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Original Article

Effects of aquatic exercises on postural control and hand function in Multiple Sclerosis: Halliwick versus Aquatic Plyometric Exercises: a randomised trial

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Abstract

Objectives: Postural control and hand dexterity are significantly impaired in people with multiple sclerosis (pwMS). Aquatic interventions may have additional benefits in the treatment of pwMS. The purpose of this study is to compare the effects of two different aquatic exercises on postural control and hand function. **Methods**: Thirty pwMS, relapsing-remitting type were randomly divided into a Halliwick (Hallw) and an Aquatic Plyometric Exercise (APE) group. The Limits of Stability test was used to evaluate postural control using the Biodex Balance System. The Nine-Hole Peg Test was used to evaluate hand dexterity. Both exercise interventions were performed twice a week for 8 weeks, in a pool with a depth of 120 cm and water temperature of 30-31°C. **Results**: Limits of stability improved significantly in both groups ($p<0.05$) and Hallw group completed the test in a significantly shorter time ($p<0.05$). Hand dexterity improved significantly in both groups ($p<0.01$). Following intergroup analysis, Hallw group showed significantly higher improvement in hand dexterity and overall limits of stability test score ($p<0.05$). **Conclusions**: This study provides evidence that both Halliwick and APE are effective to treat balance and hand dexterity. This paper is the first evidence on APE for pwMS and showed that it is safe and improved trunk control and hand dexterity.

Keywords: Dexterity, Hydrotherapy, Multiple Sclerosis, Postural Control

Introduction

Multiple Sclerosis (MS) is a degenerative central nervous system disease characterized by demyelination and axonal damage[1]. Even though symptoms vary individually, walking impairment, upper limb dysfunction, and balance problems are the most common and disabling problems in MS[2]. Postural control is essential for gait, balance and extremity movements which also relates to functional and independence status[3,4]. Postural control involves alignment and movement of the trunk and head as well as coordination of movement strategies during disturbance of stability to maintain the stabilization of centre of gravity (CoG)[5,6]. Measuring disturbance of the balance when CoG stays within the limits of the base of support is known as the limits of stability (LoS). Studies have shown that people with MS (pwMS) are limited and slower in their LoS[7] which contributes to increased fall risk. A well-controlled posture provides improved upper limb function which has been shown to be limited in almost 75% of pwMS due to weakness, spasticity or tremor[2,8]. It a known fact that hand dexterity is an indicator of fall risk due to neuromuscular impairment and/or abnormalities in the corpus callosum in pwMS[9].

There are many different treatment approaches focused on physical activity, self-management, and quality of life for pwMS. Exercise therapy (ET) is one of the most important treatments to maintain and improve functional status[2]. A plethora of studies have shown that ET has a significant positive effect on various symptoms yet there has been no consensus on the optimal exercise prescription for pwMS[10,11].

Aquatic therapy (AT) provides a safe and effective environment for many therapeutic purposes. Along with hydrodynamic properties of water, immersion effects change the response of ET. Bansi et al. showed that BDNF was

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significantly higher after AT than land therapy in pwMS[12]. Anti-inflammatory cytokine TGF-β was also elevated in the serum of people with ankylosing spondylitis after AT compared to land therapy[13]. Schaefer et al investigated the immersion effect on dual-task performance and found that participants tended to make fewer 'cognitive' errors while immersed in chest-deep water than on land[14]. Additionally, kinematics and kinetics of movement are different in water[15,16].

AT has been used for pwMS safely for many decades and research has shown that it has a positive effect on balance, muscle strength, mood, neural plasticity and pain[17-19]. Balance problems are one of the most studied subjects in AT as buoyancy and viscosity of the water help and support the body and there is increased reaction time for regaining balance[20-22].

Plyometric exercises (PE) are often used to augment performance in sport as they are resistive strengthening exercises which involve an eccentric contraction followed by a rapid concentric contraction of the same muscle. During high-velocity, high-impact activities such as hopping, jumping, bounding, and throwing; the proximal part of the body needs to be stabilized to generate a volitional, coordinated and powerful contraction in the limbs distally[23,24]. Although PE has potential to develop motor control, the literature in application to neurological impairment is scarce. One possible reason for not performing PE in people with neurological problems could be the higher ground reaction forces (GRF) in plyometrics[25]. Hydrodynamic properties of water provide a safer environment by lowering the GRF, while improving the dynamic stability[26]. Studies have shown that aquatic plyometric exercises (APE) have a similar effect of land-based plyometric exercises[23,27], however, to our knowledge there is no study that has evaluated the effects of APE in people with neurological problems.

Halliwick method is one of the most popular AT techniques used mainly with the paediatrics population and with persons with neurological problems[28-31]. Halliwick method is a neuromotor treatment approach which uses fluid and mechanical properties of water and is based on postural control by mobilizing and controlling body parts through the "Ten Point Program".

Aquatic therapy provides additional benefits to treatment for pwMS yet there are a limited number of research studies. It is important to understand the effects of type, intensity, and duration of each aquatic intervention in order to prescribe a suitable aquatic exercise program. This study aims to compare the effects of two different aquatic therapy methods on postural control and hand function in pwMS.

Patient and methods

Trial design

This is a single-blinded randomized controlled study where assessors were blinded to group allocation. The participants completed an informed consent before enrolment; then the patients were randomized to the aquatic plyometric exercise (APE) group or Halliwick group (Hallw) by a table of random numbers. The study protocol was approved by the Ethics Committee of Dokuz Eylul University in Izmir, Turkey (Approval No. 2016/14-381). This study was registered with Clinical Trials.gov, number NCT03679806.

Participants

Thirty relapsing-remitting MS participants were recruited from a local MS society between May 2016 and July 2016. Inclusion criteria were Expanded Disability Status Scale (EDSS) score between 1.0 and 6.5, no clinical relapse within the last three-month, no incontinence or persistent infections. The power analysis calculated with GPower Software (ver. 3.0.10) revealed that the study must recruit 15 participants in each group to have 80% power with 5% probability level to detect a minimum clinically significant difference in balance 32 and 80% statistical power level.

All participants and control participants eligible for the study criteria were informed about the aim and the protocol of the study and all participants signed a written informed consent.

Measurements

Postural control was evaluated with LoS test, measured with Biodex Balance System (BBS; SD 12.1"Display 115 VAC). Patients were asked to stand on the rigid surface, barefoot and eyes open, during the measure of LoS Test[3].

LoS test challenges the control of one's CoG within one's base of support. During each test trial, participants were asked to shift their weight in order to move a cursor from a centre target to a blinking target and back with as little deviation and as quickly as possible. The same process was repeated for each of the nine targets. Targets on the screen were in random order. The test was repeated three times with a 30 second rest between trials. Patients' performance was evaluated based on a total score of 100, where the higher score represents better trunk control[33].

Nine hole peg test (NHPT) is considered the gold standard for measuring manual dexterity and is used to measure upper extremity functionality[34]. The participants were seated at a table with a plastic NHPT board placed in front. The participants were asked to place pegs in the appropriate hole, in random order, as quick as possible using dominant hand first. The total time was recorded in seconds. Three consecutive trials with the dominant hand were immediately followed by three consecutive trials with the non-dominant hand.

Exercise protocol

Exercises were performed in a private pool owned by the local MS society twice a week for 8 weeks. Pool depth was 120 cm (around xiphoid level of the participants) and water and the room temperature were held between at 30-31°C and 26-28°C, consecutively. Patients were taken in groups of three for the 45 minute session. During warm up,

Table 1. Demographic characteristics of the groups at the baseline.

	Aquatic Plyometric (13)	Halliwick (15)	p
Age (yrs)	51.0 (49.5- 63.5)	56.8 (47.3- 65.8)	0.867
BMI (kg/m²)	25.9 (22.5-28.3)	25.3 (23.1-29.2)	0.351
EDSS	2.5 (2.5-5.5)	2.7 (2.3-5.4)	0.082
Disease duration (yrs)	15 (11.0-22.5)	15 (7.0-29.0)	0.817

*Mann-Whitney U Test. BMI: Body Mass Index. EDSS: Expanded Disability Status Scale, Values were given in median (quartiles) *p<0.05 between groups.*

Table 2. Comparison of baseline and after 8 weeks hand dexterity and limits of stability.

	APE Median (Quartiles)		Hallw Median (Quartiles)	
	Before	After	Before	After
Hand Dexterity (sec)	27.8 (26.4-28.17)	27.0 (25.0-27.4)*	30.5 (25.1-35.9)	27.1 (21.9-31.3)*¥
Limits of stability				
Overall	34.0 (21.5-52.0)	36.0 (15.0-45.0)*	42.0 (36.0-53.0)	56.0 (39.0-62.0)*¥
Forward	24.0 (15.0-40.5)	17.0 (14.0-26.0)	47.0 (41.0-60.0)	59.0 (40.0-82.0)
Backward	30.0(14.5-41.0)	26.0 (21.5-41.5)	47.0 (31.0-52.0)	49.0 (42.0-62.0)
Right	35.0 (26.0-45.0)	40.0 (30.0-47.0)	49.0 (42.0-55.0)	54.0 (47.0-63.0)
Left	30.0 (23.0-39.5)	35.0 (26.5-43.5)	53.0 (47.0-60)	57.0 (44.0-74.0)
Forward right	37.0 (25.5-46.0)	37.0 (25.5-41.5)	57.0 (48.0-71.0)	62.0 (37.0-73.0)*
Forward left	40.0(30.0-47.0)	34.0 (26.0-47.0)	61.0 (40.0-70.0)	59.0 (46.0-72.0)
Backward right	31.0 (17.0-50.5)	35.0 (25.0-47.5)	43.0 (34.0-63.0)	49.0 (38.0-62.0)
Backward left	33.0 (21.5-48.0)	33.0 (25.5-44.5)	50.0 (35.0-62.0)	47.0 (34.0-57.0)
Time (sec)	46.0 (44.0-70.0)	45.0 (35.0-82.0)	51.0 (48.0-56.0)	45.0 (33.0-51.0)*

*Mann-Whitney U Test; *p<0.05 within groups; ¥p<0.05 between* groups.

the participants were asked to walk in various directions at various speeds, to change direction rapidly and to keep their balance for 3-5 seconds. Arm movements combined with breathing were included in the warm-up. During cool down, at the end of each session, participants were asked to walk at their preferred speed then to lay, relaxed in a supine position, supported with two buoyant noodles for three minutes.

Aquatic Plyometric Exercises

The APE program description is provided in Appendix 1. The APE program was progressed by increasing speed and the range of motion of the movements. Patients were carefully informed not to deform the exercise just to emulate the speed. The three phases of each exercise; eccentric (or loading) phase, the amortization phase, and the concentric (or unloading) phase were explained thoroughly at the beginning of every exercise.

Halliwick Group

The Hallw program description is provided in Appendix 2. The exercise program was progressed by increasing the speed and the range of motion of the movements. Patients were asked not to accelerate the exercise and to focus on their alignment. Mental adjustment, sagittal rotation, transverse rotation, combined rotation controls, and balance in stillness steps of the Halliwick concept were included.

Statistical Analysis

The statistical package SPSS 20.0.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Level of significance was set at p<0.05. Data were presented in medians in combination with quartiles and percentiles. Mann Whitney U test used to compare results of APE and Hallw groups. The treatment effect was tested with Wilcoxon signed-rank test. Significance was set at 0.05 for the analysis.

Results

Of the 30 MS patients that participated in the 8 weeks of sessions, no harm or unintended effects were found. Two of the Hallw participants did not attend the last assessment and they were excluded from the study. There was no significant difference between the baseline characteristics of groups (Table 1).

Hand dexterity improved significantly in APE and Hallw groups after 8 weeks of aquatic intervention ($p<0.01$) (Table 2). Hallw group showed significantly higher improvement between groups ($p<0.05$). Table 2 shows that there was a significant improvement in APE and Hallw groups participants' overall LoS ($p<0.05$). Forward right stability was significantly improved only in Hallw group ($p<0.05$) and Hallw group completed the test in a significantly shorter time ($p<0.05$) there was no change in these parameters in APE group (Table 2). Statistical analyses within group showed that overall score of LoS improved significantly in Hallw group ($p<0.01$) (Table 2).

Discussion

The purpose of the study was to evaluate and compare the effects of Halliwick and aquatic plyometric exercise, APE, on postural control and hand dexterity. Halliwick method is widely used in neurological conditions to improve balance and trunk control however the literature on APE is scarce. This study was able to show that APE was a safe and effective intervention to improve hand dexterity and balance in pwMS.

Fall prevention is one of the major concerns in the treatment of MS. Even though water provides an advantageous and safe environment for fall prevention programs, only a few studies have investigated the effects of aquatic exercise on balance in pwMS[17,35,36]. The findings of these studies suggested that aquatic exercise improved postural control but none of the studies used Halliwick method or APE.

Halliwick method is widely used for the treatment of balance and gait in people with stroke and Cerebral Palsy[28,30,31,37]. The findings of our study are consistent with research on the Halliwick method and postural control in pwMS with an improvement[20]. Overall LoS score results indicate that the forward-right direction scores were most improved in the Halliwick group. However, Halliwick group did not perform specific exercises addressing the forward-right direction. We think it could be related to the dominant side or clinical features of the participants as 73% (n=22) were weak in their right limb or the primary difference in methodology was APE focussed on speed of execution and Hallw focussed on alignment. However, this study is unable to explain the mechanism behind this result. Future studies with a heterogeneous grouping that could analyze the kinetic and kinematic features of the exercises would give more information on this finding.

Hallw group completed the LoS tests in a shorter time after 8 weeks of treatment. This result shows that participants were more competent and accurate in controlling their CoG. This demonstrated decreased reaction time and increased movement velocity of CoG and could result in improvement of trunk control, balance and fewer falls.

APE group was improved in overall LoS score which indicates better trunk control, however, the test time did not decrease. APE consists of rapid and powerful movements, therefore, it might be thought that participants would move quicker after the treatment. However, the exercises in this study predominantly demanded quicker movements of the limbs where the trunk should be stabilized to allow better movement of the limbs. In future APE studies, these authors recommend an outcome measure like Step Reaction Time to measure speed improvement.

Hand dexterity is an important outcome in evaluating fall risk, physical activity level and disability progression in MS[38,39]. Neither of the interventions had fine-motor exercises or upper extremity specific exercises yet hand dexterity increased significantly in both groups. The reason behind this result could be due to the better sitting posture as a result of improved trunk control. Even though none of the exercises targeted the upper limb directly, participants in Hallw group were holding a pool noodle to maintain their upright posture. APE group had arm swinging exercises, and used their upper body to regain their balance once they had lost it. Therefore shoulder joint stabilization and upper limb strength, proprioception, and coordination may have been challenged during the interventions.

The literature suggests that exercise therapy increases balance and hand functions in pwMS 1. Exercises performed in water may have some additional benefits for pwMS[12]. During aquatic sessions, participants expressed their appreciation and enjoyment about the practice in both groups. Adherence to the treatment was high with only two dropouts who did not attend the final assessment; one of them was away for educational purposes, and the other one caring her spouse in the hospital. Evaluating fun and enjoyment was not included in our outcome measures yet it is still worth mentioning. Comments from the APE participants reported excitement and pleasure to be able to perform movements that they had not been able to do for a long time.

The temperature of the pool is a subject needed to be carefully addressed especially working with pwMS. Most of the aquatic studies for pwMS are performed in cool water in order to avoid Uhthoff's phenomenon[12,17]. The Halliwick method is a neuromuscular approach where participants move slowly in order to maintain the control and quality of the movement whereas the APE program includes jumping and hopping where participant's heart rate will increase. In order to avoid the heat effect of immersion both interventions were performed at thermo-neutral temperature (31-32°C) and none of the participants reported any adverse effect related to Uhthoff's phenomenon.

This study is the first study to use APE with pwMS and showed that it is safe and improved trunk control and hand dexterity. There are some limitations of this study. Firstly, APE intervention could have some outcomes related to velocity of extremity movement but this study design focussed on measures of trunk stability. For this reason it was not possible to see whether stepping reaction, another important strategy to maintain balance, was changed or not. Further research to measure different aspects of balance are needed to provide a better understanding of the optimal components of a comprehensive aquatic exercise program for balance in pwMS. Secondly, even though adherence of both treatment groups was high two participants did not attend the last assessment. In future research this issue should be taken into consideration with a suggested increase in the initial recruitment number.

Trunk control and hand dexterity are essential to daily living activities and important components of fall risk in pwMS. This study provides evidence that both Halliwick and APE are safe and effective interventions to improve balance and hand dexterity. Halliwick exercises involved slow and controlled trunk movements whereas APE group was asked to stabilize their trunk during rapid extremity movements. Both interventions improved trunk control and hand dexterity yet the improvement of Hallw group was greater than APE group. In Hallw group, participants experienced and learned how to elongate their trunk in a controlled movement which may be the reason for the better LoS test scores. Also, most of the Hallw exercises were performed in a sitting position (floating sitting) which may have resulted in better sitting posture for the Nine Hole Peg Test and thus a better score in hand dexterity. In future, where comparing aquatic exercise methods in pwMS, it will be interesting to evaluate outcome scores which measure the speed of lower extremity movements such as choice step reaction time.

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Appendix I. Halliwick Programme.

SAGITAL ROTATION:
Cervical lateral flexion in sitting
Trunk lateral flexion in sitting to side lying
Trunk lateral flexion in sitting to touching floor with feet
COMBINED ROTATIONS:
Sagital rotation and longitudinal rotation
Transfers rotation and longitidinal rotation
TRANSFER ROTATION:
Cervical flexion and extension in sitting
Flexion and extention legs in sitting (symmetric/asymmetric)
Kangaroo jumping
Prone/supine
LONGUTUDINAL ROTATION:
Cervical rotation in sitting
Lower trunk rotation in sitting
3 minutes of relaxation lying in supine position with two noodles one under arms and one under knees

Appendix II. Aquatic Plyometric Exercise.

Jumping tucks
Kangaroo jumping
Jumping to sides
Jumping diagonals
Star jump
Lunge jump
Reverse star jump
Keep trunk stable during arm flexion and extension: symmetric reciprocal
Keep trunk stable arm flexion and extension: asymmetric reciprocal
Keep trunk stable arm abduction-adduction: symmetric reciprocal
3 minutes of relaxation lying in supine position with two noodles one under arms and one under knees