# The Effect of Aquatic Exercise and Swimming on Standing Stability of Three Different Clinical Forms of Multiple Sclerosis

**mohammad Karimi** (mohammad.karimi.bioengineering@gmail.com)
Shiraz University of Medical Sciences https://orcid.org/0000-0001-6162-8131
**Mahnaz Marvi-Esfahani**
Islamic Azad University

**Research article**

**Keywords:** Multiple Sclerosis, Standing Stability, Aquatic Exercise and Swimming

**Posted Date:** February 5th, 2020

**DOI:** https://doi.org/10.21203/rs.2.22658/v1

# Abstract

Objective

It was a survey of the effect of a combined program of aquatic exercise and swimming on standing stability of three different clinical forms of Multiple Sclerosis (MS).

Design

31 MS subjects were divided into three groups, based on spasticity, ataxia and ataxic-spastic syndromes. Standing stability was assessed in open and closed eyes conditions in quiet standing by use of Kistler force platform. The Ashworth Scale and Brief Ataxia Rating Scale (BARS) were used to determine the rate of spasticity and ataxia rating, respectively. All patients participated in the intervention (3 sessions in week for 2 months). All tests repeated after the exercise. Paired t-test and ANOVAs (repeated measure) were used to determine the effects of exercise on standing stability parameters.

Result

The total path length of center of pressure (eyes open position) before intervention was 1415.5±575.75mm, 1216.4±817.38mm and 1662.3±540.27mm compared to 1119.7±435.51mm, 655.53±256.31mm and 1169.6±369.67mm after intervention in ataxic, spastic and ataxic-spastic subjects, respectively ($p<0.04$). The rate of spasticity, EDSS and BARS decreased after the exercise program ($p<0.05$).

Conclusion

Aquatic exercise and swimming skill improved MS subjects' standing stability. Therefore, they are recommended to use the aquatic training as a complement treatment aside from medication treatments.

# Introduction

Multiple sclerosis (MS) is one of the most common chronic, progressive and disabling neurological disorders. Its diagnosis is based on the detection of multiple inflammatory demyelinating white matter lesions (1). The main cause of this disease is still unknown. The prevalence of MS in the world varies and depends on geographical location. Its prevalence varies between 5.05/100,000 in Ecuador (2) and 80/100,000 individuals in Europe (3) and in Iran, the age ranges 16-35, 14/100,000 (4). Isfahan City in Iran has the highest level of prevalence of MS diseases (5).

The most common disabling complaint associated with this disease is balance disorder due to demyelinating vestibular nerve or areas surrounding vestibular nucleus in brain stem and it is not depending on the severity of the disease (6-8). Several studies showed that these patients have significantly more trunk sway during Romberg and tandem gait tests (9), reduced magnitude of anticipatory postural adjustments (APAs), delayed latency of APAs and had smaller anticipatory center of pressure (COP) displacement (10) as compared to healthy control subjects.

Various types of treatment methods such as use of various assistive devices (kinds of orthotics, robotics, and etc.) and rehabilitation exercise have been used to return the abilities of the MS subjects in standing and walking. Aquatic exercise is the most common treatment suggested for these patients. Some studies showed the effect of aquatic therapy exercise program on some different variables such as quality of life(11-13), enjoyment or fun(14), musculoskeletal function(15, 16), cardiovascular fitness and fatigue(17), fatigue and muscle function(18, 19), pain(20), gait(21, 22), muscular force (23) and balance (24, 25). Despite the potential benefits of aquatic therapy, there is limited research examining the effects of water activity on individuals with different clinical forms of MS. Therefore, the aim of this study was to evaluate the effects of the aquatic exercise and swimming (AE&S) program on standing stability of these subjects. The main hypothesis associated with this study was that this exercise will influence the standing stability of MS subjects with three different clinical forms.

# Method

**Trial design:** A range of symptoms such as ataxia, spasticity and both ataxia and spasticity, will be dominant in MS patients with EDSS more than 3.5. Therefore, the MS population is a heterogeneous population that is split into fairly homogenous groups. As a result, stratified sampling was used in this study. In addition, three groups of patients received only a parallel rehabilitation program. The rehabilitation program included a combination of aquatic exercise and swimming.

**Sample size:** The sample size was estimated by the sample size calculation formula for quantitative variables (26). In this formula, N=204, S=0.15 (static balance variable) (25), t=1.96 and d=0.05 (confidence interval=95%) were estimated, and n=29 was calculated. 31 patients participated in coherence to this study. Table 1 shows the characteristics of the subjects participated in this study.

A neurologist referred 204 patients with symptoms of ataxia (n=70), spastic (n=67) and ataxia-spastic (n=67), but the details of the research were unknown for the neurologist and the other investigators. For allocation of the patients, a computer-generated list of random numbers was used and the patients were randomly assigned to 3 groups. Among these, 18 patients (the larger number of patients being due to losses or exclusions after randomisation) were selected randomly in each stratum while 54 patients participated in the study with complete consent and desire. 15 patients were excluded due to lack of cooperation and irregular presence at exercise sessions, and 8 patients did not continue training due to relapse and physical problems and they were also excluded**.** At the end, 31 patients (ataxia (n=11), spastic (n=10) and ataxia-spastic (n=10)) completed exercise program.

**Subjects:** MS subjects were divided into three groups, based on spasticity, ataxia and ataxic-spastic syndromes.

The study was done at the MS clinic of Azahra Hospital in Isfahan, Iran. The MS subjects were selected from those referred to Azahra Hospital for periodic evaluation based on the following inclusion criteria.

Eligibility criteria for participants included a definite diagnosis of MS (relapsing-remitting and progressive type) with a duration of 5 years, being relapse-free during the past 30 days before testing, having an EDSS range of 4-6.5, having dominate symptoms of spasticity or ataxia, or both symptoms, and being between the ages of 25 and 52 years old. Criteria for rejection included the inability to give informed consent, pregnancy, lactation or pregnancy during the study, having cognitive disorders; severe disorders in visual function, serious psychological disorders, intense arthritis in the knees or hips, and skin diseases. Table 1 shows the characteristics of the subjects who participated in this study.

An ethical approval was obtained from Isfahan University of Medical Sciences, ethical committee (No. 5850/9/35/16 / C). Each subject was asked to sign a consent form before data collection. The neurological impairment of the MS subjects was diagnosed by a neurologist and was divided into three groups based on clinical tests. The Ashworth Scale and Brief Ataxia Rating Scale (BARS) were used to determine the rate of spasticity and ataxia rating, respectively.

The Expanded disability status scale (EDSS) is an eight functional system scale that includes: motor, sensory, cerebellar, brain stem, visual, mental, and sphincters parameters. Each domain was graded from 0 = no disability, to 6 or 6.5 = maximal disability based on history and physical examination. According to this scale, 0 was scored as normal and 10 was scored as death from MS (27). The spasticity of lower extremity musculatures was evaluated by use of modified Ashworth scale, which is considered to be a validated clinical measurement to grade spasticity (28). This involves mobilization of individual joints to provide a clinician-based assessment with an ordinal outcome. The scale ranges from a score of 0 = no increase in tone to 4 = limb rigid in flexion or extension. Four groups of lower extremity musculatures were evaluated in right and left sides separately (ankle plantar flexor, knee flexor and extensor, and hip adductor). The mean values of both right and left sides in every joint and total mean of both of the leg muscles groups were recorded for final analysis. Ataxia was scored using the Brief Ataxia Rating Scale (29) which is graded from 0 = Normal, to 30 = high disability. All of these scales measured before and after the Aquatic exercise and Swimming (AE&S) program.

**Test Protocol:** The subjects were instructed about the testing procedure and instruments, and then their weight and height were measured and recorded. A Kistler force platform (model: Kistler Instrument AG Winterthur-Switzerland, Type 5233A2; size: 400×600mm) was used to measure the Centre of Pressure (COP) which is considered to be a good approximation to sway. The reliability of the force plate, based on excursions of the COP in the mediolateral and anteroposterior directions, was measured by many investigators and was more than 0.75 (30-33). The accuracy of the force platform according to the manufacturers manual is very high and the error of this system is less than 1% (34). Analogue signals were sampled at a frequency of 120 Hz with an analogue to digital converter and were stored on a computer. The signal of the force plate was filtered with a Woltring filter with cut off frequency of 10 Hz (33, 35). They were asked to stand on the force plate for one minute. Data was acquired with subjects in double leg stance with feet at pelvic width during normal standing. They were instructed to look straight ahead, with their head erect and their arms at their sides in a comfortable position. This test was performed with opened and closed eyes conditions and was measured before and after the AE&S program. The tests were repeated 3 times and data was collected for 60 seconds.

**Standing Stability Parameters:** The standing stability of the participants was evaluated by the use of a linear approach based on COP sway. Linear analysis was done by evaluating COP excursions in both anterior-posterior and mediolateral planes and path length of COP in mediolateral and anterior-posterior directions. The following equations were used for final analysis (36, 37):

$$\text{COPEAP(mm)} = X_{max} - X_{min}$$

$$\text{COP EML (mm)} = Y_{max} - Y_{min}$$

$$\text{PLAP (mm)} = \sum^{n-1} \sqrt{(x_{i+1} - x_i)^2}$$

$$\text{PLML(mm)} = \sum^{n-1} \sqrt{(y_{i+1} - y_i)^2}$$

$$\text{TPL (mm)} = \sqrt{\left(\sum^{n-1} \sqrt{(x_{i+1} - x_i)^2}\right)^2 + \left(\sum^{n-1} \sqrt{(y_{i+1} - y_i)^2}\right)^2}$$

where COPEAP, COPEML, PLAP, PLML, and TPL are the excursion of the center of pressure in the anterior-posterior direction, excursion of the center of pressure in the mediolateral direction, path length in the anterior-posterior direction, path length in the mediolateral direction, and total path length, respectively.

**Aquatic exercise and swimming (AE&S) Program:** During the first training session, subjects were asked to control their body in water with a Noodle belt. This program was completed 3 days a week for 8 weeks (24 sessions, 70-minute exercise sessions). The study stopping guideline was a reputation of measurements in the end of 24 sessions of training. Training intensity was established at 60 to 75 percent of the subjects' estimated maximal heart rate. In addition, subjects performed 3 sets of 10 repetitions (at first) to 15 repetitions at the end of the program (rest time, 4 minutes between sets to control fatigue) (38). Repetitions on every joint in lower and upper extremities performed in small, medium, and full of range of motions (ROM). The water temperature was 27 to 28 ° C. (38). Fatigue and increased body temperature are the risk factors for MS patients and should be controlled in exercise programs. In each moment of practice, patients felt cold, fatigue, dizziness, spasms and other symptoms; therefore, they were removed quickly from the water environment and were under direct surveillance until recovery. All investigators and patients were kept masked to outcome measurements and trial results. Patients were made aware of training in water but they were blinded about the effects of aquatic exercise, the kinds of movements that were performed in water, and exercise protocol. AE&S program details are presented in Table 2.

**Statistical Analysis**: Statistical analysis was carried out using SPSS version 21. The Shapiro-Wilk test was used to check the normal distribution of the parameters. The differences between three groups in age, height, weight, and disease duration were determined by one-way ANOVAs. The difference between stability parameters, EDSS, BARS, and the Ashworth Scale before and after exercise was evaluated by a paired t-test. Measures of standing stability between three groups of MS subjects were analyzed using between-groups repeated measures general linear model. Factors were vision (two levels: eyes-open versus eyes-closed) and session (two levels: pre-intervention versus post-intervention). The significance was defined as P-value less than 0.05 (95% confidence interval).

# Result

Thirty one patients' completed the exercise protocol and their measurements were entered in the statistical analysis. The results of the Shapiro-Wilk test showed that all parameters had normal distribution. There were not any significant differences in age, height, weight of four groups, EDSS, and disease duration between three groups of MS subjects ($P > 0.05$).

According to Table 3, the mean value of EDSS was 4.64±0.98 in ataxic subjects, 5.65±0.85 in ataxic-spastic subjects, and 4.15±0.85 in spastic subjects before exercise. After the AE&S program, the data changed to 4.13±1.19, 3.65±0.97, and 5.40±0.84 in ataxic, spastic, and ataxic-spastic group, respectively ($P < 0.01$). Before the exercise program, the mean values of BARS were 9.09±4.04 and 11.00±4.6 in ataxic and ataxic-spastic groups, respectively, compared to 4.82±3.34 and 9.20±5.45 after exercise ($P < 0.01$). The total mean of spasticity decreased after the AE&S program in spastic and ataxic-spastic groups ($P < 0.006$).

The mean values of COP excursion in the anterior-posterior direction before the AE&S program were 55.66±21.68, 49.37±16.8, and 49.80±21.78 in ataxic, spastic, and ataxic-spastic subjects, respectively. In contrast, it decreased significantly in spastic and ataxic-spastic groups after exercise ($P < 0.05$). The same result was observed for COP excursion in the mediolateral direction. The path length of COP in anterior-posterior direction before the AE&S program was 940.97±318.08mm, 724.32±263.03mm, and 1099.9±461.80mm compared to 779.29±246.55mm, 494.69±102.76mm, and 801.55±311.17 after exercise in ataxic, spastic and ataxic-spastic subjects, respectively. Table 4 summarizes the results of the standing stability evaluation before and after the exercise.

The mean value of stability parameters in eyes-closed condition between three groups of MS subjects are shown in Table 5. All of the stability parameters (COP excursion in the anterior-posterior and mediolateral directions, path length of COP in the anterior-posterior and mediolateral directions, and total path length of COP) were significantly decreased after the exercise program.

Interaction between the stability of three groups of MS and vision factor was significant (p-value=0.02) (Graph 1, A). Interaction between the stability performance of three groups of MS and session factor (two levels: pre-intervention versus post-intervention) is shown in Graph 1, B. There was no interaction between the groups ($P = 0.7$).

The result of the difference between-groups is shown in Table 6. There are differences between most of the stability parameters of spastic subjects with ataxic and ataxic-spastic subjects. Also, there is no difference between the ataxic and ataxic-spastic groups.

# Discussion

Multiple Sclerosis (MS) is one of the neurological disorders, which influence the abilities of the subjects to stand and walk. Based on the results of various studies, the stability of those with MS differs from that of normal subjects. (6) (39), (8), (40). Therefore, various treatment approaches have been used to improve their stability and to decrease risk of falling. There was not enough evidence in literature regarding the effects of aquatic exercise and swimming program on the standing stability of subjects with different clinical forms of MS. Therefore, we examined the effects of aquatic exercise and swimming program on the standing stability parameters, EDSS, spasticity and brief ataxia rating of three different clinical forms of Multiple Sclerosis (spastic, ataxic and ataxic-spastic) with high EDSS.

The result of this study showed that patients with ataxic and ataxic-spastic disorder have less stability than that of spastic subjects. As seen in Tables 3–5, ataxic and ataxic-spastic MS subjects had instability in both mediolateral and anterior-posterior directions. However, those with spastic symptoms had better stability that may be due to stiffness of the muscles surround on knee and hip joints. In addition, there was a significant interaction between stability performance of three groups of MS subjects and vision factor. It means that ataxic and ataxic-spastic group in closed eyes condition had worse status than spastic subjects were. There is no doubt that subjects with ataxic and ataxic-spastic symptoms have weakness, spasm or wrong timing of muscular contraction which are the main factors which produce imbalance (41). Moreover, the result of this study also showed that these subjects are excessively, dependent on their vision as one of the sensory mechanisms to control their standing stability.

Other results of this research showed that the stability of three groups of MS subjects improved following the AE&S program, which may be due to the effects of exercise on decreasing spasticity, EDSS and rate of ataxia following exercise. Although there were contrasting studies in literature on using various exercises on stability of MS, none of them focused on various forms of MS. Kileff and Ashburn showed that aerobic exercise improved stability and walking ability and decreased fatigue and disability (42). White et al showed that resistance training exercise improved the strength of lower extremity muscles, walking and functional performance in subjects with MS (43). Yazdini et al also showed that aquatic exercise improved dynamic balance of MS subjects (based on berg balance scale) (24). Hejazi et al measured balance using a balance gauge and confirmed aerobic exercises in water improved balance in MS patients (25). Our results were confirmed by these studies. In contrast, DeBolt and McCubbin did not confirm the effects of resistance exercise on stability and mobility adults with Multiple Sclerosis (44). Coco et al did not find any effect on the rate of EDSS after the aquatic program (23), which contrasted our findings.

It should be noted that water creates weight relief and helps subjects ambulate with less assistance and without any assistive devices. Water allows subjects to move their lower and upper extremities through a full range of motion without any problem. In addition, water has a resistance effect and controls increasing body temperature. Supine swimming and lower and upper body exercises improve muscle strength, coordination, physical power, range of motion, muscle control and reduction of muscle rigidity (16, 18). Therefore, it could be emphasized that this type of exercise is helpful in improving stability of various forms of MS.

There is a limitation, which should be acknowledged in this study, which is that only static stability was evaluated in this study. In addition, the stability was evaluated only based on a linear approach. Therefore, it is recommended that both static and dynamic stability be evaluated in future studies based on linear and non-linear approaches. Another limitation is the lack of three control groups in this study. These subjects would not show the intervention effects because patterns of diseases relapse and progress. It is a difficulty for these studies to find matching control subjects. In addition, participants were selected from among women due to the exercise in the water, and ethical issues in the Muslim countries.

# Conclusion

As a whole, aquatic exercise and swimming improved stability parameters of MS patients. The stability of ataxic and ataxic-spastic groups of MS differs from spastic subjects. Ataxic and ataxic-spastic group in closed eyes condition had worse statues than spastic subjects were. The rate of spasticity, EDSS and ataxia rating decreased after aquatic exercise and exercise had the same effect on three groups of patients. Therefore, it can be concluded that this is the first study to evaluate the effects of aquatic exercise and swimming on stability of the subjects with several cases of MS disorder. Combined program of aquatic exercise and swimming is recommended for MS patients. They can use these trainings as a complement treatment beside medication treatments.

# Declarations

Ethics approval and consent to participate: An ethical approval was obtained from Isfahan University of Medical sciences, ethical committee and each subject signed a consent form.

Consent for publication: Done

Competing interests: None

Funding: None

Authors' contributions: all authors have the same contributation regarding this paper.

Acknowledgements: None

# References


1 Noseworthy JH, Lucchinetti, C., Rodriguez, M., Weinshenker, B.G., . Multiple sclerosis. The New England journal of medicine. 2000;**343**(13): 938–52.

2 Abad P, Perez M, Castro E, Alarcon T, Santibanez R, Diaz F. Prevalence of multiple sclerosis in Ecuador. Neurologia. 2010 Jun;**25**(5):309-13.

3 O'Donovan M DA, Craig A. National Physical and Sensory Disability Database Committee Annual Report 2007. Children DoHa: Health Research Board; . 2005.

4 Moghtaderi A, Rakhshanizadeh F, Shahraki-Ibrahimi S. Incidence and prevalence of multiple sclerosis in southeastern Iran. Clinical neurology and neurosurgery. 2013 Mar;**115**(3):304-8.

5 Azarbarzin M. ea. Health improvement in Moltiple Sclerosis. Azad Slamic University, Najafabad branch Publishing Corporation (Persian). 2009.

6 Soyuer F, Mirza M, Erkorkmaz U. Balance performance in three forms of multiple sclerosis. Neurological research. 2006 Jul;**28**(5):555-62.

7 Daley ML, Swank RL. Changes in postural control and vision induced by multiple sclerosis. Agressologie: revue internationale de physio-biologie et de pharmacologie appliquees aux effets de l'agression. 1983 Jun;**24**(7):327-9.

8 Martin CL, Phillips BA, Kilpatrick TJ, et al. Gait and balance impairment in early multiple sclerosis in the absence of clinical disability. Multiple sclerosis. 2006 Oct;**12**(5):620-8.

9 Corporaal SH, Gensicke H, Kuhle J, Kappos L, Allum JH, Yaldizli O. Balance control in multiple sclerosis: correlations of trunk sway during stance and gait tests with disease severity. Gait & posture. 2013 Jan;**37**(1):55-60.

10 Krishnan V, Kanekar N, Aruin AS. Feedforward postural control in individuals with multiple sclerosis during load release. Gait & posture. 2012 Jun;**36**(2):225-30.

11 Nornematolahi S, Hejazi SM, Soltani M, Ashkanifar M. The effect of aquatic aerobic training on quality of life and job satisfaction in Multiple Sclerosis (MS) patients. Annals of Biological Research. 2012;**3**(7).

12 Roehrs TG, Karst GM. Effects of an aquatics exercise program on quality of life measures for individuals with progressive multiple sclerosis. Journal of Neurologic Physical Therapy. 2004;**28**(2):63-71.

13 Fathollahi Z, Imanipour V, Mousaei M, Mahdi F. The effect of 10 weeks hydrotherapy on quality of life and coordination function in the women with multiple sclerosis. 2013.

14 Broach E, Dattilo J, McKenney A. Effects of aquatic therapy on perceived fun or enjoyment experiences of participants with multiple sclerosis. Therapeutic Recreation Journal. 2007;**41**(3):179.

15 Gehlsen GM, Grigsby SA, Winant DM. Effects of an aquatic fitness program on the muscular strength and endurance of patients with multiple sclerosis. Physical therapy. 1984 May;**64**(5):653-7.

16 Peterson JL, & Bell, G. W. . Aquatic exercise for individuals with multiple sclerosis. Clinical Kinesiology: Journal of the American Kinesiotherapy Association. 1995;**49**(3):69-71.

17 Pariser G, Madras D, Weiss E. Outcomes of an aquatic exercise program including aerobic capacity, lactate threshold, and fatigue in two individuals with multiple sclerosis. Journal of neurologic physical therapy : JNPT. 2006 Jun;**30**(2):82-90.

18 Peterson C. Exercise in 94 degrees F water for a patient with multiple sclerosis. Physical therapy. 2001 Apr;**81**(4):1049-58.

19 Ebrahimi Atri A. SM, Sarvari F., Khorshid Sokhangooy M.,. Effect of Aquatic Exercise Program on Fatigue in Women with Multiple Sclerosis. J Mazand Univ Med Sci. 2012;**22**(94):54-61 (Persian).

20 Castro-Sanchez AM, Mataran-Penarrocha GA, Lara-Palomo I, Saavedra-Hernandez M, Arroyo-Morales M, Moreno-Lorenzo C. Hydrotherapy for the treatment of pain in people with multiple sclerosis: a randomized controlled trial. Evidence-based complementary and alternative medicine : eCAM. 2012;**2012**.

21 Gehlsen G, Beekman K, Assmann N, Winant D, Seidle M, Carter A. Gait characteristics in multiple sclerosis: progressive changes and effects of exercise on parameters. Archives of physical medicine and rehabilitation. 1986 Aug;**67**(8):536-9.

22 Broach E, Dattilo J. The effect of aquatic therapy on strength of adults with multiple sclerosis. Therapeutic Recreation Journal. 2003;**37**(3):224-39.

23 Coco M MA, Perciavalle V,. Effects indused by swim on a patients with multiple sclerosis. Case report. Acta Medica. 2006;**21**:85.

24 Yazdani M, Hemayattalab R, Sheikh M, Etemadifar M. The effect of a selected aquatic exercise on balance in subject with multiple sclerosis (MS). Journal of research in rehabilitation sciences. 2013;**9**(2):143-52.

25 Hejazi SM, Soltani M, Siyahpoush AK, Mohamadi EHN, Javan SAA. Effects of Selected Aerobic Exercises in Water on Balance Improvement in Patients with MS. 2013.

26 Hafeznia M. An introduction to the research methodology in humanities: Gora Publishers; 1996.

27 Kurtzke JF. Rating neurologic impairment in multiple sclerosis: an expanded disability status scale (EDSS). Neurology. 1983 Nov;**33**(11):1444-52.

28 Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. Physical therapy. 1987 Feb;**67**(2):206-7.

29 Schmahmann JD, Gardner R, MacMore J, Vangel MG. Development of a brief ataxia rating scale (BARS) based on a modified form of the ICARS. Movement disorders : official journal of the Movement Disorder Society. 2009 Sep 15;**24**(12):1820-8.

30 Murray MP, Seireg AA, Sepic SB. Normal postural stability and steadiness: quantitative assessment. The Journal of Bone and Joint Surgery. 1975;**57**(0021-9355 (Print)):510-6.

31 Doyle TI, Newton RU, Burnett AF. Reliability of traditional and fractal dimension measures of quiet stance center of pressure in young, healthy people. Archives of Physical Medicine and Rehabilitation. 2005;**86**(0003-9993 (Print)):2034-40.

32 Swanenburg J, de Bruin ED, Favero K, Uebelhart D, Mulder T. The reliability of postural balance measures in single and dual tasking in elderly fallers and non-fallers. BMC Musculoskeletal Disorders. 2008;**9**(1471-2474 (Electronic)):159-62.

33 Lafond DF, Corriveau H, Hebert R, Prince F. Intrasession reliability of center of pressure measures of postural steadiness in healthy elderly people. Archives of Physical Medicine and Rehabilitation. 2004;**85**(0003-9993 (Print)):896-901.

34 Hall MG, Fleming HE, Dolan MJ, Millbank SF, Paul JP. Static in situ calibration of force plates. Journal of Biomechanics. 1996;**29**(0021-9290 (Print)):659-65.

35 Santos BR, Delisle A, C. L, Plamondon A, Imbeau D. Reliability of centre of pressure summary measures of postural steadiness in healthy young adults. Gait & Posture. 2008;**27**(0966-6362 (Print)):408-15.

36 Peterka RJ. Postural control model interpretation of stabilogram diffusion analysis. Biological cybernetics. 2000 Apr;**82**(4):335-43.

37 Karimi MT, Solomonidis S. The relationship between parameters of static and dynamic stability tests. Journal of research in medical sciences : the official journal of Isfahan University of Medical Sciences. 2011 Apr;**16**(4):530-5.

38 Dalgas U, Stenager E, Ingemann-Hansen T. Review: Multiple sclerosis and physical exercise: recommendations for the application of resistance-, endurance-and combined training. Multiple sclerosis. 2008;**14**(1):35-53.

39 Jackson RT, Epstein CM, De l'Aune WR. Abnormalities in posturography and estimations of visual vertical and horizontal in multiple sclerosis. The American journal of otology. 1995 Jan;**16**(1):88-93.

40 Karst GM, Venema DM, Roehrs TG, Tyler AE. Center of pressure measures during standing tasks in minimally impaired persons with multiple sclerosis. Journal of neurologic physical therapy : JNPT. 2005 Dec;**29**(4):170-80.

41 AJ. B. Mechanisms of ataxia. Phys Ther 1997;**77**:672-5.

42 Kileff J, Ashburn A. A pilot study of the effect of aerobic exercise on people with moderate disability multiple sclerosis. Clinical rehabilitation. 2005;**19**(2):165-9.

43 White L, McCoy S, Castellano V, et al. Resistance training improves strength and functional capacity in persons with multiple sclerosis. Multiple sclerosis. 2004;**10**(6):668-74.

44 DeBolt LS, McCubbin JA. The effects of home-based resistance exercise on balance, power, and mobility in adults with multiple sclerosis. Archives of physical medicine and rehabilitation. 2004;**85**(2):290-7.

# Tables

**Table 1: The characteristics of the subjects recruited in this study**

| | Ataxic G. (N=11) | Ataxic-spastic g. (N=10) | Spastic group (N=10) |
|---|---|---|---|
| Age (year) | 36.82±10.85 | 41.00±6.71 | 42.60±9.16 |
| Height (m) | 1.59±0.07 | 1.57±0.06 | 1.61±0.06 |
| Weight (kg) | 66.82±18.23 | 58.00±11.12 | 69.00±10.78 |
| disease duration(year) | 8.64±5.77 | 8.90±5.28 | 8.20±5.27 |

**Table 2: Exercise program**

| Time | Stages | Explain |
|---|---|---|
| 15 min | Warm-up | Walking; supported by Noodle belt (increased distance from 100m to 500m end of the program).<br><br>(Forward, backward, left and right sideways walking with upright position and longitude length step, maximum flexion and extension of hip and knee joints, maximum dorsiflexion of ankle with heel contact), training through a full ROM. |
| 20 min | Aquatic exercise | Upper and lower body exercise and balance training; supported by Noodle belt (stretching, endurance and strength training), worked on flexor, extensor, abductor and adductor muscles of upper and lower body. 3 set 10-15 repetitions (small, medium, and full ROM). Performing of balance training (closed-open eyes) in shallow water. |
| 20 min | Swimming | Supine swimming; wearing Noodle belt, (completed it and increase distance from 50m to 300m by end of the program) |
| 15 min | Cool-down | Walking, stretching and relaxation training. |

Table 3: Mean and standard deviation of EDSS, BARS and Modified Ashworth scales in three groups of patients

| Scales | Intervention | Ataxic G. | Spastic G. | Ataxic-Spastic G. |
|---|---|---|---|---|
| **EDSS** | Pre | 4.64±0.98 | 4.15±0.85 | 5.65±0.85 |
| | post | 4.13±1.19 | 3.65±0.97 | 5.40±0.84 |
| | P-value | 0.000 | 0.001 | 0.01 |
| **BARS** | Pre | 9.09±4.04 | 0.3±0.48 | 11.00±4.6 |
| | post | 4.82±3.34 | 0.00 | 9.20±5.45 |
| | P-value | 0.005 | 0.08 | 0.016 |
| **Ashworth Hip Adductors** | Pre | 0.00 | 0.35±0.41 | 0.55±0.36 |
| | post | 0.00 | 0.2±0.42 | 0.30±0.42 |
| | P-value | - | 0.21 | 0.14 |
| **Ashworth Knee Extensors** | Pre | 0.00 | 0.50±0.47 | 1.15±0.97 |
| | post | 0.00 | 0.15±0.33 | 0.70±0.88 |
| | P-value | - | 0.02 | 0.19 |
| **Ashworth Knee Flexors** | Pre | 0.00 | 0.45±0.68 | 0.75±0.54 |
| | post | 0.00 | 0.25±0.42 | 0.40±0.12 |
| | P-value | - | 0.10 | 0.04 |
| **Ashworth Ankle Plantar Flexors** | Pre | 0.32±0.46 | 2.35±0.94 | 2.50±0.71 |
| | post | 0.18±0.40 | 1.70±1.00 | 2.10±0.93 |
| | P-value | 0.43 | 0.004 | 0.02 |
| **Total mean Ashworth Scale** | Pre | 0.08±0.11 | 0.91±0.53 | 1.24±0.33 |
| | post | 0.05±0.10 | 0.58±0.46 | 0.87±0.37 |
| | P-value | 0.43 | 0.002 | 0.006 |

Table 4: Mean and standard deviation of Stability Parameters in eyes-open condition in three groups of subjects

| Parameter | Intervention | Ataxic G. | Spastic G. | Ataxic-spastic G. |
|---|---|---|---|---|
| COPEAP (mm) | pre | 55.66±21.68 | 49.37±16.84 | 49.80±21.78 |
| | post | 42.70±16.11 | 30.10±10.60 | 41.39±16.31 |
| | p-value | 0.06 | 0.004 | 0.01 |
| COPEML (mm) | pre | 64.27±67.96 | 25.04±12.35 | 63.85±53.78 |
| | post | 31.17±20.30 | 14.48±5.96 | 35.27±35.97 |
| | p-value | 0.09 | 0.01 | 0.006 |
| PLAP (mm) | pre | 940.97±318.08 | 724.32±263.03 | 1099.9±461.80 |
| | post | 779.29±246.55 | 494.69±102.76 | 801.55±311.17 |
| | p-value | 0.001 | 0.01 | 0.002 |
| PLML (mm) | pre | 1046.5±518.28 | 957.52±700.69 | 1229.4±350.88 |
| | post | 804.50±378.67 | 503.05±100.41 | 880.38±309.18 |
| | p-value | 0.01 | 0.08 | 0.005 |
| TPL (mm) | pre | 1415.5±575.75 | 1216.4±817.38 | 1662.3±540.27 |
| | post | 1119.7±435.51 | 655.53±256.31 | 1169.6±369.67 |
| | p-value | 0.003 | 0.04 | 0.001 |

Table 5: Mean and standard deviation of Stability Parameters in eyes-closed condition in three groups of MS subjects

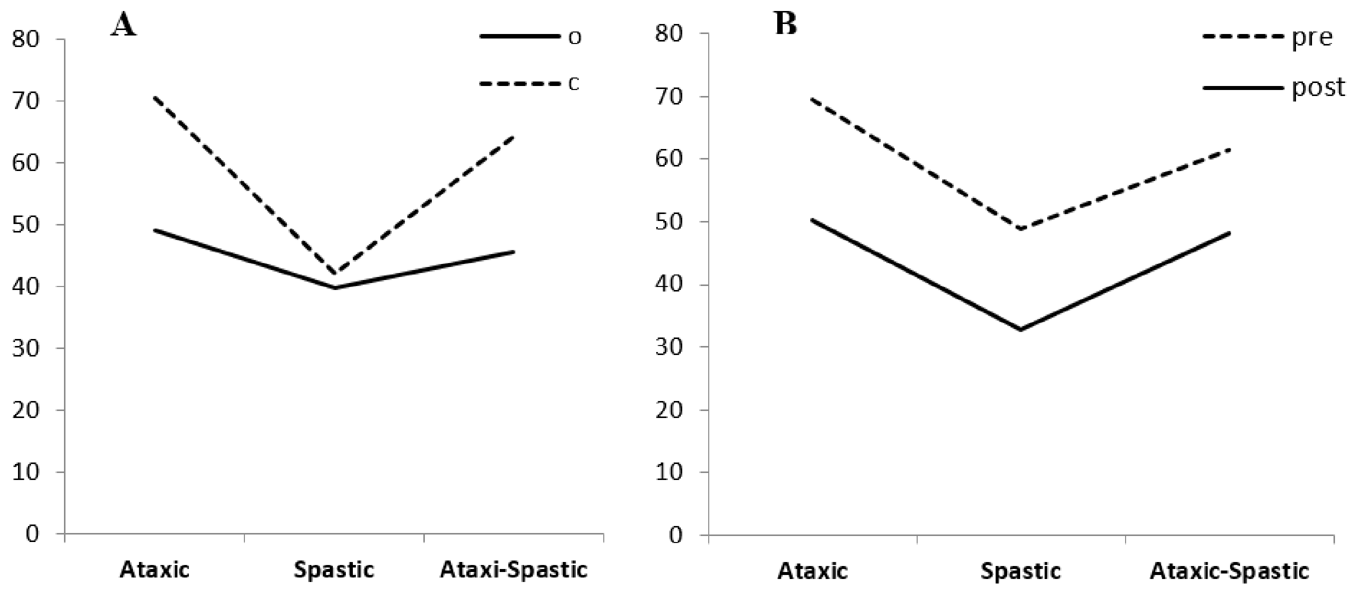
| Parameter | Intervention | Ataxic G. | Spastic G. | Ataxic-spastic G. |
|---|---|---|---|---|
| COPEAP (mm) | pre | 83.22±42.57 | 48.46±14.38 | 73.29±25.75 |
| | post | 57.84±21.51 | 35.62±12.63 | 54.96±18.23 |
| | p-value | 0.02 | 0.047 | 0.002 |
| COPEML (mm) | pre | 105.60±94.82 | 19.40±7.96 | 85.28±63.69 |
| | post | 33.48±24.71 | 19.96±10.14 | 41.91±22.60 |
| | p-value | 0.01 | 0.87 | 0.03 |
| PLAP (mm) | pre | 1627.1±720.98 | 937.19±308.27 | 1571.3±489.85 |
| | post | 1140.1±621.86 | 647.55±133.26 | 1109.0±356.18 |
| | p-value | 0.01 | 0.01 | 0.003 |
| PLML (mm) | pre | 1631.7±821.93 | 1188.3±805.07 | 1588.9±493.39 |
| | post | 1088.4±754.55 | 663.20±160.56 | 995.75±172.39 |
| | p-value | 0.000 | 0.066 | 0.002 |
| TPL (mm) | pre | 2333.4±1052.9 | 1530.5±829.96 | 2262.9±606.21 |
| | post | 1598.6±884.01 | 924.10±200.56 | 1506.1±323.64 |
| | p-value | 0.004 | 0.044 | 0.001 |

**Table 6: multiple comparisons between stability parameters of three MS groups and vision factor**

| Parameter | Interv. | At.&Sp. | At.&A.S. | Sp.&A.S. | O. Power |
|---|---|---|---|---|---|
| **COPEAP** | Pre | 0.55 | 0.74 | 0.41 | 0.99 |
| | post | 0.01 | 0.98 | 0.03 | 0.90 |
| **COPEML** | Pre | 0.001 | 0.9 | 0.007 | 0.55 |
| | post | 0.09 | 0.76 | 0.01 | 0.25 |
| **PLAP** | Pre | 0.006 | 0.97 | 0.002 | 1.00 |
| | post | 0.003 | 1.00 | 0.003 | 0.97 |
| **PLML** | Pre | 0.54 | 0.98 | 0.32 | 0.99 |
| | post | 0.01 | 1.00 | 0.02 | 0.51 |
| **TPL** | Pre | 0.13 | 0.98 | 0.06 | 1.00 |
| | post | 0.001 | 0.99 | 0.003 | 0.92 |

Interv. = Intervention, At. = ataxic, Sp. = Spastic, A.S. = Ataxic-Spastic, O. power = observed power

# Figures




## Figure 1

A: Interaction between (MS group*vision) (Pvalue=0.02), B: Interaction between (MS group*exercise) (P-value=0.7)