Effect of aquatic versus land motor dual task training on balance and gait of patients with chronic stroke: A randomized controlled trial

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Abstract

BACKGROUND: Patients with stroke are more likely to be at risk of falling, which lead to limitation in their abilities to perform daily living activities and participation in society. Falling is due to an increase in postural sway and a decline in gait ability. Exercise in water helps them to safely and comfortably improve their motor ability by providing low-risk exercise environments.

OBJECTIVE: This study was conducted to compare the effect of aquatic versus land motor dual task training on balance and gait of patients with chronic stroke.

METHODS: Fifty patients with chronic stroke of both sexes aging from 45 to 55 years were randomly assigned to aquatic or land group. Both groups received the same motor dual task training either in water or on land for 45 minutes, 3 days a week for six weeks. Measurement of the dynamic balance indices assessed using Biodex Balance System as well as kinematic gait parameters using Biodex Gait Trainer was performed before and after the intervention.

RESULTS: There was a significant improvement in all outcome variables post treatment compared with that pre-treatment in both groups \((P<0.05)\). There was a significant improvement in patients who received the motor dual task training in water compared with patients treated on the land in overall stability index \((P=0.02)\), anteroposterior stability index \((P=0.03)\), mediolateral stability index \((P=0.002)\), walking speed \((P=0.01)\), step length of affected limb \((P=0.03)\), step length of non-affected limb \((P=0.01)\), and time of support on the affected limb \((p=0.002)\).

CONCLUSION: Aquatic motor dual task training is more effective in improving balance and gait abilities of patients with chronic stroke than land motor dual task training.

Keywords: Aquatic exercise, balance, chronic stroke, gait, motor dual task training

1. Introduction

Stroke is the rapidly developing loss of brain function due to a disturbance in the blood supply to the brain. This can be due to ischemia caused by blockage or due to a hemorrhage (Sims & Muyderman,
2010). According to the statistics of World Health Organization, there are about 15 million new patients with stroke each year and one third of them suffer from permanent impairment, so stroke is one of the main causes of adult disability today (Lim & Lee, 2012). Patients with stroke often have low self-esteem, depression, and decreased quality of life, because they have difficulties in performing daily life activities (Kum & Shin, 2017).

Balance impairment is one of the major physical problems of patients with stroke that lead to limitation in performance of daily living activities and participation in society (Ijmker et al., 2013), this is because deficits in balance and posture control leads to a high incidence of falls (Park & Roh, 2011), and abnormal gait (Park et al., 2016). Patients with stroke have difficulty in controlling their movements because their movement amounts are reduced, their body sway increases approximately two-fold compared to the static standing posture of normal subjects; also their stability limits are decreased. This increase in body sway in a static posture, leading to asymmetrical loading of the weight on both lower limbs and decreasing the ability to move the center of gravity toward the affected side, which leads to instability of gait, decreases gait speed and increases the risk of falls (Park et al., 2014). So, the restoration of balance and an optimal gait is a major goal in the rehabilitation of patients with stroke (Kim et al., 2015).

To solve such problems concerning balance and walking related to stroke, various treatment methods have been used in several previous studies (Cheng et al., 2001; Jaffe et al., 2004; Macko et al., 2005; Yavuzer et al., 2006). Recently, dual task training during which patients perform two or more tasks at the same time continuously has become the main focus of research studies for rehabilitation of patients with stroke, these studies have been reported that dual task training on land is an effective intervention method for improving balance and gait ability in patients with stroke (Yang et al., 2007; Seo et al., 2012; Shim et al., 2012; Kim et al., 2013). But, although land based exercises come with a lot of benefits and can be performed by almost everyone, they cause a large amount of impact stress on joints and muscles. This may result in stress fractures, injury and soreness in the muscles, all of which contribute to a reduction in physical activity and fitness (Denning et al., 2012).

On the other hand, water is an excellent medium for achieving maximal exercise levels in those with or without disabilities. As, the buoyancy of water leads to a reduction in the gravitational forces that act on the musculoskeletal system, allowing for a greater relaxation of muscles that are constantly working against gravity and consequently reduces the biomechanical stress on muscles and joints which is important for stroke patients when exercising (Park & Roh, 2011). In addition, hydrostatic pressure and viscous force provide a different proprioceptive and sensory feedback from that experienced on land (Geigle et al., 1997), thus influencing the postural control system and balance competence (Simmons & Hansen, 1996).

Although physical and mechanical properties of water have profound effect on enhancing the rehabilitation of patients with stroke, most studies which investigated the effect of motor dual task training on balance and gait have been conducted on land. To the best of our knowledge, studies on its effect in water for stroke patients rehabilitation are still insufficient. So, the purpose of the present randomized controlled trial was to compare the effect of aquatic versus land motor dual task training on balance and gait of patients with chronic stroke.

2. Materials and methods

This randomized controlled trial was conducted at National Institute of Neumotor System, Giza, Egypt from July 2017 to May 2018. The study protocol was explained in details for each patient before the initial assessment and enrollment in the study and all patients signed an institutionally approved informed consent form which was approved by the Ethics Committee of the Faculty of Physical Therapy, Cairo University (PT REC/012/001789). The study was registered on Pan African Clinical Trial Registry database and the registration number was PACTR 201801002901262.

2.1. Study population

Patients who were diagnosed as having a stroke based on careful clinical assessment by a neurologist and radiological investigations including computed axial tomography or magnetic resonance imaging of the brain were initially screened. After the screening process, patients were eligible to participate in the study if they had (i) age ranging from 45 and 55 years; (ii) duration of illness ranged from six months to one year; (iii) muscle tone of affected lower limb ranged from 1 to 1+ according to Modified Ashworth Scale (Bohannon & Smith, 1987); (iv) a brunnstrom
stage of 4 for lower limb; (v) ability to walk 10 meters independently without assistance; (vi) ability to communicate and understand with Mini-Mental Status Examination score of over 24 points (Park & Roh, 2011). Patients were excluded if they exhibited any of the following criteria: (i) previous stroke or other neurological diseases or disorders; (ii) balance disorders due to cerebellar or vestibular dysfunction; (iii) orthopedic disorders (i.e. severe osteoarthritis, rheumatoid arthritis, peripheral nerve injuries, history of fractures or surgeries involving lower limbs, pelvis, or back, or significant low back pain); (iv) marked superficial and/or deep sensory loss, deafness, blindness and cognitive impairment (inability to follow simple verbal commands during testing); (v) an open skin wound or skin disease; (vi) fecal incontinence; (vii) fearful of walking in an underwater environment.

2.2. Randomization

A total of 67 stroke patients were assessed for eligibility. Twelve patients were excluded as they did not fulfill the inclusion criteria and five patients were excluded as they refused to participate in the study. A randomization process was performed for 50 patients by an independent person who picked one of the sealed envelopes, which contained numbers chosen by random number generator. Randomization was restricted to permuted blocks of different size to ensure that equal numbers were allocated to each group. Each random permuted block was transferred to a sequence of consecutively numbered, sealed, opaque envelopes and these were stored in a locked drawer until required. As each participant formally entered the trial, the researcher opened the next envelope in the sequence in the presence of the patient. A diagram of patients retention and randomization throughout the study is shown in Fig. 1.

Patients were randomly assigned to one of the following two groups: Aquatic group which included 25 patients (13 male and 12 female) or land group which included 25 patients (11 male and 14 female). Both groups received the same motor dual task training either in water or on land for about 45 minutes, 3 days per week for six weeks.

2.3. Outcome measures

The outcome measures were carried out for each patient individually before and after 6 weeks of treatment by the same outcome assessor. The primary outcome measure included measurement of dynamic balance indices using the Biodex Balance System (BBS) (Biodex medical system, Shirley, New York).
The BBS had been found to be a reliable device for static and dynamic balance assessment (Arifin et al., 2014). In this study the outcome measures of dynamic balance test included: Overall Stability Index (OASI) which represents the patient’s ability to control his balance in all directions, Anteroposterior Stability Index (APSI) which represents the patient’s ability to control his balance in front to back direction, and Mediolateral Stability Index (MLSI) which represents the patient’s ability to control his balance from side to side. High values of stability indices represent that patient had difficulty in maintaining balance. The BBS has eight levels of stability, extending from the least stable level (level 1) to the most stable level (level 8). In the present study, all measurements were performed at the level (8) of stability as this level represents the most stable and high resistance level of the platform, as high test–retest reliability for the BBS was reported when using high resistance levels (Cachupe et al., 2001).

Before the evaluation procedures all patients were given an explanatory session to be aware about the different test steps, also the support rails and biofeedback display screen were adjusted for each patient to ensure comfort and safety during the test procedure, then each patient was trained 1 min for adaptation to the machine. During the test, patients were instructed to stand on the platform in the most comfortable posture, and maintain their visual level by focusing straight ahead on the monitor. The platform was unlocked and subjects were allowed to adjust their foot placement until a comfortable standing position was achieved while they simultaneously maintained a moving pointer at the center point on the monitor and patients were encouraged to maintain the moving pointer at the center point throughout the test. For the trial to be complete, the patient has been asked to maintain his balance on the force platform for 30 seconds (Nichol, 2001). Each measurement was carried out three times with eyes open with a 25-second inter-trial rest period, then the average value of the three trials was displayed and taken as the final balance index; which reflected the patient’s overall performance.

The secondary outcome measure included measurement of spatiotemporal gait parameters (Walking speed (cm/sec), step length (cm) and time of support on the affected side (recorded as % of gait cycle) using the Biodex Gait Trainer (Gharib et al., 2011). For evaluations of gait parameters, each patient was first allowed to be familiar with the gait trainer set up before starting recording the selected gait parameters. This was achieved through instructing the patient to walk over the gait trainer and to follow the tread belt movement for three to five minutes. This might be repeated two or three times till the patient became adapted and familiar with the apparatus. To start the evaluation process, the tread belt was ramped up slowly to 0.3 meter/hour. The speed setting was then increased gradually to a comfortable pace for each patient. Once the patient became comfortable, the data recording was started. Each patient was allowed to walk continuously for three minutes, then the evaluation session ended and the gait trainer slowed down gradually until it stopped and the results were displayed. These procedures were repeated three successive times with three minutes rest period in between trials. For each patient, gait parameters were averaged over the trials for further data analysis.

2.4. Interventions

Patients in both the aquatic group (n=25) and land group (n=25) received the same motor dual task training 3 days per week for six weeks by the same physiotherapist. Each training session lasted for 45 min including: 5 min of warm up exercises, 25 min of the main exercises (motor dual task training) and 5 min of cool down exercises. Marching in place and stretching of upper extremities and trunk muscles were performed in the warm up and cool down periods. The motor dual task training used in this study was applied after modifying and supplementary the tasks used by Seo et al., 2012 and Shim et al., 2012, which included the following groups of exercises:

1. Walking while holding a ball in the non-paretic hand.
2. Walking with slow movement of non-paretic arm.
3. Walking at a comfortable speed while holding a 200 mL cup of water without spilling.
4. Standing on a balance board while holding a cup containing water in front of them and move it so it crossed the centerline of their body until it reached a point in front of them and on the opposite side. They repeated this movement, alternating between using their non-paretic and paretic hands. When the subjects could not actively hold the cup with paretic hand, the therapist aided them.
Various walking conditions were performed in each of the walking tasks including: walking forward, walking sideways and walking backward for about 3 minutes to each condition. Rest breaks were provided as needed, and the patients were instructed to tell the physiotherapist and stop the exercise immediately if they report any side effect such as dizziness.

For aquatic group: The motor dual task training were done by a qualified physiotherapist in water-based exercises in a large swimming pool, which equipped with suspended chair and plinth, side bars at sides of the pool and balance board. The water depth was constant at 1.3 m and the water was kept temperature at of 33–35°C (Park & Roh, 2011). All patients participating in the aquatic therapy were habituated to the water environment through warm-up periods at each session. For the land group; the patient performed the same sequence of exercises but on land.

2.5. Sample size

To avoid type II error, a preliminary power analysis [F test, MANOVA: special effects and interaction, power (1-α error) = 0.80, α = 0.05, Pillai V = 0.13, effect size f² (V) = 0.149, with a comparison of 2 independent groups, number of variables (mainly primary outcome = 3, and number of predictors = 2] determined a sample size of 25 for each group in the study using G* power 3.1 software. The Pillai V and the effect size were calculated according to a pilot study on 10 participants (5 in each group) considering OASI, APSI and MLSI as a primary outcome.

2.6. Data analysis

Subject characteristics were compared between both groups using t test. Chi-squared test was used for comparison of sex, type of stroke and affected side distribution between groups. Normal distribution of data was checked using the Shapiro-Wilk test for all variables. Levene’s test for homogeneity of variances was conducted to test the homogeneity between groups. Mixed MANOVA was conducted to compare the mean values of stability indices and kinematic gait parameters between aquatic and land groups and between pre and post treatment in each group. Partial squared eta was considered as the effect size. Post hoc tests using the Bonferroni correction were carried out for subsequent multiple comparison. The level of significance for all statistical tests was set at p < 0.05. All statistical analysis was conducted through the Statistical Package for Social Studies (SPSS) version 19 for windows (IBM SPSS, Chicago, IL, USA).

3. Results

3.1. Participants’ characteristics

Table 1 showed the mean ± SD of subjects characteristics and duration of illness of aquatic and land groups. There was no significant difference between both groups in the mean age, weight, height, body mass index and the duration of illness (p > 0.05). Also, there was no significant difference in the distribution of sex, type of stroke and affected side between both groups (p > 0.05).

3.2. Effect of treatment on balance indices

Mixed MANOVA revealed that there was no significant interaction of treatment and time (Wilk’s Lambda = 0.84; F = 1.53, p = 0.22, η² = 0.15). There was a significant main effect of time (Wilk’s Lambda = 0.17; F = 41.17, p = 0.0001, η² = 0.82). There was a significant main effect of treatment (Wilk’s Lambda = 0.73; F = 3.11, p = 0.04, η² = 0.26). Table 2 showed descriptive statistics of balance indices as well as the significant level of comparison between groups as well as significant level of comparison between pre and post treatment in each group.

There was no significant difference between the aquatic and land groups in OASI, APSI and MLSI pre-treatment (p > 0.05). Post treatment there was a

| Table 1 Demographic and clinical characteristics of all participants |
|----------------------|----------------------|----------------------|
|                      | Aquatic group | Land group | P-value |
| Age (years)          | 49.53 ± 1.8    | 50 ± 1.96    | 0.5*    |
| Weight (kg)          | 64.26 ± 7.88   | 66.6 ± 7.26  | 0.4*    |
| Height (cm)          | 165.33 ± 8.37  | 167.06 ± 9.12| 0.59*   |
| BMI (kg/m²)          | 23.42 ± 0.81   | 23.78 ± 0.67 | 0.19*   |
| Duration of illness (months) | 9.2 ± 2.06 | 8.84 ± 1.74 | 0.5*    |
| Sex                  |                |              |         |
| Male                 | 13 (52%)       | 11 (44%)     |         |
| Female               | 12 (48%)       | 14 (56%)     | 0.57*   |
| Type of stroke       |                |              |         |
| Infarction           | 15 (60%)       | 13 (52%)     |         |
| Hemorrhagic          | 10 (40%)       | 12 (48%)     | 0.39*   |
| Affected side        |                |              |         |
| Right                | 13 (52%)       | 12 (48%)     |         |
| Left                 | 12 (48%)       | 13 (52%)     | 0.42*   |

BMI, Body Mass Index; * p-value, level of significance; * non-significant.
Significant decrease in the OASI, APSI and MLSI of the aquatic group compared with that of land group \((p < 0.05)\).

Comparison between pre and post treatment in each group revealed that there was a significant decrease in the OASI, APSI and MLSI \((p < 0.01)\) post treatment compared with pre-treatment in both groups.

### 3.3. Effect of treatment on kinematic gait parameters

Mixed MANOVA revealed that there was a significant interaction of treatment and time (Wilks’ Lambda = 0.12; \(F = 26.51, \ p = 0.0001, \ \eta^2 = 0.87\)). There was a significant main effect of time (Wilks’ Lambda = 0.03; \(F = 114.13, \ p = 0.0001, \ \eta^2 = 0.96\)). There was no significant main effect of treatment (Wilks’ Lambda = 0.7; \(F = 1.59, \ p = 0.19, \ \eta^2 = 0.29\)).

Table 2 showed descriptive statistics of kinematic gait parameters as well as the significant level of comparison between groups as well as significant level of comparison between pre and post treatment in each group.

There was no significant difference between the aquatic and land groups in all kinematic gait parameters pre-treatment \((p > 0.05)\). Post treatment there was a significant increase in the walking speed, step length of the affected and non-affected side, and time of support on affected side post treatment compared with that pre-treatment in both groups \((p < 0.05)\).

### 4. Discussion

This study was conducted to compare the effect of aquatic versus land motor dual task training on dynamic stability indices and spatiotemporal gait parameters of patients with chronic stroke. The results showed that, the group receiving the motor dual task training in water showed more improvement in dynamic stability indices (OASI, APSI and MLSI) and spatiotemporal gait parameters (walking speed, step length and time of support on the affected limb) than the land group who receiving the same exercises but on the land.

The significant improvement in the dynamic stability indices in the aquatic group than land group in this study might be explained by the ability of individuals to perform activities in water more readily without any fear of falling even after passing the limit of stability (Jung et al., 2014). This is because the buoyancy of water may allow stroke patients to move with less effort, and the hydrostatic pressure can activate the peripheral nerves of the trunk and the four limbs, eventually having significant effect, enhancing of patients’ balance (Bandy & Sanders, 2001). Also, water immersion may improve the balance abilities by increasing the sensory feedback, thus increases the sensory output to the muscles to contract to stabilize postural alignment because resistance to movement through a viscous fluid like water is greater than resistance through air (Roth et al., 2006). Proprioceptive input to the immersed body may also increase, which
lead to greater body alignment and stability as joint position sense is considered to be directly associated with balance performance (Stokes, 2004). This explanation supported by Park et al., 2011, who reported that joint position sense was enhanced in an aquatic exercise group when compared with a conventional treatment group.

Furthermore, a water temperature 33–35°C may be another explanation to the improvement in dynamic balance in aquatic group than land group, because it works as an assistive element, increasing skin temperature, expanding blood vessels in the peripheral skin, increasing blood supply, accelerating muscle relaxation, decreasing sensitivity to pain or muscular spasm and enhancing balance function (Jung et al., 2014). This explanation supported by Suomi and Koceja, 2000, who reported that the condition of a temperature controlled water exercise may be a factor that helps to improve static balance ability. In addition, it was mentioned by Vivas et al., 2011, that aquatic exercises provide a big therapeutic advantage in decreasing muscle tension and increasing stability and functional mobility for postural control.

In stroke patients, walking requires massive energy consumption due to their difficulty with independent gait (Dias et al., 2007). Muscle weakness of the lower limbs is an element that limits functional restoration of the patient and it can lead to deficits in maintaining balance and gait ability (Park et al., 2015). The results of the current study concerning the significant improvement of gait ability in aquatic group than land group might be attributed to improvement of the muscle strength of the lower limb depending on the effect of two main physical properties of water; the first one is the water viscosity which can improve the muscle strength consequently improving the gait abilities. This explanation was supported by Masumoto et al., 2007, who mentioned that water exercise enhanced rectus femoris, biceps femoris, and vastus medialis by resistance of water and increased walk safety and speed at the same time. Also, it has been reported by Masumoto et al., 2008, that gait training in the water strengthened iliopsoas muscle and extensor and improved the walk stability.

Buoyancy is the second property of water which can help in improving the gait ability of stroke patients, as buoyancy may allow stroke patients to move with less effort and in movement planes that would be impossible on land without assistance (Suomi & Koceja, 2000). This is confirmed by Bale and Strand, 2008, who mentioned that buoyancy of water decreases pressure onto the joints which enables gait training with less strength requirements compared to land. Furthermore, Ki et al., 2009, mentioned that during the underwater, the load put onto the lower extremities is decreased and use of the water resistance is effective in improving muscle strength, endurance and equilibrium.

The present work has some limitations, however, each one of them considered a new point for future study. The primary one was the lack of follow-up for patients in both groups post treatment to evaluate the long lasting effect. In addition, the results of the current study can’t be generalized to all patients because the sample was not a random sample to represent the whole population.

5. Conclusion

The results obtained from this study showed that aquatic motor dual task training significantly improved balance and gait abilities of patients with chronic stroke when compared with land motor dual task training.

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Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

References


