REVISTA NEUROCIÊNCIAS

Original

Body function related to the upper limbs in individuals with Multiple Sclerosis

Função corporal relacionada aos membros superiores em indivíduos com Esclerose Múltipla

Función corporal relacionada con los miembros superiores en individuos con Esclerosis Múltiple

Laura Roberta Gimenes[1], Cláudia Tarragô Candotti[2], Henrique Möllmann Pedrotti[3], Mariana Zirkel Andriotti[4], Mauren Andrielli dos Anjos Carvalho[5], Luciano Palmeiro Rodrigues[6]

1.Physical therapy Course at Universidade Federal do Rio Grande do Sul (UFRGS). Porto Alegre-RS, Brazil. Orcid: https://orcid.org/0009-0007-1342-6157
2.PhD in Human Movement Sciences, Professor of the Physical therapy Course at UFRGS. Porto Alegre-RS, Brazil. Orcid: https://orcid.org/0000-0002-8676-9157
3.Physical therapy Course at Universidade Federal do Rio Grande do Sul (UFRGS). Porto Alegre-RS, Brazil. Orcid: https://orcid.org/0009-0006-8568-1782
4.Physical therapy Course at Universidade Federal do Rio Grande do Sul (UFRGS). Porto Alegre-RS, Brazil. Orcid: https://orcid.org/0009-0004-6826-5942
5.Physical therapy Course at Universidade Federal do Rio Grande do Sul (UFRGS). Porto Alegre-RS, Brazil. Orcid: https://orcid.org/0009-0001-0880-6979
6.PhD in Neurosciences, Professor of the Physical therapy Course at UFRGS, Coordinator of the Outpatient Neurofunctional Physiotherapy Clinic – HCPA. Porto Alegre-RS, Brazil. Orcid: https://orcid.org/0000-0002-6888-192X

Resumo

Introdução. A disfunção dos membros superiores (MS) é comum em indivíduos com Esclerose Múltipla (EM), afetando significativamente sua qualidade de vida e independência; no entanto, é abordada com menor frequência na literatura. **Objetivo.** Caracterizar a função dos membros superiores de indivíduos com esclerose múltipla em acompanhamento na Clínica Ambulatorial de Fisioterapia Neurofuncional do Hospital de Clínicas de Porto Alegre (HCPA). **Método.** Indivíduos com EM do tipo remitente-recorrente, de ambos os gêneros, foram caracterizados quanto à função dos membros superiores utilizando a Escala de Ashworth Modificada; dinamometria manual; destreza manual; e flexibilidade. **Resultados.** 96 pacientes foram avaliados, sendo 69,8% mulheres, com tempo médio de diagnóstico de 11,6±8,6 anos e uma mediana do EDSS de 2,75. Constatou-se que 82,29% dos pacientes (n=79) apresentaram algum tipo de alteração nos membros superiores, relacionado ao tônus muscular, força de preensão, destreza e flexibilidade, identificadas em qualquer dos membros superiores. Observou-se uma tendência de os pacientes não apresentarem alterações de destreza, mas demonstrarem diminuição da força de preensão (46,87%) e alterações de flexibilidade nos membros superiores (60,42%). **Conclusão.** Pacientes com esclerose múltipla remitente-recorrente apresentam alterações nas funções corporais relacionadas aos membros superiores, mesmo com um tempo de diagnóstico mais curto.

Unitermos. Esclerose múltipla; destreza motora; força de preensão; membros superiores; espasticidade muscular; Classificação Internacional de Funcionalidade, Incapacidade e Saúde

Abstract

Introduction. Upper limb (UL) dysfunction is common in individuals with Multiple Sclerosis (MS), significantly affecting their quality of life and independence; however, it is less frequently addressed in the literature. **Objective.** To characterize the upper limb function of individuals with multiple sclerosis under follow-up at the Neurofunctional Physiotherapy Outpatient Clinic of the Hospital de Clínicas de Porto Alegre (HCPA). **Method.** Individuals with relapsing-remitting MS, of both genders, were characterized regarding upper limb function using the Modified Ashworth Scale; manual dynamometry; manual dexterity; and flexibility. **Results.** 96 patients were evaluated, with 69.8% being women, a mean diagnosis time of 11.6±8.6

years, and a median EDSS of 2.75. It was found that 82.29% of patients (n=79) presented some type of alteration in the UL, related to muscle tone, grip strength, dexterity, and flexibility, identified in either UL. There was a tendency for patients not to show dexterity alterations but to demonstrate decreased grip strength (46.87%) and flexibility alteration in UL (60.42%). **Conclusions.** Patients with relapsing-remitting multiple sclerosis demonstrate alterations in body functions related to the upper limbs, even with a shorter diagnosis time.
Keywords. Multiple sclerosis; motor dexterity; grip strength; upper limbs; muscle spasticity; International Classification of Functioning, Disability and Health

Resumen

Introducción. La disfunción de los miembros superiores (MS) es común en individuos con Esclerosis Múltiple (EM), afectando significativamente su calidad de vida e independencia; sin embargo, se aborda con menor frecuencia en la literatura. **Objetivo.** Caracterizar la función de los miembros superiores de individuos con esclerosis múltiple en seguimiento en la Clínica Ambulatoria de Fisioterapia Neurofuncional del Hospital de Clínicas de Porto Alegre (HCPA). **Método.** Individuos con EM de tipo remitente-recurrente, de ambos géneros, fueron caracterizados en cuanto a la función de los miembros superiores utilizando la Escala de Ashworth Modificada; dinamometría manual; destreza manual; y flexibilidad. **Resultados.** Se evaluaron 96 pacientes, de los cuales el 69,8% eran mujeres, con un tiempo promedio de diagnóstico de 11,6±8,6 años y una mediana del EDSS de 2,75. Se constató que el 82,29% de los pacientes (n=79) presentaron algún tipo de alteración en los miembros superiores, relacionada con el tono muscular, la fuerza de prensión, la destreza y la flexibilidad, identificadas en cualquiera de los miembros superiores. Se observó una tendencia de que los pacientes no presentaran alteraciones en la destreza, pero sí demostraran disminución de la fuerza de prensión (46,87%) y alteraciones en la flexibilidad de los miembros superiores (60,42%). **Conclusión.** Los pacientes con esclerosis múltiple remitente-recurrente presentan alteraciones en las funciones corporales relacionadas con los miembros superiores, incluso con un tiempo de diagnóstico más corto.
Palabras clave. Esclerosis múltiple; destreza motora; fuerza de prensión; miembros superiores; espasticidad muscular; Clasificación Internacional del Funcionamiento, la Discapacidad y la Salud

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Corresponding address: Luciano P Rodrigues. Porto Alegre-RS, Brazil. Phone 51 33085795. Email: lucianopalmeiro@gmail.com

INTRODUCTION

Multiple Sclerosis (MS) is a chronic, progressive demyelinating disease of the Central Nervous System, typically diagnosed in young adults aged 20 to 40 years[1-3]. The prevalence of the disease is approximately twice as high in women as in men[4,5]. Currently, MS is classified into four forms, with Relapsing-Remitting (RRMS) being the most common, affecting 80 to 90% of patients[6,7].

Due to the pathophysiology of the disease, motor dysfunction can result in signs and symptoms of ataxia, spasticity, incoordination, and sensory alterations in both lower and upper limbs (UL)[8].

In a study the authors observed, according to the Expanded Disability Status Scale (EDSS), that most of the evaluated patients (59.9%) had a mild level of disease severity but exhibited disabilities related to the upper limbs and the performance of activities of daily living[9]. Motor impairments in MS occur in approximately 66% of MS patients[10].

The combination of motor, sensory, and cerebellar symptoms can lead to upper limb dysfunction and interfere with activities of daily living (ADL) and quality of life in individuals with MS[11]. Authors demonstrated that upper limb dysfunction (ULD) is highly prevalent in people with MS, even at the early stages of the disease, affecting their quality of life and independence in ADLs[12]. In this study, with a sample of 400 individuals with MS, the authors reported that approximately 10% of the sample with minimal disability showed changes in body functions such as hand strength, dexterity, and coordination. In the same population with mild disability, about 80% exhibited abnormalities in activities assessed through the Nine Hole Peg Test (NHPT).

The most frequent signs and symptoms of dysfunctions in MS in patients with MS are tremors, coordination and fine motor deficits, muscle weakness, increased muscle tone, and sensory deficits, all of which have a negative impact on the

ability of individuals with MS to perform ADLs[13,14]. Approximately 70% of patients will experience muscle weakness, usually early in the disease process[15]. In a study with 219 people with MS using the Nine Hole Peg Test, observed that 76% of the patients exhibited manual dexterity dysfunction[9].

Flexibility is another body function that is affected in MS. Individuals with MS often experience joint movement limitations due to spasticity and prolonged inactivity[16,17]. Spasticity is a common symptom of MS, present in approximately 80% of patients[18]. Flexibility exercises are recommended for these patients, targeting muscles shortened by the effects of spasticity[17]. This justifies the need for the assessment and characterization of both spasticity and flexibility in the upper limbs of individuals with MS.

Although it is known that the upper limbs are commonly affected from the early stages of the disease, there are still few studies focusing on the evaluation of the upper limbs in patients with MS[19-22]. There is a scarcity of studies focusing on the characterization of upper limb function in individuals with multiple sclerosis (MS) across the disease progression. Furthermore, there is limited understanding of the specific impairments and alterations in body function affecting the upper limbs that may arise in this population. Descriptive studies play an important role in the development of scientific and clinical knowledge, providing a foundation for future investigations on a specific population. Thus, the aim

of this study was to characterize the upper limb bodily function in individuals with MS who are being followed at the Neuroimmunology outpatient clinic of the Hospital de Clínicas de Porto Alegre.

METHOD

Sample

The exploratory descriptive *ex post facto* study, with a convenience sample. Included 96 individuals, over 18 years old and of both sexes, with Relapsing-Remitting Multiple Sclerosis (RRMS), followed at the Neurofunctional Physiotherapy Outpatient Clinic associated with the Neuroimmunology Outpatient Clinic of the Hospital de Clínicas de Porto Alegre (HCPA). Individuals currently in relapse or recently relapsed, those without a complete assessment of the upper limbs, and those not diagnosed with RRMS were excluded. The diagnosis of RRMS was made by the medical team of the Neuroimmunology Outpatient Clinic of the Hospital de Clínicas de Porto Alegre (HCPA), following McDonald's criteria[23].

The study was approved by the Ethics Committee of HCPA (CAAE 70423723.0.0000.5327). All patients were informed about the research and signed the Informed Consent Form (ICF). The datasets generated during and analyzed during the current study are not publicly available due to the patient data belonging to the Neuroimmunology outpatient clinic of HCPA. Are available from the corresponding author on reasonable request.

Procedure

For the physical assessment, in order to characterize the upper limb bodily function, tests and scales related to the upper limbs were used. Manual dexterity was assessed using the Nine Hole Peg Test, the gold-standard measure for assessment and widely used in MS research[24]. The cutoff point of 33.3 seconds (0.27 pegs)[14]. They used it to differentiate individuals with MS with low and high manual dexterity, as the evaluated population was similar to that in the present study. In this study, the manual dexterity of the assessed patients was considered impaired when the time taken to complete the task exceeded 33.3 seconds, even if only for one of the upper limbs.

Manual grip strength was measured using the Saehan® dynamometer, provided and calibrated by HCPA. The results were expressed in kilogram-force (Kgf) and compared with normal values according to the equipment manual, based on age group and sex. The positioning of the individual for the test followed the recommendations of the American Society of Hand Therapists (ASHT). The average of the values from three attempts performed with each hand was used for data analysis[25,26]. The manual grip strength of the assessed patients was considered altered when the values deviated from the predicted values, according to the age group and gender described in the equipment manual, even if for just one of the upper limbs.

The Modified Ashworth Scale was used to assess the presence of spasticity in the upper limbs[27]. It was graded

from 0 to 4, with zero representing normal muscle tone and four indicating severe spasticity, with a limb fixed in flexion or extension[27]. The assessed muscle groups in the upper limbs were the shoulder adductors, elbow flexors, pronators, wrist flexors, finger flexors, and thumb flexors. For this study, a patient was considered to have an alteration in muscle tone in the upper limbs when there was an increase in tone in the mentioned muscles, characterized by the response to stretching during the physical examination, in any of the upper limbs.

The flexibility of the pectoralis major and biceps brachii muscles was also assessed. The patient was positioned in a supine position to evaluate the flexibility of the elbow flexors, with the examiner performing a full extension of each elbow while positioning the patient's shoulder in full extension. Any restriction in passive range of motion was verified, observed through the presence of some degree of elbow flexion[28]. To assess the flexibility of the pectoral muscle, the patient was asked to place their hands behind their head, remaining in a position of shoulder flexion, abduction, and external rotation, along with elbow flexion. It was observed whether the patient's elbows touched the examination table or if there was any disparity between the two elbows. In order for the presence of an alteration in flexibility of the upper limb to be considered in this study, the evaluated patient had to demonstrate a reduction in flexibility in one of the assessed muscles in one of the upper limbs.

During the patient evaluation period, all evaluators underwent training by the coordinator of the Outpatient Clinic.

Statistical Analisys

To analyze the patient profile, descriptive statistics were performed to obtain mean ± standard deviation and median values, and nominal data were expressed as frequency (%), with a significance level of 5% (α=0.05) and assuming a 10% error, using the Statistical Package for the Social Sciences (SPSS 22.0) software.

RESULTS

The study included a sample of 96 patients with RRMS, who were characterized based on gender, age, time since diagnosis and scores on the Expanded Disability Status Scale (EDSS; Table 1).

Table 1. Sample description.

	n (96)	%	Mean ± SD
Gender			
Woman	67	69.8	-
Man	28	30.2	-
Age (18- 80 years)	-	-	45.2±13.9
Time since diagnosis (0-44 years)		-	11.6±8.6
EDSS (Minimum and maximum) (n=88)	-	-	3.2/(0-6.5)

N: number of individuals; SD: standard deviation; EDSS: Expanded Disability Status Scale.

Demographic data of the patients were also assessed, and a representative sample of the entire state of Rio Grande do Sul was observed. It was found that patients were from 6 of the 7 macro-regions of the state, with the majority being from the metropolitan region.

Right-hand dominance was predominant in the sample, with 85 patients (88.5%) being right-handed. Regarding the assessment of manual dexterity, it was found that 86.5% of the patients (n=83) had no changes in dexterity in their right hand. In the left hand, 79.2% (n=76) also showed no change in manual dexterity. When manual dexterity was analyzed in the dominant hand, it was observed that 86.5% (n=83) of the patients had no changes in dexterity. Only 26 patients (27%) showed some alteration in manual dexterity in any of the upper limbs.

In the evaluation of manual grip strength, 45 patients (46.87%) presented some weakness in their hand in any of the upper limbs. In the right upper limb (RUL), the average manual grip strength value in the sample was 24.10kg/f. In the left upper limb (LUL), the average manual grip strength value was 23.65kg/f. Sixty patients (62.5%) showed no change in grip strength in the right hand, and 65 patients (67.7%) showed no change in grip strength in the left hand. The result of the manual dynamometry in the dominant hand was altered in only 38 patients (39.5%) in the study.

Regarding changes in grip strength and manual dexterity in the RUL and LUL, Table 2 below presents the results found. When manual dexterity and grip strength alterations in the upper limbs were evaluated, it was found that only 18 (18.75%) patients presented both alterations simultaneously in one of the upper limbs.

Table 2. Alteration in manual dexterity and grip strength in UL.

	RUL	LUL
Manual grip strength alteration (N)	36	31
Manual dexterity alteration (N)	13	20
Manual dexterity and grip strength alteration (N)	10	14

RUL: Right Upper Limb; LUL: Left Upper Limb

The number of patients with both strength impairment and dexterity impairment in the dominant hand can be found in Table 3.

In terms of flexibility, 55 patients (57.3%) exhibited alterations in the pectoral muscles, indicative of shortening, whereas 96.9% of the cohort demonstrated no flexibility impairments in the biceps brachii muscles. Shortening in the pectoral muscles seems to be more common in these patients.

Table 3. Correlation between grip strength of the dominant hand and manual dexterity of the dominant hand.

		Grip strength in the dominant hand		Total
		Weak	Normal	
Manual dexterity in the dominant hand	With alteration	10	3	13
	No alteration	28	55	83
	Total	38	58	96

Muscle tone alterations, in any of the evaluated muscles, were present in 40 individuals (41.6%). When assessing the muscle tone of the shoulder adductors, 25 patients showed tone alterations, and of these, 64% (n=16) also presented flexibility alterations in the pectoral muscles. This suggests that the probable cause of the flexibility alteration in the pectoral muscles may be the increased tonicity in these muscles, as observed in these patients.

This study found that 82.29% of the patients (n=79) presented some alteration in the upper limbs (UL), considering the body functions related to muscle tone, grip strength, manual dexterity, and flexibility, identified in any of the ULs. A tendency was observed in which patients did not show alterations in manual dexterity (only 27%), but did exhibit a decrease in grip strength (present in 46.87% of the patients). It was observed that 40 patients (41.6%) had some degree of spasticity (change in muscle tone). The majority of patients (60.42%) showed flexibility alterations in the ULs.

An increase in pectoral muscle tonicity was observed in the evaluated patients, which seems to be related to the flexibility alterations in this muscle.

The findings suggest that the changes observed in patients' UL may be present even in the early stages of the disease.

DISCUSSION

The main objective of the study was to describe the body function related to the upper limbs (UL) of individuals with multiple sclerosis (MS) followed up at the Neuroimmunology outpatient clinic of the Hospital de Clínicas de Porto Alegre. In this study, grip strength, manual dexterity, muscle tone, and flexibility of the UL were evaluated to describe UL function. It was observed that 82.29% of the patients presented some alteration in the UL concerning the body functions previously mentioned. In the assessment of muscle tone and grip strength, it was found that about 41.6% presented spasticity in some of the tested muscles, and 46.87% exhibited weakness in any of the ULs. Additionally, 27% presented alterations in manual dexterity, and approximately 60.42% showed flexibility alterations in the UL.

Regarding the evaluated demographic data, it was observed that most of the patients were from the metropolitan area of Rio Grande do Sul, which may be related to the location of the HCPA in the state capital. In a pioneering study, also conducted at HCPA, clinical and

demographic data of patients with MS in Rio Grande do Sul were analyzed and described[29]. They found that the highest prevalence of the disease was in women (74.6%) and the average age was 43.5 years, data that aligns with those found in the current study within the same population at HCPA.

In a study, the authors suggest that the differences between types of multiple sclerosis (MS) and functional alterations over time can be explained by the fact that individuals with relapsing-remitting MS (RRMS) generally experience less prolonged functional limitations, at least in the early stages[30], when compared to other types of MS, which is also mentioned in other study[8]. The motor skills of the upper and lower limbs in MS worsen as disability increases[8].

Manual dexterity, assessed using the Nine-Hole Peg Test, was altered in 76% of patients in a study with 219 people with multiple sclerosis (MS), the majority of whom had a mild EDSS score (n=129)[9]. Other study also reported that 75% of patients in their study (n=105) presented bilateral manual dexterity impairments. The majority of the patients evaluated had a higher EDSS score (6.5 to 9.5)[22]. The authors noted that only 38% of participants with mild disability due to MS showed alterations in manual dexterity according to the Nine-Hole Peg Test. A similar result was found in our study, as alterations in manual dexterity were present in some upper limbs in about one-third of the sample.

Grip strength was also assessed, where it was observed that more than one-third of the sample exhibited bilateral strength impairments[22]. Muscle weakness was found through manual dynamometry in about 14% of the patients in a sample (n=257)[12].

Both grip strength and dexterity showed higher frequencies of impairment as the EDSS score increased, representing a decline in these functions with disease progression[22]. Furthermore, the authors discuss that alterations in manual dexterity affect independence in activities of daily living (ADLs), and are likely related to other factors such as sensory changes and strength, particularly in the distal segments of the upper limbs in individuals with mild to moderate impairment. This supports the findings in our study, where manual dexterity impairment was associated with grip strength alterations, as the majority of patients with strength deficits also exhibited dexterity impairments.

In a recent study, muscle strength, manual dexterity and sensitivity of the upper limbs were evaluated in 44 individuals with relapsing-remitting multiple sclerosis (RRMS), with an EDSS score greater than 4 and time since diagnosis greater than 5 years[19]. Sensitivity was assessed through two-point discrimination and vibration tests on the hands. The authors found that all three functions were affected in both upper limbs in the early stages of the disease. Additionally, in another study with a sample of 205 individuals with MS and an average EDSS score of 3, more

than 50% of them reported impairments in upper limb function[29]. Other studies also highlight upper limb dysfunction even in the early stages of the disease[9,20-22]. Similarly, in the present study, it was observed that most patients exhibited some type of alteration in the upper limbs, even with an average diagnosis duration of less than 12 years and a mild EDSS score.

Individuals with multiple sclerosis (MS) often experience limitations in joint movements due to spasticity and prolonged inactivity[17]. Flexibility in patients with MS decreases, particularly when there is an alteration in muscle tone[16]. This limitation in joint movements, as mentioned by these authors due to increased tonicity, was observed in the patients of this study. The pectoral muscles were shortened in more than half of the evaluated patients. These patients also presented muscle tone alterations in the shoulder adductors, suggesting that the flexibility impairment is related to an increase in muscle tone in the same muscle group.

The study that assessed the muscle tone of the wrist flexors, elbow flexors, and shoulder adductors using the Modified Ashworth Scale and found no alterations[22]. These results differ from the findings of the present study and the existing literature. It was observed that approximately half of the patients exhibited some alteration in muscle tone in one of the upper limbs, suggesting that tone abnormalities are present in the upper limbs of these patients.

It can be observed from the results of this study that patients with relapsing-remitting multiple sclerosis (RRMS) may exhibit motor alterations in the upper limbs (UL) in the early stages of the disease, reinforcing the importance of assessing the ULs from the time of diagnosis, even when patients do not report specific signs or symptoms. Therefore, it is crucial to perform an evaluation of the ULs by a neurofunctional physiotherapist to monitor the progression of MS from its early stages.

As limitations of the study, it is worth mentioning the small number of studies that have thoroughly assessed muscle tone alterations and those related to flexibility evaluation of the ULs in these patients. Another limitation is the lack of analysis based on diagnostic duration and EDSS classification.

As future perspectives, it is suggested to characterize the alterations in UL functions over time in a group of patients, as well as based on the EDSS classification, in order to study these alterations with disease progression.

CONCLUSION

Patients diagnosed with relapsing-remitting multiple sclerosis present changes in bodily functions related to the upper limbs even in the early stages of the disease, with a tendency to present changes in flexibility, muscle tone and strength.

REFERENCES

1.Inglese M. Multiple sclerosis: new insights and trends. Am J Neuroradiol 2006;27:954-7. https://www.ajnr.org/content/27/5/954.long

2.Lassmann H. Multiple Sclerosis Pathology. Cold Spring Harb Perspect Med 2018;8:a028936. https://doi.org/10.1101/cshperspect.a028936

3.Dobson R, Giovannoni G. Multiple sclerosis - a review. Eur J Neurol 2019;26:27-40. https://doi.org/10.1111/ene.13819

4.Wallin MT, Culpepper WJ, Campbell JD, Nelson LM, Langer-Gould A, Marrie RA, *et al*. The prevalence of MS in the United States: A population-based estimate using health claims data. Neurology 2019;92:e1029-40. https://doi.org/10.1212/WNL.0000000000007035

5.Orton SM, Herrera BM, Yee IM, Valdar W, Ramagopalan SV, Sadovnick AD, *et al*. Sex ratio of multiple sclerosis in Canada: a longitudinal study. Lancet Neurol 2006;5:932-6. https://doi.org/10.1016/S1474-4422(06)70581-6

6.Compston A, Coles A. Multiple sclerosis. Lancet 2008;372:1502-17. https://doi.org/10.1016/S0140-6736(08)61620-7

7.Brownlee WJ, Hardy TA, Fazekas F, Miller DH. Diagnosis of multiple sclerosis: progress and challenges. Lancet 2017;389:1336-46. https://doi.org/10.1016/S0140-6736(16)30959-X

8.Coghe G, Corona F, Pilloni G, Porta M, Frau J, Lorefice L, *et al*. Is There Any Relationship between Upper and Lower Limb Impairments in People with Multiple Sclerosis? A Kinematic Quantitative Analysis. Mult Scler Int 2019;2019:9149201. https://doi.org/10.1155/2019/9149201

9.Johansson S, Ytterberg C, Claesson IM, Lindberg J, Hillert J, Andersson M, *et al*. High concurrent presence of disability in multiple sclerosis. Associations with perceived health. J Neurol 2007;254:767-73. https://doi.org/10.1007/s00415-006-0431-5

10.Spooren AI, Timmermans AA, Seelen HA. Motor training programs of arm and hand in patients with MS according to different levels of the ICF: a systematic review. BMC Neurol 2012;12:49. https://doi.org/10.1186/1471-2377-12-49

11.Donzé C, Massot C. Rehabilitation in multiple sclerosis in 2021. Presse Méd 2021;50:104066. https://doi.org/10.1016/j.lpm.2021.104066

12.Pisa M, Ruiz JÁ, DeLuca GC, Crespo MA, DelMastro HM, Olson KM, *et al*. Quantification of upper limb dysfunction in the activities of the daily living in persons with multiple sclerosis. Mult Scler Relat Dis 2022;63:103917. https://doi.org/10.1016/j.msard.2022.103917

13.Koriem KMM. Multiple sclerosis: New insights and trends. Asian Pac J Trop Biomed 2016;6:429-40. https://doi.org/10.1016/j.apjtb.2016.03.009

14.Lamers I, Cattaneo D, Chen CC, Bertoni R, Wijmeersch BV, Feys P. Associations of upper limb disability measures on different levels of the International Classification of Functioning, Disability and Health in

people with multiple sclerosis. Phys Ther 2015;95:65-75. https://doi.org/10.2522/ptj.20130588
15.Hoang PD, Gandevia SC, Herbert RD. Prevalence of joint contractures and muscle weakness in people with multiple sclerosis. Disabil Rehabil 2014;36:1588-93. https://doi.org/10.3109/09638288.2013.854841
16.Sandoval AE. Exercise in multiple sclerosis. Phys Med Rehabil Clin N Am 2013;24:605-18. https://doi.org/10.1016/j.pmr.2013.06.010
17.Halabchi F, Alizadeh Z, Sahraian MA, Abolhasani M. Exercise prescription for patients with multiple sclerosis; potential benefits and practical recommendations. BMC Neurol 2017;17:185. https://doi.org/10.1186/s12883-017-0960-9
18.Bethoux F, Marrie RA. A cross-sectional study of the impact of spasticity on daily activities in multiple sclerosis. Patient 2016;9:537-46. https://doi.org/10.1007/s40271-016-0173-0
19.Ovacik U, Tarakci E, Ozdemir Z. Upper limb dysfunction in people with early-stage Multiple Sclerosis: Perceived performance can be misleading. Multip Scler Relat Dis 2023;79:104944. https://doi.org/10.1016/j.msard.2023.104944
20.Guclu-Gunduz A, Citaker S, Nazliel B, Irkec C. Upper limb function and its relationship with hand sensation and upper limb strength in patients with multiple sclerosis. NeuroRehabil 2012;30:369-74. https://doi.org/10.3233/NRE-2012-0768
21.Cattaneo D, Lamers I, Bertoni R, Feys P, Jonsdottir J. Participation restriction in people with multiple sclerosis: prevalence and correlations with cognitive, walking, balance, and upper limb impairments. Arc Phys Med Rehabil 2017;98:1308-15. https://doi.org/10.1016/j.apmr.2017.02.015
22.Bertoni R, Lamers I, Chen CC, Feys P, Cattaneo D. Unilateral and bilateral upper limb dysfunction at body functions, activity and participation levels in people with multiple sclerosis. Mult Scler 2015;21:1566-74. https://doi.org/10.1177/1352458514567553
23.Thompson AJ, Banwell BL, Barkhof F, Carroll WM, Coetzee T, Comi G, *et al*. Diagnosis of multiple sclerosis: 2017 revisions of the McDonald criteria. Lancet Neurol 2018;17:162-73. https://doi.org/10.1016/S1474-4422(17)30470-2
24.Feys P, Lamers I, Francis G, Benedict R, Phillips G, LaRocca N, *et al*. Multiple Sclerosis Outcome Assessments Consortium. The Nine-Hole Peg Test as a manual dexterity performance measure for multiple sclerosis. Mult Scler 2017;23:711-20. https://doi.org/10.1177/1352458517690824
25.Figueiredo IM, Sampaio R, Mancini MC. Grip strength test using the Jamar dynamometer. Acta Fisiatr 2007;14:45-50. https://doi.org/10.5935/0104-7795.20070002
26.Reis MM, Arantes PMM. Measurement of hand grip strength - validity and reliability of the Saehan dynamometer. Fisioter Pesqui 2011;18:176-81. https://doi.org/10.1590/S1809-29502011000200013

27.Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. Phys Ther 1987;67:206–7. https://doi.org/10.1093/ptj/67.2.206
28.Yoshikara G, Castro RC. Manual de semiologia médica: a prática do exame físico. Belém: Eduepa; 2015.
29.Finkelsztejn A, Cristovam RA, Moraes GS, Lopes MGSM, Silva AV, Garcia MS, *et al*. Clinical features of multiple sclerosis in the south of Brazil: a partial analysis. Arq Neuropsiquiatr 2009;67:1071–5. https://doi.org/10.1590/S0004-282X2009000600021
30.Holper L, Coenen M, Weise A, Stucki G, Cieza A, Kesselring J. Characterization of functioning in multiple sclerosis using the ICF. J Neurol 2010;257:103–13. https://doi.org/10.1007/s00415-009-5282-4