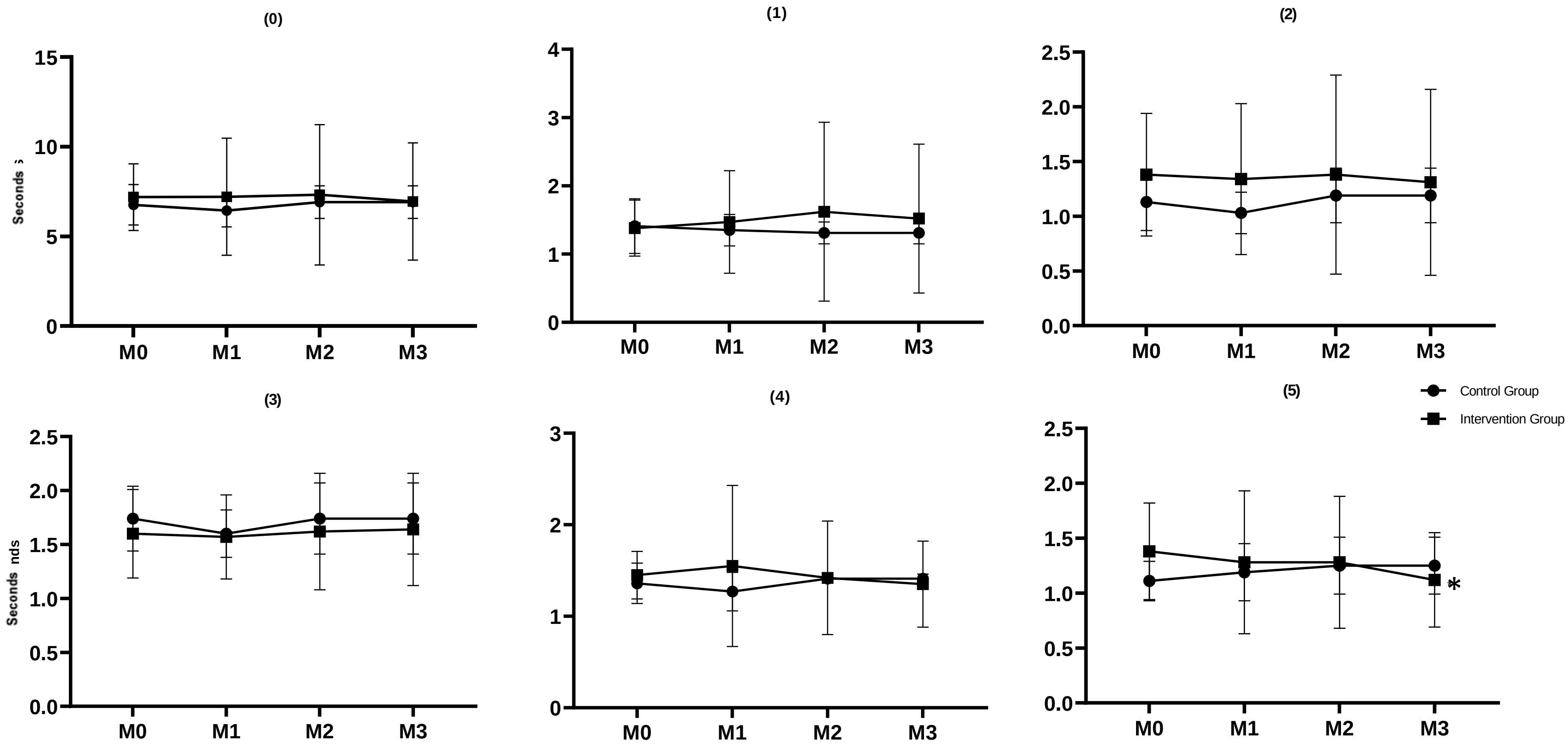


Figure 2. Drinking movement time in median (interquartile range). *Friedman test = 10.2. p = 0.017. within intervention group. M0: at the baseline; M1: after the first session of neurofunctional rehabilitation program; M2: after the 16th session. M3: after eight weeks of follow-up. (0): Drinking total movement time (seconds); (1) Reaching time (seconds); (2) Forward transporting time (seconds); (3) Drinking time (seconds); (4) Backward transporting time (seconds); (5) Returning time (seconds).

Table 1. Comparisons between control and intervention groups for the movement smoothness in anteroposterior, cephalocaudal and mediolateral movements and its phases throughout the intervention.

Movement smoothness		Control Group (n=4)				Intervention Group (n=8)			
		M0	**M1**	**M2**	**M3**	**M0**	**M1**	**M2**	**M3**
Anteroposterior	1. Reaching	0.34 (0.04)	0.34 (0.10)	0.35 (0.03)	0.36 (0.01)	0.35 (0.04)	0.33 (0.03)	0.33 (0.07)	0.35 (0.05)
	2. Forward transporting	0.56 (0.03)	0.60 (0.14)	0.57 (0.10)	0.53 (0.12)	0.55 (0.10)	0.57 (0.05)	0.61 (0.10)#	0.60 (0.03)
	3. Drinking	0.03 (0.10)	0.04 (0.03)	0.06 (0.08)	0.07 (0.03)	0.06 (0.08)	0.07 (0.07)	0.04 (0.06)	0.05 (0.03)
	4. Backward transporting	0.47 (0.08)	0.45 (0.09)	0.43 (0.07)	0.38 (0.09)	0.44 (0.03)	0.42 (0.04)	0.41 (0.08)	0.44 (0.08)
	5. Returning	0.36 (0.06)	0.31 (0.10)	0.33 (0.11)	0.29 (0.13)	0.37 (0.16)	0.35 (0.15)	0.36 (0.21)	0.41 (0.10)
Cephalocaudal	1. Reaching	0.33 (0.08)	0.40 (0.18)	0.29 (0.15)	0.31 (0.10)	0.32 (0.15)	0.28 (0.17)	0.31 (0.15)	0.37 (0.28)
	2. Forward transporting	0.52 (0.30)	0.36 (0.57)	0.35 (0.41)	0.30 (0.24)	0.33 (0.30)	0.24 (0.33)	0.29 (0.27)	0.38 (0.31)
	3. Drinking	0.22 (0.31)	0.20 (0.22)	0.15 (0.26)	0.16 (0.07)	0.16 (0.20)	0.17 (0.19)	0.11 (0.11)	0.20 (0.21)
	4. Backward transporting	0.25 (0.41)	0.29 (0.27)	0.19 (0.35)	0.21 (0.15)	0.24 (0.36)	0.24 (0.25)	0.27 (0.18)	0.19 (0.21)
	5. Returning	0.37 (0.16)	0.44 (0.20)	0.41 (0.09)	0.38 (0.03)	0.38 (0.12)	0.43 (0.21)	0.33 (0.28)	0.45 (0.20)
Mediolateral	1. Reaching	0.21 (0.07)	0.20 (0.08)	0.22 (0.08)	0.21 (0.11)	0.22 (0.09)	0.20 (0.05)	0.20 (0.06)	0.24 (0.09)
	2. Forward transporting	0.61 (0.08)	0.62 (0.07)	0.63 (0.19)	0.60 (0.22)	0.53 (0.16)	0.54 (0.10)	0.54 (0.05)	0.57 (0.10)
	3. Drinking	0.09 (0.16)	0.15 (0.15)	0.12 (0.09)	0.14 (0.03)	0.07 (0.09)	0.04 (0.11)	0.05 (0.09)	0.03 (0.13)
	4. Backward transporting	0.47 (0.08)	0.47 (0.06)	0.43 (0.03)	0.41 (0.05)	0.46 (0.06)	0.46 (0.10)	0.49 (0.06)	0.47 (0.07)
	5. Returning	0.30 (0.05)	0.29 (0.05)	0.29 (0.04)	0.29 (0.01)	0.29 (0.08)	0.30 (0.08)	0.31 (0.09)	0.34 (0.05)

Median (interquartile range). M0: at the baseline; M1: after the first session of neurofunctional rehabilitation program; M2: after the 16th session. M3: after eight weeks of follow-up. #Friedman test; within group. CG: Test statistics = 5.667; p = 0.129; IG: Test statistics = 8.250; p = 0.041; M0 > M2; p = 0.040.

DISCUSSION

The current study aimed to verify the effect of an eight-week neurofunctional rehabilitation program on upper limb movement time and smoothness, in chronic stroke patients. Considering the multifactor character that influences the motor function of individuals with chronic stroke sequelae, all variables included in the current study, did not showed difference between CG and IG (i.e. age, gender, body mass, type and quantity of the stroke and sensory-motor impairment score). The movement time at the forward transport phase decreased over time for IG and presented a borderline significance level to increase over time for CG. The smoothness of anteroposterior movement improved over time for IG.

According to a systematic review, the movement time and smoothness are most commonly used to assess upper limb in rehabilitation of chronic stroke patients at the three-dimensional reach-to-grasp tasks[35]. The movement time is a measure successfully applied in several kinematics studies with stroke patients and its improvement is attributed to a better upper limb function within a given task[28]. At the current study, IG evidenced a decrease, over time, in the amount of time spent at the returning phase. Stroke survivors tend to prolong the "drinking" task due to upper limbs atypical pattern and functionality[28,47], therefore, an improvement in this variable was due to the neurofunctional rehabilitation program. The clinical framework of neurofunctional rehabilitation program incorporates the integration of postural control and quality of task performance, selective movement, and the role of sensory information to promote typical movement that can decrease the movement time of a given task[41].

The CG almost reached the level of statistical significance established in the current study for the movement time in forward transporting to increase over time. This data should be carefully observed, because the non-intervention group showed a non-significant functional decline. meanwhile the IG improved its functional level. The stroke sequelae cause a movement difference for the entire "drinking" task and may get worse over time[47]. Corroborating with the literature that highlight the importance of using the correct therapeutic strategies to improve or keep upper limb functionality[45], the Bobath concept focuses on minimizing the effort in chronic post-stroke subjects and at the role of motor control and perception to optimize body schema and influence task performance often not allowing it to get worse[33].

Moreover, the movement smoothness is a movement quality measure and may be in dysfunction due to spasticity, muscle weakness and poor motor coordination[46,47]. It is strongly correlated with upper limbs motor impairment[2,4]. Likewise, improvements in movement smoothness could be an improvement sign of the recovery after stroke[36,39,47]. If the "drinking" task shows an improvement in its smoothness. That could indicate larger movement harmonicity, reflecting best movement trajectories[36]. The lack of smoothness could predict almost one-third of the performance in the gross manual dexterity[42]. Therefore, the current study corroborates with the literature regarding the forward transporting improvement of the "drinking" task movement smoothness during the intervention, indicating an improvement in body schema organization and better control because of the neurofunctional rehabilitation program.

The literature of motor recovery suggests changes in movement smoothness during the process of motor learning or rehabilitation process and negative changes for those not attending a rehabilitation program[39]. In the current study, the mediolateral movement smoothness during the backward transporting phase, decreased over time for CG. Once again, this is another finding that should be carefully observed, whereas not maintaining the functionality may be resulting on lack of coherence between muscles[36]. that contributes to the kinematic differences over time on CG. Smooth movements are more efficient as they require less energy and comprise less sub movements and it is one of the main characteristics of healthy upper limb movement and perceived competence[47]. Nevertheless, this study is not without limitations. Although it was not underpowered, the small sample size may not be representative of the whole stroke population and may have influenced during the different phases of time movement and smoothness analyzed.

CONCLUSIONS

A neurofunctional rehabilitation program in chronic stroke patients was effective in improving upper limb function, expressed by the kinematic variables movement time and smoothness. Moreover, the decreased of upper limb function on CG should be explored further and reinforces the need for continuous specialized rehabilitation for chronic stroke patients.

REFERENCES

1. Mesquita IA. Pinheiro ARV. Velhote Correia MFP. Silva CICd. Methodological considerations for kinematic analysis of upper limbs in healthy and poststroke adults. Part I: A systematic review of sampling and motor tasks. *Topics in stroke rehabilitation.* 2019;26(2):142-152.
2. Valkenborghs SR. Callister R. Visser MM. Nilsson M. van Vliet P. Interventions combined with task-specific training to improve upper limb motor recovery following stroke: a systematic review with meta-analyses. *Physical Therapy Reviews.* 2019:1-18.
3. Alt Murphy M. Willén C. Sunnerhagen KS. Movement kinematics during a drinking task are associated with the activity capacity level after stroke. *Neurorehab Neural Re.* 2012;26(9):1106-1115.
4. Pollock A. Farmer SE. Brady MC. et al. Interventions for improving upper limb function after stroke. *Cochrane Database Syst Rev.* 2014(11):CD010820.
5. Mandehgary Najafabadi M. Azad A. Mehdizadeh H. et al. Improvement of Upper Limb Motor Control and Function After Competitive and Noncompetitive Volleyball Exercises in Chronic Stroke Survivors: A Randomized Clinical Trial. *Arch Phys Med Rehabil.* 2019;100(3):401-411.
6. Wolf SL. Kwakkel G. Bayley M. McDonnell MN. Upper Extremity Stroke Algorithm Working G. Best practice for arm recovery post stroke: an international application. *Physiotherapy.* 2016;102(1):1-4.
7. Thompson-Butel AG. Lin G. Shiner CT. McNulty PA. Comparison of three tools to measure improvements in upper-limb function with poststroke therapy. *Neurorehab Neural Re.* 2015;29(4):341-348.

8. Lopez-Nava IH. Arnrich B. Munoz-Melendez A. Guneysu A. Variability Analysis of Therapeutic Movements using Wearable Inertial Sensors. *J Med Syst.* 2017;41(1).
9. Li KY. Lin KC. Chen CK. Liing RJ. Wu CY. Chang WY. Concurrent and Predictive Validity of Arm Kinematics With and Without a Trunk Restraint During a Reaching Task in Individuals With Stroke. *Arch Phys Med Rehab.* 2015;96(9):1666-1675.
10. Wu CY. Yang CL. Chen MD. Lin KC. Wu LL. Unilateral versus bilateral robot-assisted rehabilitation on arm-trunk control and functions post stroke: a randomized controlled trial. *J Neuroeng Rehabil.* 2013;10:35.
11. van Dokkum L. Hauret I. Mottet D. Froger J. Métrot J. Laffont I. The contribution of kinematics in the assessment of upper limb motor recovery early after stroke. *Neurorehab Neural Re.* 2014;28(1):4-12.
12. Michielsen M. Vaughan-Graham J. Holland A. Magri A. Suzuki M. The Bobath concept–a model to illustrate clinical practice. *Disabil Rehabil.* 2019;41(17):2080-2092.
13. Díaz-Arribas MJ. Martín-Casas P. Cano-de-la-Cuerda R. Plaza-Manzano G. Effectiveness of the Bobath concept in the treatment of stroke: a systematic review. *Disabil Rehabil.* 2019:1-14.
14. Pumprasart T. Pramodhyakul N. Piriyaprasarth P. The effect of the Bobath therapy programme on upper limb and hand function in chronic stroke individuals with moderate to severe deficits. *International Journal of Therapy And Rehabilitation.* 2019;26(10):1-12.
15. Bernhardt J. Hayward KS. Kwakkel G. et al. Agreed definitions and a shared vision for new standards in stroke recovery research: the stroke recovery and rehabilitation roundtable taskforce. *International Journal of Stroke.* 2017;12(5):444-450.
16. Michaelsen SM. Rocha AS. Knabben RJ. Rodrigues LP. Fernandes CG. Translation. adaptation and inter-rater reliability of the administration manual for the Fugl-Meyer assessment. *Brazilian Journal of Physical Therapy.* 2011;15(1):80-88.
17. Van Kordelaar J. Van Wegen E. Kwakkel G. Impact of Time on Quality of Motor Control of the Paretic Upper Limb After Stroke. *Arch Phys Med Rehab.* 2014;95(2):338-344.
18. Al-Durra M. Nolan RP. Seto E. Cafazzo JA. Prospective registration and reporting of trial number in randomised clinical trials: global cross sectional study of the adoption of ICMJE and Declaration of Helsinki recommendations. *bmj.* 2020;369.
19. Dogru Huzmeli E. Yildirim SA. Kilinc M. Effect of sensory training of the posterior thigh on trunk control and upper extremity functions in stroke patients. *Neurol Sci.* 2017.
20. Ezeugwu VE. Manns PJ. Sleep Duration. Sedentary Behavior. Physical Activity. and Quality of Life after Inpatient Stroke Rehabilitation. *J Stroke Cerebrovasc.* 2017;26(9):2004-2012.
21. Ku P-W. Steptoe A. Liao Y. Hsueh M-C. Chen L-J. A cut-off of daily sedentary time and all-cause mortality in adults: a meta-regression analysis involving more than 1 million participants. *BMC medicine.* 2018;16(1):74.
22. Craig CL. Marshall AL. Sjorstrom M. et al. International physical activity questionnaire: 12-country reliability and validity. *Medicine and science in sports and exercise.* 2003;35(8):1381-1395.
23. Matsudo S. Araújo T. Marsudo V. Andrade D. Andrade E. Braggion G. Questinário internacional de atividade f1sica (IPAQ): estudo de validade e reprodutibilidade no Brasil. *Rev bras ativ fís saúde.* 2001:05-18.
24. World Health Organization. World Health Organization Global recommendations on physical activity for health. *Geneva. Switzerland: WHO.* 2010.

25. Chau JY. Grunseit AC. Chey T. et al. Daily sitting time and all-cause mortality: a meta-analysis. *Plos One.* 2013;8(11):e80000.
26. Bo W. Lei M. Tao S. et al. Effects of combined intervention of physical exercise and cognitive training on cognitive function in stroke survivors with vascular cognitive impairment: a randomized controlled trial. *Clinical rehabilitation.* 2019;33(1):54-63.
27. Schneider EJ. Lannin NA. Ada L. Schmidt J. Increasing the amount of usual rehabilitation improves activity after stroke: a systematic review. *J Physiother.* 2016;62(4):182-187.
28. Murphy MA. Resteghini C. Feys P. Lamers I. An overview of systematic reviews on upper extremity outcome measures after stroke. *Bmc Neurol.* 2015;15.
29. Wu G. van der Helm FC. Veeger HE. et al. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion--Part II: shoulder. elbow. wrist and hand. *J Biomech.* 2005;38(5):981-992.
30. de los Reyes-Guzman A. Dimbwadyo-Terrer I. Trincado-Alonso F. Monasterio-Huelin F. Torricelli D. Gil-Agudo A. Quantitative assessment based on kinematic measures of functional impairments during upper extremity movements: A review. *Clin Biomech (Bristol. Avon).* 2014;29(7):719-727.
31. Pereira S. Silva CC. Ferreira S. et al. Anticipatory postural adjustments during sitting reach movement in post-stroke subjects. *J Electromyogr Kinesiol.* 2014;24(1):165-171.
32. Alt Murphy M. Sunnerhagen KS. Johnels B. Willen C. Three-dimensional kinematic motion analysis of a daily activity drinking from a glass: a pilot study. *J Neuroeng Rehabil.* 2006;3:18.
33. Alt Murphy M. Willen C. Sunnerhagen KS. Kinematic variables quantifying upper-extremity performance after stroke during reaching and drinking from a glass. *Neurorehabil Neural Repair.* 2011;25(1):71-80.
34. Aizawa J. Masuda T. Koyama T. et al. Three-dimensional motion of the upper extremity joints during various activities of daily living. *Journal of Biomechanics.* 2010;43(15):2915-2922.
35. Mesquita IA. Fonseca P. Pinheiro ARV. Velhote Correia MFP. Silva C. Methodological considerations for kinematic analysis of upper limbs in healthy and poststroke adults Part II: a systematic review of motion capture systems and kinematic metrics. *Top Stroke Rehabil.* 2019;26(6):464-472.
36. Murphy MA. Willén C. Sunnerhagen KS. Kinematic variables quantifying upper-extremity performance after stroke during reaching and drinking from a glass. *Neurorehab Neural Re.* 2011;25(1):71-80.
37. Kim K. Song W-K. Lee J. et al. Kinematic analysis of upper extremity movement during drinking in hemiplegic subjects. *Clinical Biomechanics.* 2014;29(3):248-256.
38. Aprile I. Rabuffetti M. Padua L. Di Sipio E. Simbolotti C. Ferrarin M. Kinematic Analysis of the Upper Limb Motor Strategies in Stroke Patients as a Tool towards Advanced Neurorehabilitation Strategies: A Preliminary Study. *Biomed Res Int.* 2014.
39. Van Peppen RP. Hendriks HJ. van Meeteren NL. Helders PJ. Kwakkel G. The development of a clinical practice stroke guideline for physiotherapists in The Netherlands: a systematic review of available evidence. *Disabil Rehabil.* 2007;29(10):767-783.
40. Royal Dutch Society for Physical Therapy. KNGF Clinical Practice Guideline for Physical Therapy in patients with stroke. In: Koninklijk Nederlands Genootschap voor Fysiotherapie K. ed2014.
41. Schwarz A. Kanzler CM. Lambercy O. Luft AR. Veerbeek JM. Systematic Review on Kinematic Assessments of Upper Limb Movements After Stroke. *Stroke.* 2019;50(3):718-727.

42. Schiefelbein ML. Salazar AP. Marchese RR. et al. Upper-limb movement smoothness after stroke and its relationship with measures of body function/structure and activity–A cross-sectional study. *Journal of the neurological sciences.* 2019;401:75-78.
43. Tomita Y. Rodrigues MR. Levin MF. Upper limb coordination in individuals with stroke: poorly defined and poorly quantified. *Neurorehab Neural Re.* 2017;31(10-11):885-897.
44. Collins KC. Kennedy NC. Clark A. Pomeroy VM. Kinematic components of the reach-to-target movement after stroke for focused rehabilitation interventions: systematic review and meta-analysis. *Frontiers in neurology.* 2018;9.
45. van Delden AE. Beek PJ. Roerdink M. Kwakkel G. Peper CE. Unilateral and bilateral upper-limb training interventions after stroke have similar effects on bimanual coupling strength. *Neurorehab Neural Re.* 2015;29(3):255-267.
46. Wu C-y. Chuang L-l. Lin K-c. Chen H-c. Tsay P-k. Randomized trial of distributed constraint-induced therapy versus bilateral arm training for the rehabilitation of upper-limb motor control and function after stroke. *Neurorehab Neural Re.* 2011;25(2):130-139.
47. Popović MD. Kostić MD. Rodić SZ. Konstantinović LM. Feedback-mediated upper extremities exercise: increasing patient motivation in poststroke rehabilitation. *Biomed Res Int.* 2014;2014.

CHAPTER IV

GENERAL DISCUSSION AND FINAL CONSIDERATIONS

DISCUSSION

The current thesis aimed to compare upper limbs functional capacity before and after an eight-week program of neurofunctional rehabilitation. through clinical scales and three-dimensional kinematics assessments, with changes in lifestyle and physical condition improvements as secondary outcomes. Although every individual affected by stroke is unique. with specific complexity and characteristics, the control and intervention groups did not differ from each other in characterization and classification. Therefore, the comparison of the two groups became possible, to enable better understandings about the intervention results.

The decline in the physical activity level in stroke survivors is one of the conditions that also interfere in the individual's functional decline[1,2]. There are still biopsychosocial barriers to be overcome by society, when it comes to the inclusion and social participation of stroke survivors, mainly related to maintaining a healthy lifestyle[1,3]. Changing habits and/or lifestyle is necessary for any individual seeking better quality of life and functionality, especially when referring to stroke survivors[1-3]. Even if minimal, any changes must be stimulated and sought by the multi-professional team as well as for the individual itself[1-3]. In the present work, it was possible to describe changes related to this aspect, namely the reclassification of physical activity level, which showed improvement for the IG, after the intervention.

In a recent study, it was found that more than a fifth of stroke survivors showed a decline in the level of physical activity[1]. which relates stroke as one of the clinical conditions that is responsible for the individual's functional decline. Indeed, the difficulties subsequent to the episode can be explained by several possibilities, including the lack of knowledge of stroke patients that exercise is extremely beneficial and viable, and the lack of access to resources and adequate guidance after a stroke[1]. In the current thesis, there was an improvement between the total physical activity at the baseline and at the M3, for the IG, where some individuals were reclassified as physically active, as well as non-sedentary. Thus, it seems that the intervention was effective regarding changes in lifestyle and possible improvement in the physical condition of the volunteers.

This changes in lifestyle also appeared in the movement quality, in study 1, in the "turning on the light" task, for linear relation of shoulder/hand, elbow/hand, movement time and peak velocity variables, in study 2, and in the "drinking" task, for movement time and smoothness variables, in study 3. Regarding the results of the study 1, it is important to highlight that the motor outcomes related to the assessment provided by the Wolf Motor Functional Test were the most expressive about the influence of the intervention program. Indeed, there is evidence that this scale is the most appropriate to assess movement function and quality, especially in cases of moderate impairment, as it demonstrates a high level of quality of motion measurement and clinical utility[6,8]. However, in contradiction to our findings, other studies have shown great expressiveness of the Fugl-Meyer Upper Extremity Assessment[4,5] for assessing chronic stroke survivors and low expressiveness of Wolf Motor Function Test[5-8]. In face of these results more research should be performed, to clarify which clinical scales the most suitable for assessing motor function and therefore avoid some wasting of time.

Since the study 1 had its objective based on quantification of movement quality in each test task[9,10], the results bring the due importance of the evaluations and indicate the need for their clinical application.

In a recent systematic review it was shown that task/movement time and peak velocity were the most commonly assessed stroke physiological constructs and metrics[11]. Three-dimensional kinematic analysis is considered a great complement to clinical scales, with the quality of better characterizing the structure of movement and understanding the underlying neural mechanisms of functional improvements[4,7].

Thereby, at the study 2, to analyze the coordination between joints during reaching tasks performance, the shoulder/hand and elbow/hand linear relation[12] were assessed, through reaching task three-dimensional motion analysis. The results seem to indicate that the rehabilitation program decreased shoulder movement excess at the “turning on the light” task, becoming the relation between the joint displacements more organized and coordinated[12,13]. This may indicate a new optimal movement with decreased pathological synergy patterns and compensatory movements[11]. Furthermore, the “turning on the light” movement time is a quantitative variable often used in clinical and research assessment and is frequently described as longer in stroke patients[13]. Then, an important finding was found here, since the “turning on the light” movement tend to be highly exacerbated after stroke[13].

At the study 3 the improvement of the “drinking” task movement was found in the amount of time spent at the returning phase, forward and backward transporting phases as well as in smoothness. All these variables presented better results after the intervention, which related to an improvement in movement time, movement quality and better control. These findings are important because stroke survivors tend to prolong the “drinking” task due to upper limbs atypical pattern and functionality[12,14] and highlight the importance of using the correct therapeutic strategies to improve or keep upper limb functionality[15], minimizing the effort in chronic post-stroke subjects and at the role of motor control and perception to optimize body schema and influence task performance often not allowing it to get worse[16]. As the “drinking” movement task shows an improvement in its smoothness, that could indicate greater movement harmony, reflecting better movement trajectories[17].

On the other hand, the quality of life improved over time in both groups, while the sensory-motor impairment remained stable. This happened regarding the movement speed in study 1, the peak velocity decreased, and the movement smoothness increased over time in both groups in study 2, and a borderline significance level for CG in movement smoothness in study

3. These findings may be related to the learning effect due to repetition of the test tasks[18,19], i.e. there was an improvement in the speed requested to perform the pre-established tasks. The results about sensory-motor impairment are supported by previous findings[10,20] that considered the scale that assesses this outcome as ideal for individuals in acute and subacute phases but has failed sensitivity to assess changes in individuals at chronic phase.

The sensory-motor impairment has been considered essential for the motor function classification in stroke individuals, very efficiently in the acute and subacute periods[21] and for its characteristic of identifying major functional changes[20]. Thereby, the movement smoothness increased for both groups, what could be explained by the test learning factor[18,19] for CG and movement rehabilitation for IG, respectively, and velocity profiles are assumed to reflect efficient of motor control[11] and the chronic stage improvements are generally reliant on intense task repetition[22].

Moreover, despite the statistical analysis, the improvement over time in the perception of quality of life of all study participants was well received, because it is an evaluation of a construct with complex and multifactor characteristics in a group of individuals who needs this improvement. The expression "quality of life useful to health" refers to the perceptions of patients about their disease and its effects on their lives, including a personal satisfaction associated with physical well-being, functional, emotional, and social[23,24]. A specialized and lasting rehabilitation can guarantee an improvement in stroke patients, mainly in terms of quality of life[25].

Furthermore, regarding the use of different assessment tools, in some studies, the kinematic analysis did not show changes, while the clinical scales did[4,7]. This result was attributed to the great variability of movement patterns after stroke[4,7]. The solution proposed by a study to minimize the wide range of movement patterns of stroke survivors was to stratify and segment the sample groups according to the sequelae, injury sites and movement patterns presented[7]. Providing more power to find changes with three-dimensional kinematic variables[4,7]. Therefore, using the variability of stimuli for rehabilitation strategies, to benefit the best learning and relearned by stroke survivors[6].

Considering the variability of stimuli and rehabilitation strategies, training on a multiday skill task focused on activities of daily living and functional activities were considered essential to improve dexterity, reduce abnormal movement synergies and avoid compensatory movements[26,27]. The neurofunctional rehabilitation program efficiently uses the problem-solving strategy for upper limb rehabilitation[26,27]. The effectiveness of the neurofunctional rehabilitation program approach should consider the therapist's ability to apply the concept and knowledge of how to use the appropriate tools for clinical evaluation and three-dimensional kinematics[27]. Aiming to minimize patients' disability after onset and quickly restore the performance of activities of daily living[6] with the most appropriate assessment and rehabilitation tools.

Lastly, the evolution found at the current thesis could be due to the functional, repetitive training and sensory motor stimuli and should be used as an ally for the rehabilitation of chronic stroke individuals[18,25,28]. Stroke survivors had better movement times after neurofunctional reabilithation[29]. due to the information processing which may increase with the task complexity[12,30]. Likewise, the stroke may also imply impairment of the parameterization capacity, based on the schema theory which an individual may add specific values to the motor program to meet the specific environmental demands[30]. Individuals with chronic stroke sequelae have a 37 to 55% impairment in the ability to perform daily and functional activities, such as postural transitions, locomotion and related to personal hygiene, food and wearing clothes, due to the planning and sequencing actions being impaired[18,19,28,31,32]. The main concern was the return of the patients/volunteers to daily living activities and this thesis was able to contribute to this aspect.

LIMITATIONS

This study is not without limitations. In fact, although it was not underpowered, the ample size may not be representative to extrapolate the findings in the global population. The small and unequal sizes of the groups also warrant caution in the interpretation of results. The use of the physical activity and sedentary behavior questionnaire may have a bias in the respondents' memory. For instance, chi-square statistical test results should not be extrapolated because some categories do not meet test assumptions (n = 0).

CONCLUSIONS

We conclude that a neurofunctional rehabilitation program in chronic stroke patients was effective in improving upper limbs function, expressed by functional activities, speed and movement quality, in daily life functional activities, in the participants physical activity level, sedentary behavior, upper limb peak velocity, movement time, smoothness and joint displacement relationships. Moreover, the decreased of upper limb function on CG should be explored further and reinforces the need for continuous specialized rehabilitation for chronic stroke patients. Future perspectives bring the need to extrapolate the findings of the upper limbs with the trunk kinematic data could be a way to understand the motor control processes and compensations.

REFERENCES

1. Chen HF. Wu CY. Lin KC. et al. Measurement Properties of Streamlined Wolf Motor Function Test in Patients at Subacute to Chronic Stages After Stroke. *Neurorehab Neural Re.* 2014;28(9):839-846.
2. Persson CU. Hansson P-O. Early Prediction of Physical Inactivity in 215 Individuals 6 Months After a Mild Stroke: The Fall Study of Gothenburg. *Journal of rehabilitation medicine.* 2020;52(6):1-8.
3. Kringle EA. Barone Gibbs B. Campbell G. et al. Influence of interventions on daily physical activity and sedentary behavior after stroke: a systematic review. *Pm&r.* 2020;12(2):186-201.
4. Villepinte C. Verma A. Dimeglio C. De Boissezon X. Gasq D. Responsiveness of kinematic and clinical measures of upper-limb motor function after stroke: a systematic review and meta-analysis. *Annals of Physical and Rehabilitation Medicine.* 2020.
5. McGlinchey MP. James J. McKevitt C. Douiri A. Sackley C. The effect of rehabilitation interventions on physical function and immobility-related complications in severe stroke: a systematic review. *BMJ open.* 2020;10(2).
6. Song B-K. Han S-Y. Jeong J-W. Kim H-N. The Effect of Task-based upper Limb Training on Activities of Daily Living and Upper Limb Function in Chronic Stroke Patients. *Medico Legal Update.* 2020;20(1):2069-2073.
7. Adans-Dester C. Fasoli SE. Fabara E. et al. Can kinematic parameters of 3D reach-to-target movements be used as a proxy for clinical outcome measures in chronic stroke rehabilitation? An exploratory study. *Journal of NeuroEngineering and Rehabilitation.* 2020;17(1):1-13.
8. Laffont I. Froger J. Jourdan C. et al. Rehabilitation of the upper arm early after stroke: Video games versus conventional rehabilitation. A randomized controlled trial. *Annals of physical and rehabilitation medicine.* 2020;63(3):173-180.
9. Thompson-Butel AG. Lin G. Shiner CT. McNulty PA. Comparison of three tools to measure improvements in upper-limb function with poststroke therapy. *Neurorehabil Neural Repair.* 2015;29(4):341-348.
10. Murphy MA. Resteghini C. Feys P. Lamers I. An overview of systematic reviews on upper extremity outcome measures after stroke. *Bmc Neurol.* 2015;15.
11. Schwarz A. Kanzler CM. Lambercy O. Luft AR. Veerbeek JM. Systematic Review on Kinematic Assessments of Upper Limb Movements After Stroke. *Stroke.* 2019;50(3):718-727.
12. de los Reyes-Guzman A. Dimbwadyo-Terrer I. Trincado-Alonso F. Monasterio-Huelin F. Torricelli D. Gil-Agudo A. Quantitative assessment based on kinematic measures of functional impairments during upper extremity movements: A review. *Clin Biomech (Bristol. Avon).* 2014;29(7):719-727.
13. van Dokkum L. Hauret I. Mottet D. Froger J. Métrot J. Laffont I. The contribution of kinematics in the assessment of upper limb motor recovery early after stroke. *Neurorehab Neural Re.* 2014;28(1):4-12.
14. Kim K. Song W-K. Lee J. et al. Kinematic analysis of upper extremity movement during drinking in hemiplegic subjects. *Clinical Biomechanics.* 2014;29(3):248-256.
15. Schiefelbein ML. Salazar AP. Marchese RR. et al. Upper-limb movement smoothness after stroke and its relationship with measures of body function/structure and activity– A cross-sectional study. *Journal of the neurological sciences.* 2019;401:75-78.

16. Michielsen M. Vaughan-Graham J. Holland A. Magri A. Suzuki M. The Bobath concept–a model to illustrate clinical practice. *Disabil Rehabil.* 2019;41(17):2080-
17. van Delden AE. Beek PJ. Roerdink M. Kwakkel G. Peper CE. Unilateral and bilateral upper-limb training interventions after stroke have similar effects on bimanual coupling strength. *Neurorehab Neural Re.* 2015;29(3):255-267.
18. Pollock A. Farmer SE. Brady MC. et al. Interventions for improving upper limb function after stroke. *Cochrane Database Syst Rev.* 2014(11):CD010820.
19. Winstein CJ. Wolf SL. Dromerick AW. et al. Effect of a task-oriented rehabilitation program on upper extremity recovery following motor stroke: the ICARE randomized clinical trial. *Jama.* 2016;315(6):571-581.
20. Lewthwaite R. Winstein CJ. Lane CJ. et al. Accelerating stroke recovery: body structures and functions. activities. participation. and quality of life outcomes from a large rehabilitation trial. *Neurorehab Neural Re.* 2018;32(2):150-165.
21. van Kordelaar J. van Wegen EE. Nijland RH. Daffertshofer A. Kwakkel G. Understanding adaptive motor control of the paretic upper limb early poststroke: the EXPLICIT-stroke program. *Neurorehab Neural Re.* 2013;27(9):854-863.
22. Harcum S. Conroy SS. Boos A. et al. Methods for an Investigation of Neurophysiological and Kinematic Predictors of Response to Upper Extremity Repetitive Task Practice in Chronic Stroke. *Archives of Rehabilitation Research and Clinical Translation.* 2019;1(3-4):100024.
23. Silva SM. Correa FI. Pereira GS. Faria CDCdM. Corrêa JCF. Construct validity of the items on the Stroke Specific Quality of Life (SS-QOL) questionnaire that evaluate the participation component of the International Classification of Functioning. Disability and Health. *Disabil Rehabil.* 2018;40(2):225-231.
24. Pedersen SG. Heiberg GA. Nielsen JF. et al. Validity. reliability and Norwegian adaptation of the stroke-specific quality of life (SS-QOL) scale. *SAGE open medicine.* 2018;6:2050312117752031.
25. Schneider EJ. Lannin NA. Ada L. Schmidt J. Increasing the amount of usual rehabilitation improves activity after stroke: a systematic review. *J Physiother.* 2016;62(4):182-187.
26. Mawase F. Cherry-Allen K. Xu J. Anaya M. Uehara S. Celnik P. Pushing the Rehabilitation Boundaries: Hand Motor Impairment Can Be Reduced in Chronic Stroke. *Neurorehab Neural Re.* 2020;34(8):733-745.
27. Han S-Y. Kim H-N. Jeong J-W. The Effect of Reaching and Hand Function Based on Individual Problem-Solving Approach in Hemiplegic Patients after Stroke: A Randomized Controlled Study. *Journal of Korean Society for Neurotherapy.* 2020;24(1):47-53.
28. Valkenborghs SR. Callister R. Visser MM. Nilsson M. van Vliet P. Interventions combined with task-specific training to improve upper limb motor recovery following stroke: a systematic review with meta-analyses. *Physical Therapy Reviews.* 2019:1-18.
29. Collins KC. Kennedy NC. Clark A. Pomeroy VM. Kinematic components of the reach-to-target movement after stroke for focused rehabilitation interventions: systematic review and meta-analysis. *Frontiers in neurology.* 2018;9.
30. dos Santos Palma GC. Corrêa UC. Torriani-Pasin C. The differentiated effect of the task complexity on retention and transfer of stroke survivors. *Human movement science.* 2020;69:102545.
31. Dogru Huzmeli E. Yildirim SA. Kilinc M. Effect of sensory training of the posterior thigh on trunk control and upper extremity functions in stroke patients. *Neurol Sci.* 2017.

32. Van Peppen RP. Hendriks HJ. van Meeteren NL. Helders PJ. Kwakkel G. The development of a clinical practice stroke guideline for physiotherapists in The Netherlands: a systematic review of available evidence. *Disabil Rehabil*. 2007;29(10):767-783.

ANNEXES

Annex A: Mini Mental State Examination (MMSE)

Mini Mental State Examination (MMSE)

1. **Orientação** (1 ponto por cada resposta correta)
    a. Em que ano estamos? _____
    b. Em que mês estamos? _____
    c. Em que dia do mês estamos? _____
    d. Em que dia da semana estamos? _____
    e. Em que estação do ano estamos? _____

Nota:____

    f. Em que país estamos? _____
    g. Em que distrito vive? _____
    h. Em que terra vive? _____
    i. Em que casa estamos? _____
    j. Em que andar estamos? _____

Nota:____

2. Retenção (contar 1 ponto por cada palavra corretamente repetida)

"Vou dizer três palavras; queria que as repetisse, mas só depois de eu as dizer todas; procure ficar a sabê-las de cor".

Pêra _____ Gato _____ Bola _____

Nota:____

3. Atenção e Cálculo (1 ponto por cada resposta correta. Se der uma errada, mas depois continuar a subtrair bem, consideram-se as seguintes como corretas. Parar ao fim de 5 respostas)

"Agora peco-lhe que me diga quantos são 30 menos 3 e depois ao número encontrado volta a tirar 3 e repete assim até eu lhe dizer para parar".

27_ 24_ 21 _ 18_ 15 **Nota**:____

4. Evocação (1 ponto por cada resposta correta.)

"Veja se consegue dizer as três palavras que pedi há pouco para decorar".

Pêra ______ Gato ______ Bola ______

Nota:____

5. Linguagem (1 ponto por cada resposta correcta)

a. "Como se chama isto? Mostrar os objectos:
Relógio ____ Lápis______ **Nota**:____

b. "Repita a frase que eu vou dizer: O RATO ROEU A ROLHA"

Nota:____

c. "Quando eu lhe der esta folha de papel, pegue nela com a mão direita, dobre-a ao meio e ponha sobre a mesa"; dar a folha segurando com as duas mãos.

Pega com a mão direita____ Dobra ao meio ____ Coloca onde deve____ **Nota**:____

d. "Leia o que está neste cartão e faça o que lá diz". Mostrar um cartão com a frase bem legível, "FECHE OS OLHOS"; sendo analfabeto lê-se a frase.

Fechou os olhos____ **Nota**:____

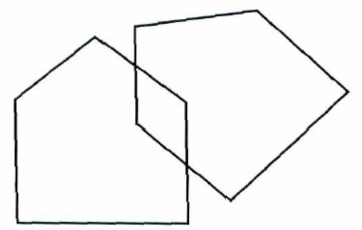
e. "Escreva uma frase inteira aqui". Deve ter sujeito e verbo e fazer sentido; os erros gramaticais não prejudicam a pontuação.

Frase:

Nota:____

6. Habilidade Construtiva (1 ponto pela cópia correcta.)

Deve copiar um desenho. Dois pentágonos parcialmente sobrepostos; cada um deve ficar com 5 lados, dois dos quais intersectados. Não valorizar tremor ou rotação.



Cópia:

Nota:____

TOTAL(Máximo 30 pontos):____

Annex B: Informed Consent Form

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Gostaríamos de solicitar sua autorização para a participação na pesquisa intitulada **Avaliação cinemática tridimensional na reabilitação neurofuncional do membro superior em pacientes com acidente vascular cerebral crônico,** que faz parte do curso do Programa de Doutorado da Faculdade Desporto da Universidade do Porto – Porto – Portugal, orientado pela professora Dr. **Cláudia Isabel Costa da Silva** e colaboração do Laboratório de Biomecânica e Comportamento Motor da Universidade Estadual de Maringá (UEM), com coordenação e supervisão do professor Dr. **Pedro Paulo Deprá**.

O objetivo da pesquisa será avaliar e comparar de forma quantitativa as características dos movimentos dos membros superiores de pacientes com acidente vascular cerebral crônico antes e após um programa de reabilitação NEUROFUNCIONAL e de indivíduos sem patologias na cidade de Maringá – Paraná – Brasil. Não estão previstos riscos ou desconfortos inaceitáveis durante a coleta de dados, pois o movimento analisado, que é beber água em um copo, será acompanhado. As avaliações e intervenções tem duração de aproximadamente 1 hora e 30min, para cada etapa. Para isto a participação será muito importante e ela se daria da seguinte forma:

(I) Será recolhido inicialmente os dados clínicos, a função motora e dados de qualidade de vida dos voluntários por meio de questionários.

(II) O nível de atividade física será recolhido por meio de um Questionário Internacional de Atividade Física (IPAQ).

(III) Após essa primeira semana, um sorteio será realizado para a divisão dos voluntários com acidente vascular encefálico em 2 grupos, em que todos os voluntários receberão o mesmo programa de reabilitação, de 2 vezes por semana, com duração de 1 hora cada sessão. Grupo Intervenção receberá 8 semanas de reabilitação neurofuncional, com 3 etapas de avaliações, além 8 semanas de acompanhamento sem reabilitação, seguido de 1 etapa de avaliação. Os voluntários que forem sorteados para o Grupo Controle, receberão 3 etapas de avaliações em 8 semanas sem reabilitação, seguido do mesmo programa de reabilitação e avaliações do Grupo Intervenção. Os voluntários sem patologias, serão avaliados em uma única etapa desta fase, a etapa de avaliação inicial.

(IV) Para a avaliação do membro superior, serão recordados os movimentos de pegar uma garrafa de água, desligar e ligar um interruptor, na posição sentada, com capturas de imagem de alta definição e questionários durantes o processo de reabilitação. Todas as etapas de avaliações e intervenções serão realizadas por um Fisioterapeuta previamente treinado.

Gostaríamos de esclarecer que a participação é totalmente voluntária, podendo você: recusar-se a participar, ou mesmo desistir a qualquer momento sem que isto acarrete qualquer ônus ou prejuízo à sua pessoa. Informamos ainda que as informações serão utilizadas somente para os fins desta pesquisa, serão tratadas com o mais absoluto sigilo e confidencialidade, de modo a preservar a identidade. Durante a realização da pesquisa as imagens recordadas, somente serão utilizadas sob sigilo de informação, ou seja, somente pelos pesquisadores. Após a conclusão do estudo e apuração de todas as informações, as imagens serão inutilizadas/descartadas permanentemente. Você terá pleno acesso, a qualquer momento, às informações. Nos momentos de divulgação dos resultados da pesquisa, em eventos e revistas científicas, não será identificado nenhum voluntário, ou seja, será assegurado o anonimato de todos os participantes. A participação nesta pesquisa não implica nenhum gasto para você e também não podemos oferecer nenhuma compensação financeira para sua participação. Após o término do estudo, um relatório geral das atividades e situações clínicas será entregue para todos os participantes.

Os benefícios esperados são: contribuir para qualidade de vida dos indivíduos com acidente vascular cerebral crônico, uma vez que as avaliações e intervenções direcionadas e específicas sobre a função do membro superior, podem proporcionar um melhor conhecimento, aos profissionais de saúde e aos indivíduos acometidos por essa patologia, visando facilitar o desenvolvimento terapêutico e estimular a reabilitação mais eficientemente.

Caso você tenha mais dúvidas ou necessite maiores esclarecimentos, pode nos contatar nos endereços a seguir ou procurar o Comitê de Ética em Pesquisa da UEM, cujo endereço consta deste documento.

Este termo deverá ser preenchido em duas vias de igual teor, sendo uma delas, devidamente preenchida e assinada entregue a você.

Além da assinatura nos campos específicos pelo pesquisador e por você, solicitamos que sejam rubricadas todas as folhas deste documento. Isto deve ser feito por ambos (pelo pesquisador e por você, como sujeito ou responsável pelo sujeito de pesquisa) de tal forma a garantir o acesso ao documento completo.

Eu,……………………………………………………………………………………………...(NOME DO VOLUNTÁRIO) declaro que fui devidamente esclarecido e concordo em participar VOLUNTARIAMENTE da pesquisa coordenada pelo ....…………………………………………………………………… (NOME DO PESQUISADOR RESPONSÁVEL).

____ Data:______________

Assinatura ou impressão datiloscópica

Eu,……

(nome do pesquisador ou do membro da equipe que aplicou o TCLE), declaro que forneci todas as informações referentes ao projeto de pesquisa supra-nominado.

____ Data:..............................

Assinatura do pesquisador

Qualquer dúvida com relação à pesquisa poderá ser esclarecida com o pesquisador, conforme o endereço abaixo:
Nome: Fellipe Bandeira Lima
E-mail: lima_fisioterapia@hotmail.com Celular: (44) 9-9828-2768
Qualquer dúvida com relação aos aspectos éticos da pesquisa poderá ser esclarecida com o Comitê Permanente de Ética em Pesquisa (COPEP) envolvendo Seres Humanos da UEM, no endereço abaixo:

COPEP/UEM - Universidade Estadual de Maringá.
Av. Colombo, 5790. Campus Sede da UEM. - Bloco da Biblioteca Central (BCE) da UEM.
CEP 87020-900. Maringá-Pr. Tel: (44) 3261-4444 - E-mail: copep@uem.br

Annex C: International Physical Activity Questionnaire (IPAQ)

QUESTIONÁRIO INTERNACIONAL DE ATIVIDADE FÍSICA.

Nome:____ **Data: ___/ ___/ ___ Idade : ____ Sexo: F ( ) M ( ) Você trabalha de forma remunerada: ( ) Sim ( ) Não.**
Quantas horas você trabalha por dia: ____ Quantos anos completos você estudou: _____
De forma geral sua saúde está: ( ) Excelente ( ) Muito boa ( ) Boa ( ) Regular ( )Ruim

Nós estamos interessados em saber que tipos de atividade física as pessoas fazem como parte do seu dia a dia. Este projeto faz parte de um grande estudo que está sendo feito em diferentes países ao redor do mundo. Suas respostas nos ajudarão a entender que tão ativos nós somos em relação à pessoas de outros países. As perguntas estão relacionadas ao tempo que você gasta fazendo atividade física em uma semana **ultima semana**. As perguntas incluem as atividades que você faz no trabalho, para ir de um lugar a outro, por lazer, por esporte, por exercício ou como parte das suas atividades em casa ou no jardim. Suas respostas são MUITO importantes. Por favor, responda cada questão mesmo que considere que não seja ativo. Obrigado pela sua participação!

Para responder as questões lembre que:
- Atividades físicas **VIGOROSAS** são aquelas que precisam de um grande esforço físico e que fazem respirar MUITO mais forte que o normal
- Atividades físicas **MODERADAS** são aquelas que precisam de algum esforço físico e que fazem respirar UM POUCO mais forte que o normal

SEÇÃO 1- ATIVIDADE FÍSICA NO TRABALHO

Esta seção inclui as atividades que você faz no seu serviço, que incluem trabalho remunerado ou voluntário, as atividades na escola ou faculdade e outro tipo de trabalho não remunerado fora da sua casa. **NÃO** incluir trabalho não remunerado que você faz na sua casa como tarefas domésticas, cuidar do jardim e da casa ou tomar conta da sua família. Estas serão incluídas na seção 3.

1a. Atualmente você trabalha ou faz trabalho voluntário fora de sua casa?
( ) Sim ( ) Não – Caso você responda não **Vá para seção 2: Transporte**

As próximas questões são em relação a toda a atividade física que você fez na **ultima semana** como parte do seu trabalho remunerado ou não remunerado. **NÃO** inclua o transporte para o trabalho. Pense unicamente nas atividades que você faz por **pelo menos 10 minutos contínuos**:

1b. Em quantos dias de uma semana normal você **anda,** durante **pelo menos 10 minutos contínuos**, como **parte do seu trabalho**?Por favor, **NÃO** inclua o andar como forma de transporte para ir ou voltar do trabalho.

_______dias por **SEMANA** ( ) nenhum - **Vá para a seção 2 - Transporte**.

1c. Quanto tempo no total você usualmente gasta POR DIA caminhando **como parte do seu trabalho** ?

____ horas ______ minutos

1d. Em quantos dias de uma semana normal você faz atividades **moderadas,** por **pelo menos 10 minutos contínuos,** como carregar pesos leves **como parte do seu trabalho**?

_______dias por **SEMANA** ( ) nenhum - **Vá para a questão 1f**

1e. Quanto tempo no total você usualmente gasta POR DIA fazendo atividades moderadas **como parte do seu trabalho**?

_____ horas ______ minutos

1f. Em quantos dias de uma semana normal você gasta fazendo atividades **vigorosas,** por **pelo menos 10 minutos contínuos,** como trabalho de construção pesada, carregar grandes pesos, trabalhar com enxada, escavar ou subir escadas **como parte do seu trabalho:**

_______dias por **SEMANA** ( ) nenhum - **Vá para a questão 2a.**

1g. Quanto tempo no total você usualmente gasta POR DIA fazendo atividades físicas vigorosas **como parte do seu trabalho**?

_____ horas ______ minutos

SEÇÃO 2 - ATIVIDADE FÍSICA COMO MEIO DE TRANSPORTE

Estas questões se referem à forma típica como você se desloca de um lugar para outro, incluindo seu trabalho, escola, cinema, lojas e outros.

2a. O quanto você andou na ultima semana de carro, ônibus, metrô ou trem?

________dias por **SEMANA** ( ) nenhum - **Vá para questão 2c**

2b. Quanto tempo no total você usualmente gasta POR DIA **andando de carro, ônibus, metrô ou trem?**

_____horas _____minutos

Agora pense **somente** em relação a caminhar ou pedalar para ir de um lugar a outro na ultima semana.

2c. Em quantos dias da ultima semana você andou de bicicleta por **pelo menos 10 minutos contínuos** para ir de um lugar para outro? (NÃO inclua o pedalar por lazer ou exercício)

_____ dias por **SEMANA** ( ) Nenhum - **Vá para a questão 2e**.

2d. Nos dias que você pedala quanto tempo no total você pedala POR DIA para ir de um lugar para outro?

_______ horas _____ minutos

2e. Em quantos dias da ultima semana você caminhou por **pelo menos 10 minutos contínuos** para ir de um lugar para outro? (NÃO inclua as caminhadas por lazer ou exercício)

_____ dias por **SEMANA** ( ) Nenhum - **Vá para a Seção 3**.

2f. Quando você caminha para ir de um lugar para outro quanto tempo **POR DIA** você gasta? (**NÃO** inclua as caminhadas por lazer ou exercício)

_______ horas _____ minutos

SEÇÃO 3 – ATIVIDADE FÍSICA EM CASA: TRABALHO, TAREFAS DOMÉSTICAS E CUIDAR DA FAMÍLIA.

Esta parte inclui as atividades físicas que você fez na ultima semana na sua casa e ao redor da sua casa, por exemplo, trabalho em casa, cuidar do jardim, cuidar do quintal, trabalho de manutenção da casa ou para cuidar da sua família. Novamente pense ***somente*** naquelas atividades físicas que você faz **por pelo menos 10 minutos contínuos**.

3a. Em quantos dias da ultima semana você fez atividades **moderadas** por pelo menos 10 minutos como carregar pesos leves, limpar vidros, varrer, rastelar **no jardim ou quintal.**

________dias por **SEMANA** ( ) Nenhum - **Vá para questão 3b**.

3b. Nos dias que você faz este tipo de atividades quanto tempo no total você gasta **POR DIA** fazendo essas atividades moderadas **no jardim ou no quintal**?

_______ horas _____ minutos

3c. Em quantos dias da ultima semana você fez atividades **moderadas** por pelo menos 10 minutos como carregar pesos leves, limpar vidros, varrer ou limpar o chão **dentro da sua casa**.

_____ dias por **SEMANA** ( ) Nenhum - **Vá para questão 3d.**

3d. Nos dias que você faz este tipo de atividades moderadas **dentro da sua casa** quanto tempo no total você gasta **POR DIA**?

_______ horas _____ minutos

3e. Em quantos dias da ultima semana você fez atividades físicas **vigorosas** **no jardim ou quintal** por pelo menos 10 minutos como carpir, lavar o quintal, esfregar o chão:

_____ dias por **SEMANA** ( ) Nenhum - **Vá para a seção 4.**

3f. Nos dias que você faz este tipo de atividades vigorosas **no quintal ou jardim** quanto tempo no total você gasta **POR DIA**?

_______ horas _____ minutos

SEÇÃO 4- ATIVIDADES FÍSICAS DE RECREAÇÃO, ESPORTE, EXERCÍCIO E DE LAZER.

Esta seção se refere às atividades físicas que você fez na ultima semana unicamente por recreação, esporte, exercício ou lazer. Novamente pense somente nas atividades físicas que faz **por pelo menos 10 minutos contínuos**. Por favor, **NÃO** inclua atividades que você já tenha citado.

4a. **Sem contar qualquer caminhada que você tenha citado anteriormente**, em quantos dias da ultima semana você caminhou **por pelo menos 10 minutos contínuos** **no seu tempo livre**?

_____ dias por **SEMANA** ( ) Nenhum - **Vá para questão 4b**

4b. Nos dias em que você caminha **no seu tempo livre**, quanto tempo no total você gasta POR DIA?

_______ horas _____ minutos

4c. Em quantos dias da ultima semana você fez atividades **moderadas no seu tempo livre** por pelo menos 10 minutos, como pedalar ou nadar a velocidade regular, jogar bola, vôlei , basquete, tênis :

_____ dias por **SEMANA** ( ) Nenhum - **Vá para questão 4d.**

4d. Nos dias em que você faz estas atividades moderadas **no seu tempo livre** quanto tempo no total você gasta POR DIA?

_______ horas _____ minutos

4e. Em quantos dias da ultima semana você fez atividades **vigorosas no seu tempo livre** por pelo menos 10 minutos, como correr, fazer aeróbicos, nadar rápido, pedalar rápido ou fazer Jogging:

_____ dias por **SEMANA** ( ) Nenhum - **Vá para seção 5.**

4f. Nos dias em que você faz estas atividades vigorosas **no seu tempo livre** quanto tempo no total você gasta POR DIA?

_______ horas _____ minutos

SEÇÃO 5 - TEMPO GASTO SENTADO

Estas últimas questões são sobre o tempo que você permanece sentado todo dia, no trabalho, na escola ou faculdade, em casa e durante seu tempo livre. Isto inclui o tempo sentado estudando, sentado enquanto descansa, fazendo lição de casa visitando um amigo, lendo, sentado ou deitado assistindo TV. Não inclua o tempo gasto sentando durante o transporte em ônibus, trem, metrô ou carro.

5a. Quanto tempo no total você gasta sentado durante um **dia de semana**?
______horas ____minutos

5b. Quanto tempo no total você gasta sentado durante em um **dia de final de semana**?
______horas ____minutos

Annex D: Evaluation Form.

FICHA DE AVALIAÇÃO EM FISIOTERAPIA NEUROLÓGIA
AVE

ANAMNESE

Nome:____ Data de Nasc.: __/__/____ Idade: _____anos
Sexo: ( ) M ( ) F Estado civil:______________ Religião: __________Etnia:___________________
Profissão: _____________________________________Escolaridade:__________________________
Naturalidade: _____________________________ Procedência: _______________________________
Endereço:____ Bairro: ______________________
HMA: ____
____
____
____
____
____
____
DIAGNÓSTICO:____
QP:____
AP:____
AF: ____
AC:____
Medicamentos:____
Exames Complementares: ____

EXAME FÍSICO

DADOS VITAIS: FC_____ bpm FR: _____ rpm PA: ______/_______
INSPEÇÃO: ____
____
____
AVALIAÇÃO DERMATOLÓGICA:____
____
TROFISMO: MMSS:____
____
MMII:____
____
TÔNUS: MMSS: ____
MMII: ____
ADM: Ombro: ____
Cotovelo: ____
Punho: ____
Quadril: ____
Joelho: ____
Tornozelo: ____
MOTRICIDADE VOLUNTÁRIA:
1. Solicitação de movimentos ativos: ____
____
____
____
____
____

MOTRICIDADE INVOLUNTÁRIA: ( )Ausente ( ) Presente ____________________________________

REFLEXOS PROFUNDOS

BICIPITAL	D:	E:
TRICIPITAL	D:	E:
ESTILORRADIAL	D:	E:
CUBITOPRONADOR	D:	E:
ADUTOR	D:	E:
PATELAR	D:	E:
AQUILEU	D:	E:

*Obs:*____

REFLEXOS SUPERFICIAIS

CUTÂNEO ABDOMINAL	D:	E:
CUTÂNEO PLANTAR	D:	E:

*Obs:*____

CLÔNUS

PUNHO	D:	E:
PATELAR	D:	E:
AQUILEU	D:	E:

SENSIBILIDADE SUPERFICIAL

OMBRO	D:	E:
BRAÇO	D:	E:
ANTEBRAÇO	D:	E:
MÃO	D:	E:
TÓRAX	D:	E:
COXA	D:	E:
PERNA	D:	E:
PÉ	D:	E:

SENSIBILIDADE PROFUNDA (Cinética-postural)

Ombro: D:___________________________________; E:____;
Cotovelo: D:________________________________; E:____;
Punho: D:___________________________________; E:____;
Quadril: D:_________________________________; E:____;
Joelho: D:__________________________________; E:____;
Tornozelo: D:_______________________________; E:____;
Hálux: D:___________________________________; E:____;

ATIVIDADES FUNCIONAIS

DD->DL's:____

____

DD->Sentado:____

____

DL->DV:____

____

DV->Gato:____

____

Gato->Sentado:____

____

AVD *(Dependente, semi-dependente ou independente);*

Alimentação:____

Vestuário:____

Higiene:____

EQUILÍBRIO(30s):

Romberg: OA: ______________________________ OF: ____________________________________

Tandem: OA: ______________________________ OF: ____________________________________

Unipodal: OA: ______________________________ OF: ____________________________________

COORDENAÇÃO (+:normal; -: alterado)

Index-index ( ) Index-Nariz ( ) Index-Index-Nariz ( ) Calcanhar-joelho ( )

Rechaço ( ) ____

Diadococinesia ( ) ____

LOCOMOÇÃO: ( ) Independente ( ) Semi dependente ( ) Dependente

____

MARCHA:____

____

____

____

AVALIAÇÃO POSTURAL:____

____

DIAGNÓSTICO CINETICO-FUNCIONAL

____

____

____

____

____

OBJETIVOS FISIOTERÁPICOS

____

____

____

Avaliado por: ____________________________________

Annex E: Fugl-Meyer Upper Extremity Motor Scale

NOME:	IDADE:	SEXO
DIAGNÓSTICO:		
SEQUELAS:		

FUGL MEYER AVALIAÇÃO DA EXTREMIDADE SUPERIOR

A. EXTREMIDADE SUPERIOR, posição sentada			
I. Motricidade reflexa		**Ausente**	**Presente**
Flexores: Bíceps e flexores dos dedos __		0	2
Extensores: Tríceps __		0	2
Subtotal I (Max. 4)			

II. Motricidade Ativa, sem ajuda gravitacional.			**Ausente**	**Par ial**	**Completo**
Sinergia Flexora:	Ombro	Retração __	0	1	2
		Elevação __	0	1	2
		Abdução (90º) __	0	1	2
		Rotação __	0	1	2
	Cotovelo	Flexão __	0	1	2
	Antebraço	Supinação __	0	1	2
Sinergia Extensora:		Adução do ombro/rotação interna __	0	1	2
		Extensão do cotovelo __	0	1	2
		Pronação do antebraço __	0	1	2
		Subtotal II (Max. 18)			

III. Movimentos sinergéticos combinados, sem compensação		**Ausente**	**Parcial**	**Completo**
Mão á coluna lombar	-Não realizou -Mão passa espinha ilíaca ântero-posterior -Realiza á ação	0	1	2
Flexão de ombro de 0 a 90º; Cotovelo em 0º e pronação-supinação em 0º	-Imediata abdução de braço ou flexão de cotovelo -Abdução ou flexão do cotovelo durante o do movimento -Movimentação normal	0	1	2
Pronação-Supinação do antebraço; contovelo em 90º e ombro em 0º	-Não há pronação/supinação, não dá início -Pronação/supinação limitada, mantém posição -Movimentação normal	0	1	2
	Subtotal III (Max. 6)			

IV. Movimento com leve ou sem sinergia		**Ausente**	**Par ial**	**Completo**
Abdução do ombro de 0 á 90º, com cotovelo extendido e pronado	-Imediata supinação ou flexão de cotovelo -Abdução do ombro ou supinação do cotovelo durante o movimento -Movimentação normal	0	1	2
Flexão do ombro de 90º para 180º, com antebraço neutro	-Imediata abdução ou flexão de cotovelo -Abdução do ombro ou flexão de cotovelo durante o movimento -Movimentação normal	0	1	2

Pronação/Supinação, cotovelo em 0º, ombro em 30 á 90º fletido	-Não há pronação/supinação, não dá início -Pronação/supinação limitada, mantendo extensão -Movimentação normal	0	1	2
	Subtotal IV (Max. 6)			
V. Atividade reflexa normal, avaliado somente se alcançado o escore de 6 pontos na parte IV				
Bíceps, tríceps e flexores dos dedos	-0 pontos na parte IV ou 2 de 3 reflexos hiperativos -1 reflexo hiperativo ou ao menos 2 reflexos presentes -No máximo 1 reflexo presente, sem hiperatividade	0	1	2
	Subtotal V (Max. 2)			
	Total A (Max. 36)			

B. PUNHO, pode ser prestado apoio no cotovelo para acionar ou manter a posição, sem apoio no pulso, e verificar a ADM passivo antes do teste		**Ausente**	**Parcial**	**Completo**
Estabilidade em 15º de extensão; cotovelo em 90º, antebraço pronado	-Não consegue extender o punho á 15º -Consegue extender em 15º, sem resistência -Extende 15º contra alguma resistência	0	1	2
Flexão/extensão alternada; cotovelo a 90º, antebraço pronado	-Não ocorre movimento voluntário -Não consegue mover ativamente o punho -Movimento ativo normal	0	1	2
Estabilidade em 15º de extensão; cotovelo em 0º, antebraço pronado, leve flexão/abdução de ombro	-Não consegue extender o punho á 15º -Consegue extender em 15º, sem resistência -Extende 15º contra alguma resistência	0	1	2
Flexão/extensão alternada; cotovelo a 0º, antebraço pronado, leve flexão/abdução de ombro	-Não ocorre movimento voluntário -Não consegue mover ativamente o punho -Movimento ativo normal	0	1	2
Circundução	-Não ocorre movimento voluntário -Movimento incompleto ou oscilante -Movimentação completa	0	1	2
	Total B (Max. 10)			

C. MÃO, pode ser prestado apoio no cotovelo para manter 90º de flexão, compare com a mão não afetada os objetos preensados ativamente*		**Ausente**	**Parcial**	**Completo**
Flexão em Massa, com extensão ativa ou passiva		0	1	2
Extensão em Massa, com flexão ativa ou passiva		0	1	2
PREENSÃO				

A - Flexão IFD e IFP (II á V) **e extensão MCF** (II á V)	-Posição não pode ser executada -Executada com preensão fraca -Mantém posição contra resistência	0	1	2
B - Adução do polegar, com um de papel entre o polegar e o segundo MCF	-A função não pode ser realizada -Segura o papel, mas não contra leve puxão -Segura o papel firmemente	0	1	2
C - Oposição, polpa do polegar contra a polpa do 2º dedo, com caneta interposta	-A função não pode ser realizada -Segura a caneta, mas não contra leve puxão -Segura a caneta firmemente	0	1	2
D – Objeto cilíndrico, segura á superfície volar do 1º e 2º dedos contra outros	-A função não pode ser realizada -Segura o cilindro, mas não contra leve puxão -Segura o cilindro firmemente	0	1	2
E – Objeto esférico, Segurar com firmeza uma bola de tênis	-A função não pode ser realizada -Segura a esfera, mas não contra leve puxão -Segura a esfera firmemente	0	1	2
	Total C (Max. 14)			

D. COORDENAÇÂO/VELOCIDADE, com os 2 braços, olhos vendados, levando a ponta do dedo indicador até o nariz 5 vezes, o mais rápido possível		**Acentuado**	**Leve**	**Nenhum**
Tremor __		0	1	2
Dismetria	-Dismetria grave ou não sistemática -Dismetria leve e sistemática -Nenhuma dismetria	0	1	2
		>5s	**2 – 5s**	**<1s**
Velocidade	-Mais do que 5s em comparação ao lado não afetado -2 á 5 segundos á mais comparado ao lado não o afetado -Diferença máxima de 1 segundo	0	1	2
	Total D (Max. 6)			
	Total A á D (Max. 66)			

H. SENSIBILIDADE, de olhos vendados, comparando braço afetado/não afetado		**Anestesia**	**Hipoestesia/ Disestesia**	**Normal**
Toque leve (exteriocepção)	-Membro superior __ -Palma da mão __	0 0	1 1	2 2
		>3/4	**<3/4**	**Pequena/nenhum a diferença**
Posição (propriocepção)	-Ombro __ -Cotovelo __ -Punho __ -Polegar __	0 0 0 0	1 1 1 1	2 2 2 2
		Total H (Max. 12)		

J. MOVIMENTO ARTICULAR PASSIVO				J. DOR ARTICULAR, movimento passivo		
Posição inicial, comparando com membro não afetado	Poucos graus (<10º em ombro)	diminuído	normal	Relatando dor durante e/ou ao fim do movimento	Pouca dor	Sem dor
Ombro						
Flexão (0º - 180º) __	0	1	2	0	1	2
Abdução (0 - 90º) __	0	1	2	0	1	2
Rotação externa __	0	1	2	0	1	2
Rotação interna __	0	1	2	0	1	2
Cotovelo						
Flexão __	0	1	2	0	1	2
Extensão __	0	1	2	0	1	2
Antebraço						
Pronação __	0	1	2	0	1	2
Supinação __	0	1	2	0	1	2
Punho						
Flexão __	0	1	2	0	1	2
Extensão __	0	1	2	0	1	2
Dedos						
Flexão __	0	1	2	0	1	2
Extensão __	0	1	2	0	1	2
Total (Max. 24)				**Total** (Max. 24)		

A. EXTREMIDADE SUPERIOR	/36
B. PUNHO	/10
C. MÃO	/14
D. COORDENAÇÃO/VELOCIDADE	/6
TOTAL A-D (função motora)	/66

H. SENSIBILIDADE	/12
J. MOVIMENTO ARTICULAR PASSIVO	/24
J. DOR ARTICULAR	/24

Avaliador:_____________________________________ Data:___/___/___

Annex F: Wolf Motor Function Test (WMFT)

WMFT – Wolf Motor Function Test

Nome do paciente: ____

Data:____/____/____

Teste do braço (checagem 1): Mais afetado_______ Menos afetado________

Tarefa	Tempo	Habilidade funcional (HF)	Comentário
1. Antebraço na mesa		012345	
2. Antebraço na caixa		012345	
3. Extensão de cotovelo		012345	
4. Extensão do cotovelo (com peso)		012345	
5. Mão na mesa		012345	
6. Mão na caixa		012345	
7. Com peso na caixa*		____________g	
8. Alcançar e retroceder		012345	
9. Levantar lata		012345	
10. Levantar lápis		012345	
11. Levantar clipe de papel		012345	
12. Empilhar peças		012345	
13. Virar cartas		012345	
14. Força de preensão*		____________Kgf	
15. Virar chave		012345	
16. Dobrar toalha		012345	
17. Levantar cesta		012345	

* os itens de força não são incluídos no desempenho final do tempo ou na HF

Descrição das tarefas do WMFT

1. Antebraço na mesa (de lado): colocar o antebraço na mesa fazendo abdução de ombro.
2. Antebraço na caixa (de lado): colocar o antebraço na caixa fazendo abdução de ombro.
3. Extensão de cotovelo (de lado): Levar a mão do outro lado da mesa estendendo o cotovelo.
4. Extensão de cotovelo com peso (de lado): Empurrar o peso para o outro lado da mesa estendendo o cotovelo.
5. Mão na mesa (de frente): Colocar a mão testada na mesa.
6. Mão na caixa (de frente): Colocar a mão na caixa.
8. Alcançar e retroceder (de frente): Puxar peso de 1 kg através da mesa usando flexão de cotovelo, antebraço na posição neutra e mão em concha.
9. Levantar lata (de frente): Levantar a lata e aproximá-la dos lábios com preensão cilíndrica.
10. Levantar lápis (de frente): Levantar lápis usando preensão com três dedos.
11. Levantar clipe de papel (de frente): Levantar um clipe de papel usando pinça polpa-polpa.
12. Empilhar peças de dama (de frente): Empilhar três peças de dama.
13. Virar cartas (de frente): Virar três cartas usando a pinça e supinação de antebraço.
15. Virar chave na fechadura (de frente): Utilizando a pinça da chave, virá-la para ambos os lados e voltar ao meio.
16. Dobrar toalha (de frente): Dobrar toalha longitudinalmente, em seguida, usa a mão testada para dobrar a toalha ao meio novamente.
17. Levantar a cesta (de pé): Pegar a cesta pela alça e colocá-la na superfície ao lado.

Annex G: Modified Ashworth Scale

NOME:	IDADE:	SEXO
DIAGNÓSTICO:		
SEQUELAS:		

ESCALA MODIFICADA DE ASHWORTH Classificação da Espasticidade		
Grau		Descrição
	0	Sem aumento do tônus muscular
	1	Discreto aumento do tônus muscular, manifestado pelo apreender e liberar, ou por mínima resistência ao final da amplitude de movimento, quando a parte (ou as partes) afetada é movimentada em flexão e extensão.
	1+	Discreto aumento no tônus muscular, manifestado pelo apreender, seguido de mínima resistência através do resto (menos da metade) da amplitude de movimento.
	2	Marcante aumento do tônus muscular através da maior parte da amplitude de movimento, porém as partes afetadas são facilmente movimentadas.
	3	Considerável aumento do tônus muscular; movimentos passivos dificultados.
	4	A parte (ou partes) afetada mostra-se rígida à flexão ou extensão.

Annex H: Specific quality of life scale for stroke

Escala de Qualidade de Vida Específica para AVE (EQVE-AVE)	
Pontuação: cada item será pontuado com o seguinte critério	
Ajuda Total – Não pude fazer de modo algum – Concordo inteiramente	1
Muita ajuda – Muita dificuldade – Concordo mais ou menos	2
Alguma ajuda – Alguma dificuldade – Nem concordo nem discordo	3
Um pouco de ajuda – Um pouco de dificuldade – Discordo mais ou menos	4
Nenhuma ajuda necessária – Nenhuma dificuldade mesmo – Discordo inteiramente	5
ITEM	**PONTUAÇÃO**
Energia	
1. Eu me senti cansado a maior parte do tempo.	
2. Eu tive que parar e descansar durante o dia.	
3. Eu estava cansado demais para fazer o que eu queria.	
Papéis Familiares	
1. Eu não participei em atividades apenas por lazer/diversão com minha família.	
2. Eu senti que era um fardo/peso para minha família.	
3. Minha condição física interferiu com minha vida pessoal.	
Linguagem	
1. Você teve dificuldade para falar? Por exemplo, não achar a palavra certa, gaguejar, não conseguir se expressar, ou embolar as palavras?	
2. Você teve dificuldade para falar com clareza suficiente para usar o telefone?	
3. Outras pessoas tiveram dificuldade de entender o que você disse?	
4. Você teve dificuldade em encontrar a palavra que queria dizer?	
5. Você teve que se repetir para que os outros pudessem entendê-lo?	
Mobilidade	
1. Você teve dificuldade para andar? (Se o paciente não pode andar, vá para questão 4 e pontue as questões 2 e 3 com 1 ponto.)	
2. Você perdeu o equilíbrio quando se abaixou ou tentou alcançar algo?	
3. Você teve dificuldade para subir escadas?	
4. Ao andar ou usar a cadeira de rodas você teve que parar e descansar mais do que gostaria?	
5. Você teve dificuldade para permanecer de pé?	
6. Você teve dificuldade para se levantar de uma cadeira?	

Humor	
1. Eu estava desanimado sobre meu futuro.	
2. Eu não estava interessado em outras pessoas ou em outras atividades.	
3. Eu me senti afastado/isolado das outras pessoas.	
4. Eu tive pouca confiança em mim mesmo.	
5. Eu não estava interessado em comida.	
Personalidade	
1. Eu estava irritável/irritado. ("Com os nervos à flor da pele")	
2. Eu estava impaciente com os outros.	
3. Minha personalidade mudou.	
Auto-cuidado	
1. Você precisou de ajuda para preparar comida?	
2. Você precisou de ajuda para comer? Por exemplo, para cortar ou preparar a comida?	
3. Você precisou de ajuda para se vestir? Por exemplo, para calçar meias ou sapatos, abotoar roupas ou usar um zíper?	
4. Você precisou de ajuda para tomar banho de banheira ou chuveiro?	
5. Você precisou de ajuda para usar o vaso sanitário?	
Papéis Sociais	
1. Eu não saí com a freqüência que eu gostaria.	
2. Eu dediquei menos tempo aos meus hobbies e lazer do que eu gostaria.	
3. Eu não encontrei tantos amigos meus quanto eu gostaria.	
4. Eu tive relações sexuais com menos freqüência do que gostaria.	
5. Minha condição física interferiu com minha vida social.	
Memória / Concentração	
1. Foi difícil para eu me concentrar.	
2. Eu tive dificuldade para lembrar das coisas.	
3. Eu tive que anotar as coisas para me lembrar delas.	
Função da Extremidade Superior	
1. Você teve dificuldade para escrever ou digitar?	
2. Você teve dificuldade para colocar meias?	
3. Você teve dificuldade para abotoar a roupa?	
4. Você teve dificuldade para usar o zíper?	
5. Você teve dificuldade para abrir uma jarra?	
Visão	
1. Você teve dificuldade em enxergar a televisão o suficiente para apreciar um programa?	

2. Você teve dificuldade para alcançar as coisas devido à visão fraca?	
3. Você teve dificuldade em ver coisas nas suas laterais/de lado?	
Trabalho / Produtividade	
1. Você teve dificuldade para fazer o trabalho caseiro diário?	
2. Você teve dificuldade para terminar trabalhos ou tarefas que havia começado?	
3. Você teve dificuldade para fazer o trabalho que costumava fazer?	
PONTUAÇÃO TOTAL:	___