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RESEARCH PAPER

Effects of the Bad Ragaz Ring Method on muscle activation of the lower limbs and balance ability in chronic stroke: A randomised controlled trial

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KEYWORDS
Bad Ragaz Ring method;
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Abstract *Background:* Recovery of balance and walking abilities is important for the rehabilitation of stroke patients.

Objectives: To evaluate the effects of the Bad Ragaz Ring method on functional recovery in chronic stroke patients.

Methods: Twenty-two chronic stroke patients were randomly assigned to two groups: a Bad Ragaz Ring method group (the experimental group) or a control group. Stroke patients in the experimental group underwent Bad Ragaz Ring exercise and comprehensive rehabilitation therapy, whereas patients in the control group underwent comprehensive rehabilitation therapy alone. The participants in both groups received therapy 3 days per week for 6 weeks. Muscle activations, balance indices, and Timed Up and Go test results were assessed before and after the 6-week therapy period.

Results: The experimental group showed significant improvements in activations of tibialis anterior and gastrocnemius muscles, balance index, and Timed Up and Go test results as compared with preintervention results ($p < 0.05$), whereas the control group showed significant improvement in Timed Up and Go test ($p < 0.05$). Significant differences in posttraining gains in the activations of tibialis anterior and gastrocnemius muscles and in balance index were observed between the experimental and control groups ($p < 0.05$). Effect sizes for gains in the experimental and control groups were strong for tibialis anterior and gastrocnemius muscles (effect sizes, 1.04 and 1.45 respectively).

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Conclusion: The Bad Ragaz Ring method may be beneficial for improving balance and leg muscle activation of chronic stroke patients.

Introduction

Thanks to the advancements made in medical technologies and increased awareness of stroke, stroke-related death rates continue to decline. However, many stroke patients suffer from physical and mental disabilities, and of these physical disabilities, balance and walking disorders are major concerns [1].

Common balance disorders include postural instability and sway [2], and walking disorders include decreased walking speed [3], hemiplegic gate pattern [4], and reduced weight shift to the affected leg. Balance and walking disorders delay the recovery of mobility and motion, and thus, increase the risk of falls [5]. Therefore, the recoveries of balance and walking abilities are important for the rehabilitation of stroke patients.

Many studies have been conducted to develop therapeutic techniques to minimize the after effects of stroke. Therapy programs depend on patient status and usually include balance training, postural awareness training, strengthening exercise, transfer activities, and gait training [6]. Of these, balance training, postural training, and motor learning intervention, proprioceptive neuromuscular facilitation (PNF), and neurodevelopment treatment (NDT) are most commonly and widely used [7].

Aquatic therapies designed to improve balance and walking abilities, have recently attracted attention, and have been suggested for the rehabilitation of stroke patients. Currently, aquatic therapy is widely used to treat chronic diseases, such as, arthritis, nerve disorders, and cerebral palsy [8], as water provides an excellent medium for healthy individuals and those with disability due to its physical characteristics of viscosity, buoyancy, density, specific gravity, and hydrostatic pressure [9]. Furthermore, when submerged in water, hydrostatic pressure promotes equal resistance to all muscle groups and increase sensory input [10]. In addition, the hydrodynamic elements of water, including metacentric effects and inertia, are essential for the maintenance and restoration of balance [11].

As balance recovery and walking abilities are essential features of the rehabilitation of stroke patients, aquatic therapy is likely to be advantageous, as is being increasingly realized. Various types of aquatic therapy, including the Halliwick Method, the Watsu method, and the Bad Ragaz Ring Method are being used to rehabilitate stroke patients. Noh et al [8] reported that aquatic therapy helped stroke patients control posture and strengthens muscles.

Florian et al [12] found aquatic therapy significantly improved the functional movements of subacute stroke patients. Montagna et al [13] found Hallwicik therapy significantly improved quality of life and balance ability in stroke patients, and Kwon et al [14] confirmed that postural sway reduced and vestibular functions improved in stroke patients that underwent Halliwick therapy underwater.

In the present study, we applied the Bad Ragaz Ring Method to patients with chronic stroke to determine its impacts on lower limb muscle activity and balance ability.

Materials and methods

Participants

Patients were recruited from the neurological physical therapy outpatient clinic of the Faculty of Physical Therapy, Eulji University Hospital in Daejeon. Patients ($n = 50$) with stroke were screened for this study from June 2015 to August 2015. The inclusion criteria were: (1) sufficient cognitive ability to follow instructions (Mini-Mental State Examination score ≥ 24) [15]; (2) mild spasticity in all joints of the affected limb (Modified Ashworth Scale score < 3) [16]; (3) no muscular—skeletal disorder or history of lower extremity surgery; (4) a higher than fair score on the Manual Muscle test [17]; (5) the ability to walk > 10 m without any assistive device, such as, a cane or walker; (6) no unilateral neglect, hemianopsia, or apraxia; and (7) no psychological or emotional problem.

The exclusion criteria were as follows: (1) participation in a drug or experimental rehabilitation project within the previous 6 months; (2) serious vision or visual perception impairment (e.g., neglect or poor visual field) [18]; and (3) the presence of a severe neuropsychologic, neuromuscular, or orthopedic disease.

Twenty-two chronic stroke patients met the study criteria. The Research Ethics Committee of Eulji University Hospital approved the study, and all participants provided informed, written consent prior to enrolment. After initial assessments, participants were randomly assigned to an experimental group ($n = 11$) or a control group ($n = 11$).

For randomisation, sealed envelopes were prepared in advance and marked inside with an A or B, indicating the experimental and control groups, respectively. The randomisation was performed by a third party totally unaware of the study content. Participant characteristics and all outcome measures before and after treatment were assessed by a physician, who was blinded to treatment allocations.

The sample size for this study was calculated using the G* Power program 3.1.0 (G power program Version 3.1, Heinrich-Heine-University Düsseldorf, Düsseldorf, Germany). Based on data from a pilot study, the estimated sample size required to obtain a minimum power of 80% at a significant alpha level of 95% was 18. Accordingly, 22 participants were recruited to account for a potential dropout rate of 20%.

The 11 participants in the experimental group received aqua therapy and conventional rehabilitation therapy for 60 minutes per day (aqua therapy 30 minutes [19], conventional rehabilitation therapy 30 minutes), with a 10-minutes rest period halfway through the 70-minutes long sessions. Participants in the experimental group received training 3 days per week for 6 weeks. Conventional rehabilitation therapy was performed using neurodevelopmental facilitation techniques. The 11 participants in the control group received conventional rehabilitation therapy for 60 minutes per day, 3 days per week for 6 weeks. All participants in each group completed 18 sessions of training.

Interventions

Aqua therapy

The Bad Ragaz Ring method was performed by a physical therapist who had completed a course on the Bad Ragaz Ring method and had > 3 years of clinical practice experience. Comprehensive rehabilitation therapy was performed by a physical therapist who had completed a course on neurodevelopment treatment and had > 3 years of clinical practice experience. Bad Ragaz Ring method body Pattern 1 and leg Patterns 1 and 2 were applied for 10 minutes during each session [20]. The method was conducted one on one with a therapist in a 2.12 m wide, 2.44 m long pool containing water at 33.33–36.67°C. The water depth was constant at 1.3 m [21]. The individual lay supine on the pool's surface wearing body ring floats between L5 and S2, neck ring floats around the neck, and ring floats around wrist and ankle joints. To ensure therapist stability, water depth was adjusted to under T8–T10 with the therapist standing. This depth was determined based on considerations of therapist safety and to ensure secure therapist foot placement when applying the Bad Ragaz ring method [20].

To expand the basal plane, the therapist positioned his feet approximately shoulder width apart in a walk stand position, with hip and knee joints slightly bent. First, trunk rotation was conducted with the individual on the pool's surface in a supine posture with neck and trunk neutrally positioned and elbow joints laid down comfortably. The therapist stood alongside the patient's head and held the patient's armpits. The patient was then asked to turn his/her trunk left and right so as to lift outer hip joints. Second, leg Pattern 1 was conducted. During Diagonal 1 and 2 flexion patterns, the therapist's hands were placed on top of the individual's feet and on the inner side of the femoral region. For Diagonal 1 and 2 extension patterns, the therapist's hands were placed below individual's feet and back-centre of the femoral region. Hip flexion, abduction, internal rotation, ankle dorsiflexion, foot eversion, and toe extension was conducted during the Diagonal 1 flexion pattern, and hip extension, adduction, external rotation, ankle plantar flexion, foot inversion, toes flexion were conducted during the Diagonal 1 extension pattern. Third, leg Pattern 2 was conducted and involved hip flexion, adduction, external rotation, ankle dorsiflexion, foot inversion, and toe extension during the Diagonal 2 flexion pattern, and hip extension, abduction, internal rotation, ankle plantar flexion, foot eversion, and toe flexion during the Diagonal 2 extension pattern. Each method was applied for 10 minutes, and thus, a total of 30 minutes was taken [19]. For the exercise method, PNF upper and lower-extremity patterns were applied only to the affected side [22].

Outcome measurements

Electromyography

To measure lower limb muscle activity, we used a four channel surface electromyography (EMG) (QEMG-4 System, LXM 3204 Laxtha, Daejeon, Korea). To reduce errors caused by repeated measurements, electrode locations were displayed with a 1-cm diameter circle, and electrodes were attached at regular intervals. To reduce errors caused by contact between electrodes and skin, hair at measuring sites was removed using a razor and measuring sites were then cleansed with medical alcohol prior to electrode attachment. Muscle activities of the lateral gastrocnemius and tibialis anterior, which greatly affect walking, were measured [23].

Surface electrodes were applied to certain regions on affected sides as follows: (1) lateral gastrocnemius: the lateral surface 2 cm below the centre line of the popliteal region; and (2) tibialis anterior: the lateral surface 2 cm lateral to the tibial line [23]. Manual muscle testing positions were used to measure muscle activities during voluntary isometric contractions. The method suggested by Hislop and Montgomery [24] was used to determine muscle locations manually. Maximum isometric contraction value of each muscle was obtained by averaging the values obtained from three repeated measurements. During maximum isometric contraction, data were obtained for 5 seconds, but values obtained during the 1st second and 5th second were excluded. For surface EMG, analogue signals were converted to digital signals using Telescan 2.89 software (Laxtha). The sample rate of surface EMG was set as 1024 Hz. A 60-Hz notch filter was used to remove unnecessary waves generated by electrical signals. Measured EMG signals were analysed using root mean square (RMS) values.

Balance index

Balance index (BI) scores were obtained using a balance measurement system (Biodex Balance Master; Biodex Medical Systems, Inc., New York, USA) equipped with a monitor, a movable force platform (providing up to 20° of surface tilt and a 360° range of motion), and a visual feedback system. BI scores reflect ability to maintain a vertical body axis within a suitable range of the balance centre of the platform tilt. A low BI score indicates excellent balance.

To evaluate balance ability, an overall index was used to quantify changes in overall movement, an anterior/posterior stability index was used to quantify changes in the sagittal plane, and a medial/lateral stability index was used to quantify changes in the frontal plane.

BI scores have been shown to have strong internal consistency and acceptable intrarater ($r = 0.82$) and interrater ($r = 0.70$) reliabilities [25].

Timed Up and Go test

The Timed Up and Go test is commonly used as a clinical outcome measure to assess walking and functional abilities in elderly people. It measures the time taken by an individual to stand up from a standard-height chair with arm rests, walk a distance of 3 m (with an assistive device, if needed), turn around, walk back to the chair, and sit down again. The Timed Up and Go test has excellent intrarater ($r = 0.99$) and interrater ($r = 0.99$) reliabilities [26].

Statistical analysis

An intention to treat analysis was performed by using SPSS 20.0 software (SPSS Inc., Chicago, IL, USA). Shapiro—Wilk test were completed to assess whether the dependent variable confirmed to a normal distribution. The results of the Shapiro—Wilk test indeed suggested that the dependent variable was normally distributed ($p > 0.05$). An independent *t* test was used to compare the client characteristics for continuous data (e.g., height, weight, age) and the Chi-square test was used to compare the categorical data (e.g., the proportion of men and women).

Intragroup comparisons of gait before and after training were performed using the paired samples *t* test, and intergroup comparisons of pre- and posttest differences in gait were performed using the independent *t* test.

Results

A flow diagram of the study is provided in Figure 1. Table 1 provides a summary of the clinical and demographic features of the study participants ($n = 22$), and shows that no significant differences were observed between the baseline characteristics of the experimental and control groups ($p > 0.05$). Twenty-two participants (experimental group = 11, control group = 11) completed the study. The characteristics of the two groups ($n = 22$) before and after intervention are summarized in Table 2.

The experimental group showed significant improvements in the activations of tibialis anterior and gastrocnemius muscles, balance index, and Timed Up and Go test results after intervention ($p < 0.05$), whereas the control group showed significant improvement in Timed Up and Go test results only ($p < 0.05$). Significant differences in

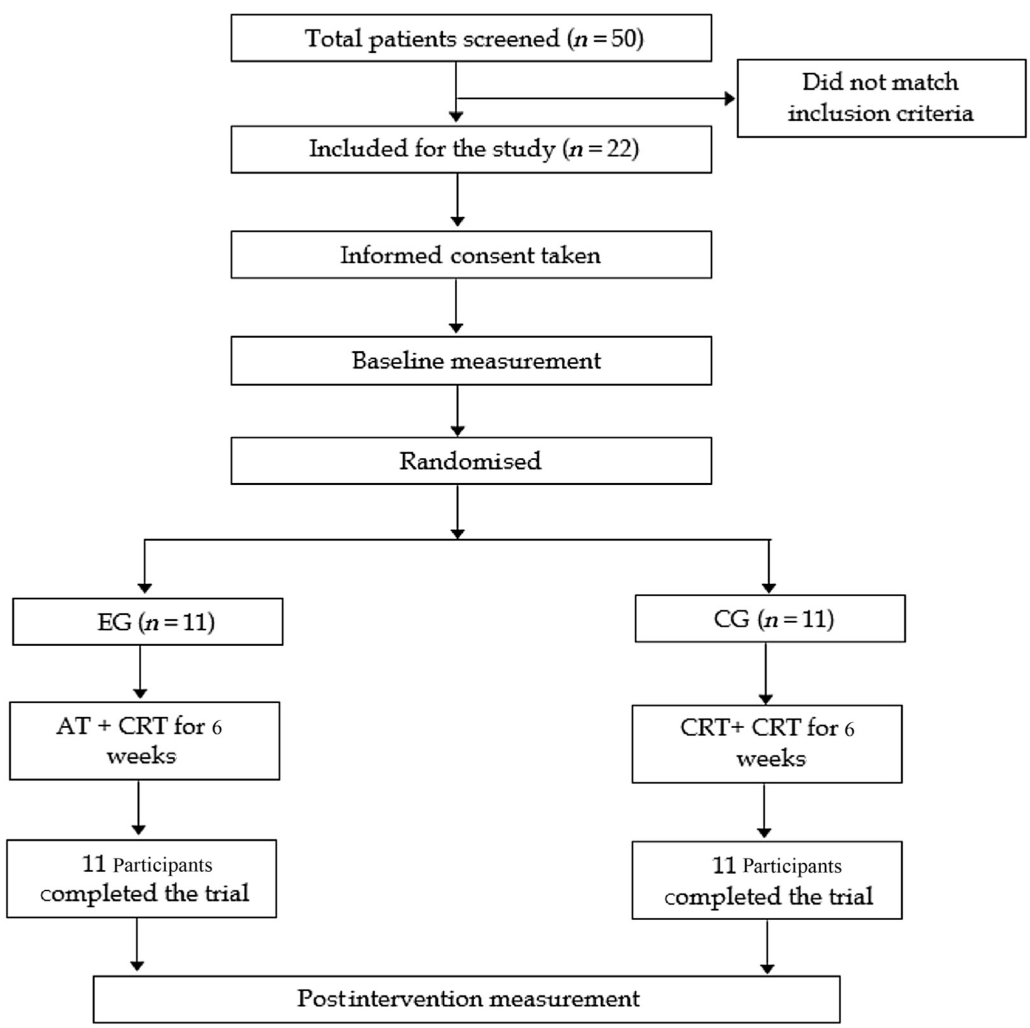

Figure 1. Study flowchart. AT = aqua therapy; CG = control group; CRT = comprehensive rehabilitation therapy; EG = experimental group.

Table 1 General characteristics of the study participants (n =22).

Characteristics	EG (n = 11)	CG (n = 11)
Age (y)	64.0 (12.1)	63.3 (12.1)
Height (cm)	162.8 (6.9)	157.7 (5.9)
Weight (kg)	65.1 (9.7)	63.0 (6.8)
Time since onset (mo)	16.6 (4.0)	18.9 (5.1)
MMSE (score)	25.8 (1.8)	26.4 (1.7)
Gender (male/female)	6/5	7/4
Type of stroke (Ischemia/haemorrhage)	7/4	9/2

Values are expressed as means (SDs).
CG = control group; EG = experimental group; MMSE = mini-mental state examination; SD = standard deviation.

posttraining gains in the activations of tibialis anterior and gastrocnemius muscles and balance index were observed between the experimental and control groups ($p < 0.05$).

Effect sizes for gains in the experimental and control groups were strong for tibialis anterior and gastrocnemius muscles (effect sizes = 1.04, 1.45 respectively).

Discussion

This study confirmed that the Bad Ragaz Ring method significantly improved lower limb muscle activities and dynamic and static balance in patients with chronic stroke. Effect sizes for gains in this study were strong for tibialis anterior and gastrocnemius muscles in the experimental group.

This result supports the primary hypothesis of the study that Bad Ragaz Ring method was performed underwater, buoyancy acted as resistance, and as a result, muscle activation was increased in the experimental group. The reason for the increase in balance index score in the experimental group is that when the Bad Ragaz Ring Method was applied underwater, muscle activation and proprioception for maintaining balance and stabilizing the trunk were enhanced. Therefore, the Bad Ragaz Ring Method is considered to be a method that can clinically improve the leg strength and balance ability of stroke patients without putting an excessive joint load on the joint.

Mehdi et al [27] reported that aquatic exercise therapy can be a useful method to improve muscle strength and range of motion in hemophilia patients. Han et al [28] confirmed that the 10 weeks of aquatic therapy exercise can enhance low back muscle strength and reduce low back pain in elderly women.

Muscle activities of the lateral gastrocnemius and tibialis anterior, which greatly affect walking, were measured. The reason for measuring these two muscles is that during standing and walking, the ankle joint plays an important role in maintaining correct balance, and thus, increasing diminished muscle strengths of gastrocnemius and tibialis anterior, which are involved in plantar flexion and dorsiflexion of the ankle joint, provides a means of improving walking and balance abilities. DasSarma et al [29] reported disabilities of the arm, shoulder, and hand (DASH) scores decreased among patients with rotator cuff impingement after 3 weeks of aquatic therapy using the Bad Ragaz Ring Method, and that aquatic therapy significantly improved painless range of motion. Furthermore, John et al [19] confirmed that gross motor function measure (GMFM) total scores improved among children with cerebral palsy after 20 weeks of aquatic therapy using the Bad Ragaz Ring method.

Park et al [30] reported that muscle activity and walking ability improved significantly among stroke patients treated using the Halliwick Method, the Watsu Method, or a trunk exercise program underwater. Park et al [21] compared a land exercise group and an aquatic exercise group and reported that in stroke patients static balance improved significantly more in the aquatic group.

The above-mentioned findings and those of the present study show aquatic therapy can have positive impacts on muscle activity and balance ability in chronic stroke. Furthermore, water reduces joint load, and thus, offers an effective exercise tool for elderly stroke patients who commonly have concurrent joint conditions. In addition, the buoyancy of water reduces physical demands made of therapists during exercise and helps stroke patients move independently and encourages active participation [31]. In addition, aqua therapy allows safe, comfortable, and active movements and prevents falls, which are all too common during land-based exercises.

The Timed Up and Go test can be categorized into four levels of mobility, according to the time taken to complete the test: (1) normal mobility (< 10 seconds); (2) good mobility (< 20 seconds, can go out alone or is mobile without walking aids); (3) limited mobility (< 30 seconds, cannot go outside alone or requires walking aids); and (4)

Table 2 Postintervention changes in the characteristics of the experimental and control groups.

	EG (n = 11)			CG (n = 11)			p	Effect size
	Pretest	Posttest	CWG	Pretest	Posttest	CWG		
TA (μV)[a, b]	58.91 (15.74)	80.82 (14.03)	21.91 (24.66)	60.82 (18.59)	63.91 (18.11)	3.09 (10.44)	0.036	1.04
GN (μV)[a,b]	75.55 (12.27)	96.73 (9.96)	21.18 (12.19)	76.18 (12.38)	84.91 (5.66)	8.73 (12.55)	0.029	1.45
BI(score)[a]	6.45 (1.04)	2.64 (1.85)	−3.82 (1.82)	5.82 (1.17)	4.82 (1.47)	−1.00 (2.00)	0.002	−1.47
TUG (Sec)	34.18 (2.79)	25.64 (5.70)	−8.55 (7.45)	32.45 (7.46)	26.36 (4.41)	−6.09 (6.35)	0.415	−0.35

Values are expressed as means (SDs).
BI = balance index; CG = control group; CWG = changes within groups; EG = experimental group; GN = gastrocnemius; TA = tibialis anterior; TUG = Timed Up and Go test.
[a] Significant intergroup difference in intervention-induced gains, $p < 0.05$.
[b] Effect size > 0.70.

dependent mobility (> 30 seconds, dependent for most activities of daily living and mobility skills) [32,33]. In general, a score of ≥ 15 seconds has been recognized to indicate high risk of falls [33].

Even though both experiment and control group showed an increase in TUG scores, mean values in both groups were < 30 seconds, which means limited mobility.

Water effectively provides support and resistance, and when turbulent, pressurized, or heated/cooled increases motor and sensory perceptions. In particular, the support offered by water aids the achievement of full active range of motion [34], which is an important factor for proper balance control, and increases motor, sensory, proprioception, and vestibular simulation [35].

During the course of this study, it was evident that the efforts made by patients to maintain posture in water helped strengthen lower extremity muscles, and thus, contributed to improvements in balance ability [36], and that time spent in water during exercise body improves the effectiveness of rehabilitation [37].

In our opinion the therapeutic concepts and goals of the Bad Ragaz Ring method produced significant results in this study. The technique utilizes a modified PNF pattern while the patient floats on water, and has treatment goals that include muscle tone improvement, muscle reeducation, and muscle strengthening and elongation [38]. Due to the buoyancy of water and the manual resistance applied by a therapist, we believe the Bad Ragaz Ring method would be beneficial for isotonic and isometric muscle contraction exercises [31].

Some limitations of this study warrant consideration: (1) the sample size was small, which makes it difficult to generalize; and (2) the absence of follow-up after intervention did not allow the durability of the effects of therapy to be determined. Accordingly, further larger-scale studies with long-term follow-up are required.

Conclusion

We conclude that the Bad Ragaz Ring method may be beneficial for improving balance and muscle activation in chronic stroke patients.

Conflicts of interest

The authors have no conflict of interest to declare.

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Authors' contributions

Hyun-Gyu Cha - primary author, experimental procedure.

Young-Jun Shin - manuscript writing, critical discussion, interpretation of the results.

Myoung-Kwon Kim - corresponding author, management of the study.

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