의학석사 학위논문

Development of Body Function Evaluation Tool for Aquatic Rehabilitation Therapy

아쿠아 재활치료를 위한 신체기능평가도구 개발

2018년 8월

서울대학교 대학원
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와물완개 리에토

A Thesis of Master’s Degree

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Development of Body Function Evaluation Tool for Aquatic Rehabilitation Therapy

by

Wamulwange Lieto

A thesis submitted to the Department of Medicine in partial fulfillment of the requirements for the Degree of Master of Science at Seoul National University College of Medicine

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Approved by Thesis Committee:

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ABSTRACT

Introduction: Aquatic rehabilitation therapy is proving to be one of the modalities of choice for neurologic, orthopedic and other conditions. By means of the biophysical properties of water such as buoyancy, hydrostatic pressure, viscosity and cohesion, the effects of reduced joint loading, prevention of venous stasis and muscle strengthening can be obtained in the pool. In order to know whether the body function in the water can be converted to the body function on the ground, an evaluation tool for the body function in the water is needed. However, there have been few commonly accepted body function evaluation tools for aquatic rehabilitation therapy. The aims of this study were to develop an evaluation tool for aquatic rehabilitation therapy and to investigate correlations between the newly developed tool and the on land body function scores such as Modified Bartel Index (MBI) and Medical Research Council (MRC) sum score.

Methods: Patients with hemiplegia (traumatic brain injury and stroke) and spine injuries (spinal cord injury and spine fractures) treated at Labor Welfare Corporation Incheon Hospital from January 2012 to May 2017 were retrogressively recruited. Their data on aquatic performance, manual muscle testing (MMT), and MBI were recorded for analysis. The scores of MMT were transformed into MRC sum score. In order to develop a body function evaluation tool for aquatic rehabilitation therapy, the 16 items related to swimming in the existing aqua evaluation tool were removed. The Exploratory Factor Analysis was used to categorize the remaining 21 items from the existing aqua evaluation tool. Spearmann's correlation analyses between the developed evaluation tool and modified Bartel index as well as MRC sum score were conducted to compare underwater and on the ground body function.

Results - Data for 95 patients (F = 10; M = 85) was included in this study. 25 Patients presented with brain lesion and 70 patients presented with Spinal injuries.

Mean age of all the patients was 53.4years, with the youngest being 27 and the oldest being 73years old.

A body function evaluation tool for aquatic rehabilitation therapy which consists of 21 items was newly developed. Three categories of the assessment tool were identified. The three categories were related to altering the center of gravity, basic functional activity, and progressive basic functional activity. These activities were rated at four levels from zero to three. The sum of the scores in the developed evaluation tool showed a strong correlation with the sum of the MBI ($r = 0.636$, $p = 0.000$). The sum of the developed scales was also correlated with the MRC sum score ($p = 0.01$). However, the strength of the correlation was weaker than that of MBI score ($r = 0.298$).

Conclusion: The evaluation tool developed in this study could be used not only to record the progress of aquatic rehabilitation therapy but also to study that the improvement of physical function in water which can be transformed into improvement of physical function on the ground.

Key Words: aquatic therapy, halliwick, physical function, evaluation

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INTRODUCTION

The *Aquatic Therapy Association of Chartered Physiotherapists (ATACP,* United Kingdom) defines aquatic physical therapy as: "A therapy program utilizing the properties of water, designed by a suitably qualified physiotherapist specifically for an individual to improve function, carried out by appropriately trained personnel, ideally in a purpose built, and suitably heated hydrotherapy pool." (1) It includes but is not limited to treatment, rehabilitation, prevention, health, wellness, and fitness. It may or may not include the use of assistive, adaptive, orthotic, protective, or supportive devices and equipment. A wide patient/client population, ranging from infants to the elderly, can benefit from safe and effective physical therapy intervention in the aquatic environment, addressing neurologic, orthopedic, and other conditions (2). Aquatic Therapy is also used by Occupational therapists, chiropractors, therapeutic recreational specialists and athletic trainers. As a result of this wide use of aquatic therapy, several other names such as aquatic exercise therapy, aquatic rehabilitation, pool therapy, and hydrotherapy are being used rather than aquatic therapy.

Properties of Water

There are four identified biophysical properties of water that impact its use in rehabilitation:

i. Buoyancy and the principle of Archimedes. When a body is immersed in water, it experiences an upward thrust that is equal to its weight. This is the property of buoyancy known as Archimedes' principle. It decreases gravity, which in turn causes weightlessness that allows reduction in joint compression forces. As a result of this, a pain-free mobility is achieved and the patient is able to perform pain-free activities or at least with lower levels of pain. Buoyancy can also be used to challenge patients who have postural deficits.

ii. Hydrostatic pressure and Pascal's law. When a body is immersed in water, there is pressure exerted by the fluid upon the tissue, called hydrostatic pressure. This pressure can vary due to either the density of the fluid and/or depth of immersion. There is more pressure on the tissue when the density of the fluid is high and when the body is immersed deep in water. The clinical effect of this property is to prevent venous stasis in cases of venous insufficiency. It can also be used in re-education of breathing patterns for patients with weak primary respiratory musculature.

iii. Viscosity, Cohesion, and the Application of Bernoulli's Law. Bernoulli's law addresses viscosity, which is the density of the water and its effect on a body as it moves through the liquid, and Cohesion, which is the gathering of molecules to form a liquid. The law establishes a relationship between the fluid friction and the velocity of the movement of the body. Thus, these two properties can be used for muscle strengthening and gait training.

iv. Bougier's Theorem and the Concept of the Metacenter. The metacenter is the center of buoyancy which is located at T11 level. When metacenter is directly above the center of gravity, S2 level, the body is in a state of equilibrium in the water. This determines the stability of the body in water and is called Bougier's Theorem (3)

In the RCTs where aquatic therapy compared with other groups (e.g. vs. conventional or on-land therapies), it was shown that these physical properties of hydrodynamics benefit mobility in people with disabilities (4). These four main properties are vital in the benefits of Aquatic therapy.

Aquatic Therapy Techniques

Water acts as a unique medium, allowing for weight-bearing exercise without stressing the joints, for movement and stability drills without the fear of falling, and for multi-directional resistance training without the need for free weights or bands. Aquatic therapy for general rehabilitation purposes and for special populations, is commonly performed in a warm (above 30◦C), shallow (chest-deep) pool and may involve a variety of exercise modalities including aerobic, stretching/range of motion (ROM), resistance, and stability training (5). At Labor Welfare Corporation Incheon Hospital in Seoul, two aquatic therapy techniques are used. These are: Halliwick/Water Specific Therapy (WST) and Bad Raggaz Ring Method (BRRM).

Halliwick

The concept of water education was first introduced in 1952, by the Association of Swimming Therapy in the United Kingdom, when James McMillan (1913 - 1994) trained Halliwick School for Crippled Girl pupils in order to integrate them with the local community in Southgate, London (6).This gave birth to the Halliwick concept which is an approach to teaching people with physical and/or learning difficulties to participate in water activities; to move independently in water, and to swim (7). The practice utilizes a Ten Point Program. The key concepts in the ten point program include Mental Adjustment (MA), Balance in Control (BC), and Movement (M) with functional activities scattered throughout these stages. It is used to reach the goals of motor learning, and eventually leads to independence in the water. The Halliwick's Ten-point-program includes Possibilities and constraints of the client that are analyzed. It is also developed to include a systematic intervention, Water Specific Therapy (WST) which is focused on treating impairments of body functions or body structure to help the client increase function, independence and participation (6, 8, 9, 10 & 11).

Bad Ragaz

This technique originated in Germany in 1957 and was introduced by a German therapist to the therapeutic thermal pools of Bad Ragaz in Switzerland. The technique has since become more clearly defined as the Bad Ragaz Ring Method (BRRM). It involves a stabilization component provided by three floatation rings at the neck, pelvis and ankles (3). Bad Ragaz is a method of muscle re-education using specific patterns of resistance, endurance, elongation, relaxation, range of motion, and tonal reduction.

The other commonly used aquatic techniques worldwide include:

Watsu

Developed by Harold Dull, Watsu (water + shiatsu) is a cradling, one-on-one program that is utilised in a very warm (approx. 94^{0}F degrees) pool. The client is held in the water by the practitioner and moved using the water to massage the body. Shiatsu (acupressure) points are stimulated along the meridians of the body during the massage. Watsu is used for pain reduction, increased range of motion, increased circulation, easing psychological problems, relaxation, and reduction of stress. It has been used in rehabilitation programs for people with orthopedic problems or physical disabilities, for pregnant mothers, and the elderly.

Ai Chi

Created by Jun Konno of Japan. Ai Chi is performed standing in shoulder-depth water in group classes, one-on-one therapy sessions, or individually. Ai Chi is a combination of deep, simple breathing techniques and slow broad movements in a progression from the upper extremities, trunk, lower extremities, and finally to involvement of the full torso, with a gradual narrowing of the base of support using concepts of T'ai Chi, Shiatsu, and Qigong. It consists of 19 movements or katas, performed while breathing at a rate of about 14-16 breaths per minute.

Aquatic Therapy Evaluation

Generally, the Aquatic Exercise Review of System (AERS) (12), the International Classification of Function (ICF) and Diagnostic Aquatics Systems Integration Theory (DASI) (3) are used on land to evaluate patients before aquatic therapy. The **Aquatic performance evaluation tool** (Appendix 1), which has been revised to Water Assessment Test Alyn (WOTA), is used to assess the Halliwick Ten-Point skills (13). It is used to assess patient safety only in the pool, for the preparatory stage of treatment in water, as well as consequent re-evaluation of patient's functional activities in water. It includes items such as: Dipping a face in water and foaming/bubbling, swimming, and use of snorkels and fins that are not related to on-land activities. This tool is a widely used assessment tool in domestic aqua treatment and is used as a basic underwater activity evaluation tool before applying various aqua treatment techniques- like Bad Ragaz, Ai chi, etc- internationally. Tirosh et al. (14, 15) showed high test-retest reliability (ICC = .97) of WOTA among 33 disabled children, but the correlation with activity on the ground such as Gross Motor Function Measure (GMFM) was moderate (r = .60). The limitation of activity on the ground and the limitation of activity in water are similar, but explained that there are other aspects.

STATEMENT OF THE PROBLEM

In many research studies being done comparing aquatic therapy and land based therapy, aquatic therapy shows its significance. It has been shown that the Aquatic treatment is superior to general rehabilitation treatment (5). In previous studies, there were various treatment techniques applied to each study in order to evaluate their application on land, when such techniques are used for strength and gait training in water (16, 17). Limitation in these studies is that they have not been able to relate specific activities, in water, that have direct benefits on land. Safety in water does not correlate to functional ability on land. It is believed that repeated activity in the pool eventually leads to functional ability on land. However, there is no single assessment tool that can be used to evaluate the functional ability in the pool and on land. Therefore, evaluation of functional effectiveness of aquatic therapy patients before and after therapy requires more attention.

Purpose of the study

It is important to find out how any therapy and training performed in the water can be successful when transitioning to land and for function in daily life. In clinical practice, it is practical to achieve the maximum rehabilitation effect by determining the appropriate type of aqua treatment technique to be applied to the patient. The important reason for this difficulty has been the lack of a validated assessment tool for physical activity in the water, which could be compared with physical function on land. The purpose of this study, therefore, was to evaluate the validity of the questionnaire of the Halliwick based Aquatic performance evaluation tool which has been in use, and to develop a tool that can be used to evaluate the body function in water. These body functional activities in water must be directly related to functional activity on land. Therefore, another purpose of the study was to investigate whether the scores of the developed body functions evaluation tool in water correlated with physical functions on the ground.

METHODS

This was a retrospective analysis performed on records of patients at Labor Welfare Corporation Incheon Hospital. Data was collected from the hospital's database of the Electronic Medical System (EMS). The Institutional Review Board (IRB) reviewed and approved the study. This procedure was necessary because the study was conducted using human subjects. There was, however no need for informed concert. According to Bellary, Krishnankutty and Lantha (18), a Case Report Form (CRF) is used in order to help to preserve, maintain and improve the integrity of data quality. Data should be organized in a format that facilitates and simplifies data analysis. A CRF was used to organize data that was specific and relevant to the study. Records for patient's functional evaluation using three assessment tools, i.e. Halliwick Aquatic Performance Evaluation tool, commonly referred to as WOTA (Water Orientation Test Alyn), Manual Muscle Testing (MMT), Modified Barthel Index (MBI) were analyzed. One evaluation of each tool for each patient was used.

Records of 420 patients treated with Aquatic Therapy (AT) were collected. The records were from the inception of AT at the Hospital in 2008. However, only data from January 2012 to May 2017 could be used in the study. Either diagnosis was not clearly indicated, or evaluation and follow-up record was absent in 275. Aquatic performance evaluation was missing in 50 of the records. This may be, in part, because the Electronic Medical System was only introduced in 2014. Before then, patient records were hand-written and were hard to retrieve.

The records were for patients who presented with any of the following neurological conditions: Hemiplegia [Traumatic Brain Injury (TBI), Hemorrhagic and Ischemic stroke], Spine Injuries [Spinal Cord Injury (SCI) at various levels and Cauda Equine Syndrome (CES)].

Aquatic Performance Evaluation Tool /WOTA

WOTA is used to assess swimming and function in the pool. During this study, the items on the Halliwick's Aquatic performance evaluation tool were divided into two, namely:

1. **Swimming** (or items not relevant to functional activities) and these included - mouth bubble, Nose bubble, Head underwater blowing, Rhythmic exhalation (with mouth), and exhalation alternately through mouth and nose. Float up, gliding supine, and glide prone. Swimming supine, swimming prone, water over the head and moving around using equipment (mask or goggles, Snorkel, fins, floating, and other).
2. **Functional activities** which included - shifting center of gravity forward/backward, shifting center of gravity left/ right, sitting down, standing up, lying down, sitting up, rolling over right/ left, and turning and glide/ with sagittal rotation control (SRC) or transverse rotation control (TRC). Stand, sit, supine/ oblique. Walking, changing direction, turning 360, jumping, entry and exit. Legs pushing, kicking, arms pushing, pulling, arms reaching, hands passing an object. Transport objects. These components are based on an internationally recognized Halliwick-ICF evaluation form (7). Some of these functional activity items are explained in Appendix 2.

The swimming components of the evaluation tool were removed from the assessment form. The purpose for doing this was to isolate the functional activity components in the pool that can relate to functional activity on land. The Exploratory Factor Analysis (EFA) was used to analyze this data. These items are scored on a 5 points (x, 0 ~ 3 points) scale as follows:

x. Cannot be assessed due to physical disability

0. Does not perform or seems capable but does not cooperate

1. Performs a task with the instructor's full support

2. Performs a task with the instructor's partial support

3. Independent, performs a task without the instructor's support

Manual Muscle Test (MMT)

Manual Muscle Testing (MMT) evaluates muscle strength of the affected limbs. MMT is a procedure for the evaluation of the function and strength of individual muscles and muscle groups based on the effective performance of a movement in relation to the forces of gravity and manual resistance (19). The grades of 0, 1, and 2 are tested in the gravity-minimized position (contraction is perpendicular to the gravitational force). The grades obtained with MMT are largely subjective and depend on a number of factors including the effect of gravity, the manual force used by the clinician, the patient's age, the extent of the injury, and cognitive and emotional factors of both patient and clinician (20, 21)

The grades obtained from MMT were transformed to Medical Research Council Sum Score (MRC Sum Score). The score is the sum of the MRC score of 6 muscles (3 at the upper and 3 at the lower limbs) on both sides, each muscle graded from 0 to 5. The following muscles are examined: Deltoid, Biceps, Wrist extensor, Iliopsoas, Quadriceps femoris, and Tibialis anterior (22). In this study, muscle strength of six leg muscles was obtained by adding both sides of muscle force measurement values of three leg muscles. Therefore, the total MRC sum score ranges from 0 (total paralysis) to 30 (normal strength)

Modified Barthel Index (MBI)

This is an ordinal scale that is used to measure performance in activities of daily living (ADL). Each performance item is rated on this scale with a given number of points assigned to each level or ranking (23). In MBI, 3 components were analyzed. The names of components and grading are as follows:

i. **Ambulation**,

0. Dependent in ambulation
3. Constant presence of one or more assistant is required during ambulation.
8. Assistance is required with reaching aids and/or their manipulation. One person is required to offer assistance.
12. The patient is independent in ambulation but unable to walk 50 meters without help, or supervision is needed for confidence or safety in hazardous situations.
15. The patient must be able to wear braces if required, lock and unlock these braces, assume standing position, sit down, and place the necessary aids into position for use. The patient must be able to use crutches, canes, or a walkarette, and walk 50 meters without help or supervision.

ii. **Stair climbing**

0. The patient is unable to climb stairs.
2. Assistance is required in all aspects of stair climbing, including assistance with walking aids.
5. The patient is able to ascend/descend but is unable to carry walking aids and needs supervision and assistance.
8. Generally no assistance is required. At times supervision is required for safety due to morning stiffness, shortness of breath, etc.
10. The patient is able to go up and down a flight of stairs safely without help or supervision. The patient is able to use hand rails, cane or

crutches when needed and is able to carry these devices as he/she ascends or descends.

iii. **Transfer**

0. Unable to participate in a transfer. Two attendants are required to transfer the patient with or without a mechanical device.
3. Able to participate but maximum assistance of one other person is required in all aspects of the transfer.
8. The transfer requires the assistance of one other person. Assistance may be required in any aspect of the transfer.
12. The presence of another person is required either as a confidence measure, or to provide supervision for safety.
15. The patient can safely approach the bed walking or in a wheelchair, lock brakes, lift footrests, or position walking aid, move safely to bed, lie down, come to a sitting position on the side of the bed, change the position of the wheelchair, transfer back into it safely and/or grasp aid and stand. The patient must be independent in all phases of this activity (24).

Analysis

Several items that are related to swimming activities were deleted from the WOTA evaluation form because these items were not related to functional activities. As can be seen on Appendix 1, these items are from three (3) groups: i. Respiratory function, ii. Moving around, walking and transferring one self, and iii. Moving around using equipment. With the remaining items, data was analysed using factor analysis. The remaining twenty one items were analysed.

In order to explore the structure of the latent variable inherent in the data, an Exploratory Factor Analysis (EFA) was carried out.

The developed body function evaluation tool for aqua therapy was then analyzed for functional correlation with on land assessment tools –MRC sum score and MBI using Spearman’s Correlation Analysis (25).

RESULTS

Records of 420 patients treated with Aquatic Therapy (AT) were collected. However, because of the missing vital information, only data from January, 2012 to May, 2017 was used. Diagnosis was not clearly indicated, or evaluation and follow-up record was absent in 275 of the records. Aquatic performance evaluation was missing in 50 records.

Therefore, out of 420 patient records, only 95 patients were included in this study.

Subject characteristics

Twenty six (26) Patients presented with brain lesion [19 traumatic brain injury, 6 hemorrhagic stroke, and 1 ischemic stroke] and 69 patients presented with spine injuries (4 spinal cord injury, 59 spine fractures with peripheral nerve injury, and 6 cauda equine syndrome). Sixteen among spinal injury patients had multiple injuries; 1 traumatic brain injury with spine fracture, 8 limb/rib/skull fracture with spine fracture, 12 multilevel spine fractures. Mean age of all the patients was 53.4 years, with the youngest being 27 years old and the oldest being 73 years old. Table 1 shows the distribution of subject characteristics.

Traumatic Brain Injury (TBI)

TBI is characterized as “An alteration in brain function, or other evidence of brain pathology, caused by an external force” (26) and is present in all societies (27). TBI occurrence peaks during both youth and later life, and is one of the most common causes of morbidity and mortality of young adults less than 45 years of age (28). Brain injuries can range in scope from mild to severe and result in permanent neurobiological damage that can produce lifelong deficits to varying degrees. Moderate brain injury results in a loss of consciousness from 20 minutes to 6 hours and a Glasgow Coma Scale of 9 to 12. Severe brain injuries typically refer to injuries that result in a loss of consciousness of greater than 6 hours and a Glasgow Coma Scale of 3 to 8. The impact of a moderate to severe brain injury depends on: The severity of an initial injury, rate/completeness of physiological recovery, functions affected, meaning of dysfunction to the individual, resources available to aid recovery, and areas of function not affected by TBI. TBI can affect or cause the following problems cognitive deficits, speech and language, sensory, perceptual, vision, hearing, smell, taste, seizures, physical changes and social-emotional effects. The physical disability of a TBI patient leads not only to a burden on the health care system but more importantly, functional impairments impeding quality of life (29, 30, 31). TBI can also lead to outcomes of physical inactivity such as obesity, diabetes, and heart disease (32, 33, 34, and 35).

Hemorrhagic and Ischemic Stroke

Stroke is one of the most common causes of morbidity and mortality in the developed and the developing world (36). There are two major stroke subtypes, ischemic and hemorrhagic stroke. Hemorrhagic strokes are relatively uncommon compared with ischemic strokes. Actually, hemorrhagic strokes account for only 15% of all stroked compared to the 40% of all stroke deaths that are attributable to hemorrhagic strokes. The commonest of the hemorrhagic types is the subarachnoid hemorrhage (SAH), followed by intraventricular hemorrhage (IVH) and then intracerebral hemorrhage (ICH) - subtype. The definition of stroke is “rapidly developing clinical signs of focal disturbance of cerebral function, with symptoms lasting 24 hours or longer or leading to death, with no apparent cause other than of vascular origin," by WHO (The World Health Organization). Stroke can happen to any person at any time. It happens because of poor blood flow to an area of the brain, and brain cells begin to die because of lack of oxygen. Abilities such as memory and muscle control controlled by that area of the brain are damaged. The common causes of hemorrhagic strokes include arteriolar hypertensive diseases, burst aneurysm, arteriovenous malformation (AVM), bleeding disorders, head injury, and blood thinners. In addition to this, some clinical scientists find that hemorrhagic strokes sometimes occur after spine and joint surgeries. Although postoperative stroke rarely happens, it may cause severe consequences and high mortality rates.

In this study, for the 26 patients who had TBI, Hemorrhagic or ischemic stroke were additionally evaluated with three items of MBI out of the 11 MBI items. These items included ambulation, stair climbing and transfer. The lowest score was 16/100 while the mean average score was 74.6.

Spinal Cord Injury (SCI)

SCI is an insult to the spinal cord resulting in a change, either temporary or permanent, in the cord's normal motor, sensory, or autonomic function. Signs and symptoms of SCI may present immediately or some symptoms may be delayed as swelling and bleeding occur in or around the injured area (37). One or more of the following symptoms may occur:

- Pain and numbness, or burning sensation
- Inability to move the extremities or walk
- Inability to feel pressure, heat, or cold
- Muscle spasms

- Loss of bladder or bowel control
- Difficulty breathing

Specific regions of the spine may present signs and symptoms as follows:

1. ***Cervical*** **(C1-C8)** - Damage to the spinal cord in the cervical spine is considered the most severe because it can be life-threatening. Symptoms of cervical spinal cord damage may affect the arms, legs, trunk, and even the ability to breathe. The higher up in the cervical spine the damage occurs, the worse the injury. Symptoms may be felt on one or both sides of the body.
2. ***Thoracic*** **(T1-T12)** - Damage to the spinal cord in the thoracic spine typically affects the legs. Thoracic spinal cord damage high up in the area may affect blood pressure.
3. ***Lumbar*** **(L1-L5)** - Damage to the spinal cord in the lumbar spine typically affects one or both legs. Patients with lumbar spinal cord damage may also have trouble controlling their bladder and/or bowel

The sacral spine does not contain spinal cord tissue. Consequently, though there may be damage to the sacral vertebrae or nerves and not to the cord at that level.

Patients with SCI usually have permanent and often devastating neurologic deficits and disability. The extent of injury is defined by the American Spinal Injury Association (ASIA) Impairment Scale (modified from the Frankel classification), using the following categories:

A = Complete: No sensory or motor function is preserved in sacral segments S4-S5

B = Incomplete: Sensory, but not motor function is preserved below the neurologic level and extends through sacral segments S4-S5

C = Incomplete: Motor function is preserved below the neurologic level, and most key muscles below the neurologic level have a muscle grade of less than 3

D = Incomplete: Motor function is preserved below the neurologic level, and most key muscles below the neurologic level have a muscle grade that is greater than or equal to 3

E = Normal: Sensory and motor functions are normal

The most important aspect of clinical care for the SCI patient is preventing complications related to disability (38).

Cauda Equina Syndrome (CES)

Cauda Equina Syndrome is an uncommon compression of the nerves at the end of the spinal cord within the spinal canal. The term Cauda equina literally means “tail of horse” and refers to the normal anatomy of the end of the spinal cord in the low back where it divides into many bundles of nerve tracts resembling a horse’s tail. Compression of the spinal cord at this level can lead to typical symptoms that include: Low back pain, sciatica, paraparesis, and bladder and/or bowels incontinence. Causes of Cauda Equina Syndrome include herniation of lumbar intervertebral discs, tumor/cancer adjacent to the lower spinal cord, localized infection near the spinal cord (epidural abscess, and localized bleeding (epidural hematoma) causing pressure on the spinal cord in the low back (39, 40 and 41).

Four participants were diagnosed with SCI, one with thoracic spine injury with ASIA- C and three with cervical spine injuries with ASIA- D.

The majority of participants had spinal fractures. There are many different types of spinal fractures: Compression, Burst, Flexion-distraction, and Fracture-dislocation. Other terms used to describe a fracture include stable, unstable, minor, and/or major. Spinal fractures can affect the other parts of the spine - the nerves, spinal cord, and ligaments. All patients showed some weakness in the affected limbs as shown by the Manual Muscle Test evaluation records.

Table 1. Baseline Characteristics of Participants

	TBI	Ischemic Stroke	Hemorrhagic Stroke	SCI	Spine#	CES	Total
Gender							
Male	17	1	5	4	52	6	85
Female	2	0	1	0	7	0	10
Average Months from onset	4.5 months to first Aqua Evaluation – The earliest was 1month and latest was 12 months						
Mean Age (Years)	53.4+/- 23 - The youngest was 27years old, while the oldest was 73years old.						

Exploratory Factor Analysis (EFA)

In order to explore the number of the factors inherent in the data, the eigenvalues and the proportions of the variances that are explained were calculated as in Table 2. Firstly, as a result of creating the random data with the 21 questions and the 97 subjects, in the same way as this datum, it was able to confirm that the eigenvalue turns around in the 5^{th} factor. As a result, it can be considered that the number of the factors that are possible can be the maximum of 4. If we take a look at the eigenvalues, the clear changes appeared between number 1 and number 2 and between number 2 and number 3. And we can't find out that the differences relatively appeared between number 3 and number 4 and between number 4 and number 5. This can be confirmed through the screen chart in Fig.1, too. As a result, we assumed that the number of the factors will be three (3) based on the eigenvalue.

Table 3 presents the factor loadings of the structures of the three factors. Ordinarily, it is recommended that the size of the factor loading should be 0.4 or bigger. The items: Rolling and turnings appear in factors 1 and 2, but they are recorded under factor 1 because of the higher loading in factor. Supine/oblique also is moved for the same reason (42).

Table 2. Eigenvalues and Variance Explained for Each Factor (First 10 Factors)

Number	Eigenvalue	Difference	Variance explained	Cumulative Variance Explained	Random Eigenvalue
1	13.878	10.443	0.661	0.661	1.179
2	3.435	2.096	0.164	0.824	0.950
3	1.339	0.554	0.064	0.888	0.824
4	0.785	0.0277	0.037	0.926	0.728
5	0.508	0.130	0.024	0.950	0.617
6	0.378	0.121	0.018	0.968	0.535
7	0.257	0.073	0.012	0.980	0.454
8	0.184	0.035	0.009	0.989	0.366
9	0.149	0.024	0.007	0.996	0.287
10	0.125	0.036	0.006	1.002	0.196

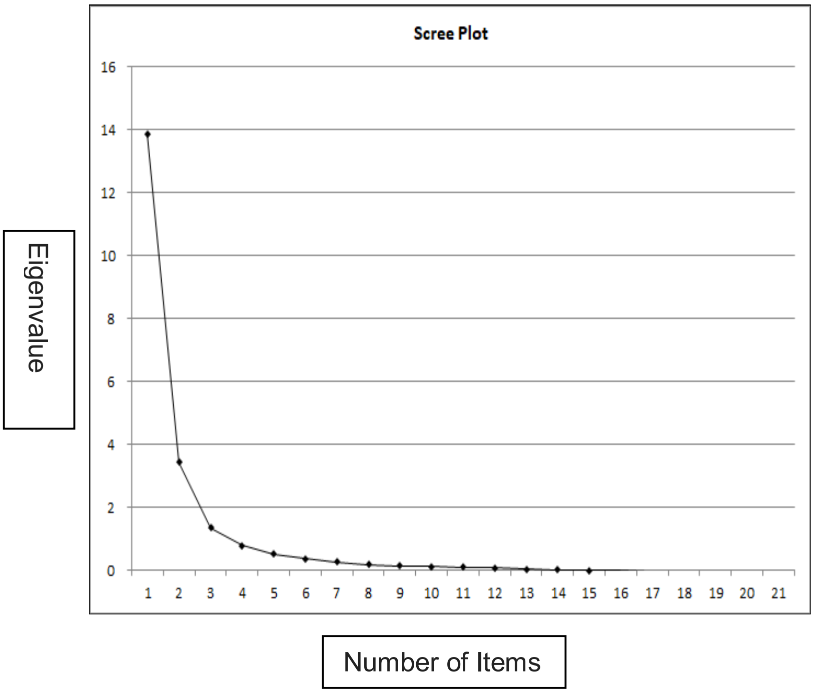

Figure 1. Scree Plot

Table 3. Factor Loading for Three Factor Model

Item	3-factor		
	Factor1	Factor2	Factor3
Shifting C. G* Forward/ Backward	0.531	0.262	0.329
Shifting C. G* Left/ Right	0.534	0.292	0.291
Sit Down	0.955	-0.035	0.031
Stand Up	0.985	-0.070	-0.014
Lying Dow	1.071	-0.194	0.050
Sitting Up	1.126	-0.239	-0.094
Rolling	0.906	0.043	-0.411
Turning	0.920	0.000	-0.419
Stand	0.132	0.915	-0.127
Sit	0.260	0.780	0.006
Supine/Oblique	0.651	0.194	0.035
Walk	0.391	0.631	-0.009
Change Direction	0.178	0.799	0.078
Turn 360	0.126	0.865	0.032
Jump	0.323	0.754	-0.098
Entry	-0.017	0.787	0.286
Exit	-0.017	0.787	0.286
Legs: Pushing/ Kicking	0.260	0.342	0.566
Arms: Pushing/ Pulling	0.370	-0.008	0.856
Arm: Reaching out	0.307	0.022	0.863
Hand: Passing Object	-0.001	0.258	0.762

*C. G – Center of Gravity

The New Functional Evaluation Tool

The functional components of WOTA were analyzed using the Exploratory Factor Analysis. The result of the analysis led to a recommendation that a 3-factor structure forms a suitable tool for this purpose. This structure categorizes activities in order of functional progression from least to most action. This structure is as shown in Table 4 and is divided into:

Factor 1 – Altering the center of gravity – Activities in this category involve displacement of the patient's center of gravity. These basic activities are of use for testing and training of balance by acquiring different positions, from an initial/ starting sitting or standing position, and then regain the starting position. The activities are: Shift gravity forward/backward, Shift gravity to the left/right, Sit down, Stand up, Lying down, Sitting up, Rolling, Turning, Supine oblique.

Factor 2 – Basic functional activity – This category is a progression to balance training that can challenge the patient further by initiating basic functional movements. Emphasizing training, or repetition of these activities, can be used to train the patient's independence. Some of the activities in this category can be modified into strengthening exercises. The activities are: Stand, Sit, Walk, Change direction, Turn 360, Jump, Entry into pool, and Exit out of pool.

Factor 3 – Progressive basic functional activity – For further progression, more muscle involvement would help foster more confidence in the patient as activities in this category involve higher centers. Muscle strength, balance and coordination improvement are guaranteed with these activities. The activities are: Legs pushing/kicking, Arms pulling/pushing, Arms reaching and Hands passing an object. These items are graded with the 5 points (x, 0 ~ 3 points) scale, as used for WOTA.

Correlation analysis

Spearman's correlation coefficient between score of the developed aqua rehabilitation therapy tool and MRC sum score for the lower limbs is presented in Table 5. Spearman's Correlation coefficient between the developed tool and MBI is presented in Table 6. The sum of the scores in the developed evaluation tool showed strong correlation with the sum of the MBI ($r = 0.636$, $p = 0.000$). The sum of the developed scales was also correlated with the MRC sum score ($p = 0.01$). However, the strength of the correlation was weaker than that of the MBI score ($r = 0.298$). The 'Basic Functional Activity' part of the developed tool showed stronger correlation than 'Altering the Center of Gravity' or 'Progressive Functional Activity' part of the tool and presented in Figure 2.

Table 4. Three Factor Structure

GROUP	TEST	SCORE
Altering the Center of Gravity	Shift gravity forward/ backward	
	Shift gravity left/right	
	Sit down	
	Stand up	
	Lying down	
	Sitting up	
	Rolling	
	Turning	
	Supine oblique	
Basic Functional Activity	Stand	
	Sit	
	Walk	
	Change direction	
	Turn 360	
	Jump	
	Entry	
	Exit	
Progressive Functional Activities	Legs pushing/kicking	
	Arms pulling/pushing	
	Arms reaching	
	Hands passing an object	

Scored on 5 points (x, 0 ~ 3 points) scale:

x. Cannot be assessed due to physical disability

0. Does not perform or seems capable but does not cooperate

1. Performs a task with the instructor's full support

2. Performs a task with the instructor's partial support

3. Independent, performs a task without the instructor's support

Table 5. Correlation Between WOTA and MRC Sum Score

	Total WOTA score	Group 1	Group 2	Group 3
MRC sum score	0.298*	0.259*	0.382**	0.319**

* *P* < 0.05

** *P* < 0.01

Table 6. Correlation Between WOTA and MBI

	Total WOTA score	Group 1	Group 2	Group 3
MBI Total	0.636**	0.503**	0.760**	0.522**
MBI Ambulation	0.554**	0.481*	0.669**	0.479*
MBI Stair Climbing	0.590**	0.491**	0.606**	0.380*
MBI Transfer	0.604**	0.557**	0.674**	0.469*

* $P < 0.05$

** $P < 0.01$

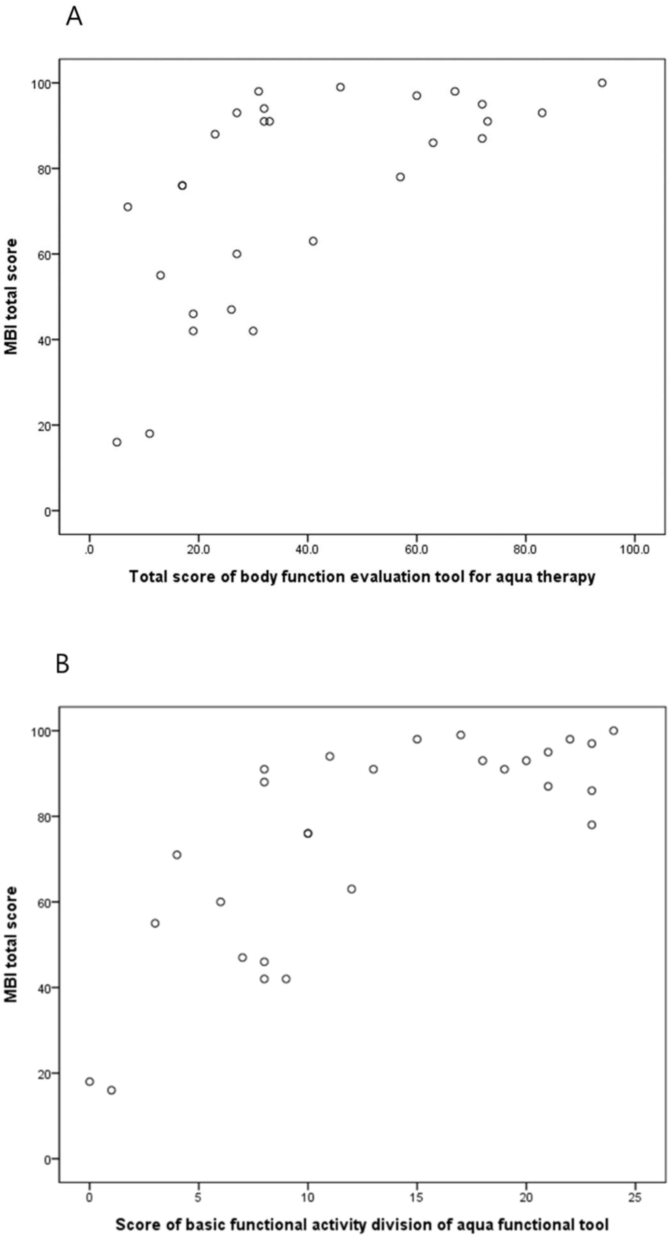

Figure 2. Correlation of MBI total score to total score of body function Evaluation tool for aqua rehabilitation therapy (A) and to score of basic functional activity division of the tool (B).

DISCUSSION

This study is the first to identify and isolate the components of aquatic rehabilitation therapy that can specifically be used to train patients. Those components that are not only relevant therapy and training when performed in the water, but are also effective when transitioning to land and for functioning in daily life. Even though it is believed that repeated activity in the pool can eventually lead to functional ability on land, it cannot be quantified as to how much this repetition can translate into the desired land function. This study has taken advantage of the available activities on the questionnaire of the Halliwick based Aquatic performance evaluation tool in order to use them as evaluation as well as functional rehabilitation items for both water and land.

Marinho-Buzelli et al (4) indicates that there is lack of RCTs demonstrating strong evidence that aquatic therapy would be superior to land therapy in improving mobility outcomes in patients with neurological disorders. However, he states that there is fair evidence among randomized and non-randomized studies that aquatic therapy improves dynamic balance and gait performance in these (neurologic) patients. This report, and many like it, could be as a result of non-availability of a tool that is specifically tailored for these activities in the pool.

The formulation of the basic tool by this study should be the beginning of better results to come in terms of aquatic functional rehabilitation.

The EFA results suggested a recommendation that a 3-factor structure be formulated. This structure categorizes activities in order of functional progression from least to most patient action. This structure is as shown in table 2 and is divided into: **Factor 1** – Altering the center of gravity, **Factor 2** – Basic functional activity and **Factor 3** – Progressive basic functional activity. Many studies have shown the significance of aquatic therapy for rehabilitation. The physical properties of hydrodynamics such as buoyancy, viscosity and cohesion, hydrostatic pressure, the concept of metacenter and the thermodynamics of water produce desirable results in rehabilitation. Appropriate techniques are also needed to accompany these properties for even better results.

The tools developed in this study highly correlated with the MBI, a functional assessment tool on the ground. In particular, the second part of this assessment tool (basic functional activities) was strongly correlated with the MBI. In the clinical and research field, it has been an important issue whether the enhancement of physical function in the water could be linked with the improvement of the physical function on the ground. The correlation analysis results of this study suggest that the tools presented in this study could be an effective tool for investigating this issue.

However, the tools developed in this study showed only weak correlation with MRC sum score ($r = 0.298$, $p = 0.01$). This could be explained at least in part by buoyancy in the water. Because of the buoyancy, there is a possibility that patients had more functional activities in the water compared to the strength of their muscles.

The tool produced by this study can be a stepping stone for better use of aquatic rehabilitation therapy. Adhering to this tool with appropriate progression for rehabilitation can change the outlook of aquatic therapy, not only for patients with neurological diseases but also for all patients eligible for aquatic therapy for example, patients with musculoskeletal injury without neurologic lesion.

Limitations of the study

First, it is the sample. As it is heterogeneous, the 4 point scale and with the distribution concentrated on a specific score in some cases, drove datum far from the continuous variable and therefore could not assume a normal distribution. As a result, the measurement variable was regarded as an ordered-categorical variable. In that case, the sample size should have been in excess of 200 as opposed to only 95 in order for a normal distribution to be assumed.

Second, the study has just formulated a tool that could bring about many benefits in aquatic rehabilitation. This study has not been able to guide as to what improvement in scale would translate to improvement in function on land.

Suggestions for future studies

Studies that will test the grading of this tool need to be done in future. Since it is the first step of the formulation, and in order to set the water/land relationship, there is need to evaluate the appropriateness of the 4point (0-3) score. The activities may have to be reviewed by adding, modifying or removing some of the activities in order to make the tool more effective.

APPENDICES

Appendix 1. Aquatic Performance

Evaluation Date____________________

Group	Test	Score
Respiratory function	Mouth : bubble(5 sec)	
	Nose : bubble(3 sec)	
	Head under, blowing(5 sec)	
	Rhythmic exhalation (with mouth, 6-9 time/min)	
	Exhalation alternately through mouth and nose (3 time)	
Changing a basic body position	Shifting CG forward / backward(25m)	
	Shifting CG left / right(25m)	
	Sitting down	
	Standing up	
	Lying down	
	Sitting up	
	Rolling over right / left	
	Turning and glide / with SRC or TRC	
Maintaining a body position	Stand(30 sec)	
	Sit(40 sec)	
	Supine / Oblique(15 sec)	
	Floating up(5 sec)	
	Gliding supine(10 sec)	
	Gliding prone(5 sec)	
Moving around, Walking and Transferring one self	Walking(6m or more)	
	Changing direction	
	Turning 360(< 4 sec)	
	Jumping(+ blowing, 5 time)	
	Swimming supine(5m, 10m, 15m, 25,)	
	Swimming prone(5m, 10m, 15mm 25m)	
	Swimming sec/25m (check time)	
	Entry	
	Exit	
Use of hands, arms, legs or fine hand use	Legs : pushing, kicking	
	Arms : pushing, pulling	
	Arms : reaching	
	Hands : passing an objects	

Halliwick	Water over the head	
Carrying objects	Transport object	
Moving around using equipment	Mask or goggles	
	Snorkel	
	Fins	
	Floating	
	Other	

3 : No difficulty, High quality performance

2 : Moderate difficulty, Medium quality

1 : Severe difficulty, Low quality

0 : complete difficulty, Dose not perform

Ⅳ. Other evaluation related

Ⅴ. Comments

Rater (평가자) ________________

Appendix 2. Aquatic Performance Evaluation / Water Orientation Test of Alyn (WOTA)

Some of the Functional Activities as Described by Tirosh (14)

Change position from back float to standing (TRC) Instructed to stand up by bringing his head forward while blowing out bubbles, extending arms forward and flexing knees up, towards the chest.

Change position from standing to back floating (TRC) He is instructed to sit in the water and slowly move to float on the back, without jumping, while lifting pelvis and looking diagonally up at the ceiling. If the patient cannot stand in the water (e.g., paraplegia), the therapist should place him in a vertical starting position and continue the assessment from there.

Change position from prone floating to standing (TRC) He is to flex his knees towards his chest, bringing the extended arms towards the knees, straighten legs towards the floor and take the head out of the water.

Sitting in the water (Chair (box) position) (BIS) (MA) Patient to sit up straight unsupported, as if there is a chair underneath for 20 seconds, arms stretched forwards. An angle of 90degrees must be maintained as much as possible at the ankle, knee, and hip joints. Feet should be at width of the pelvis. It is recommended to add a comment about the sitting quality.

Longitudinal Rotations (change position from back to prone to back float) (LRC) Changing position from back to prone, to back float. The patient floats on his back and the therapist stands at his side in the direction of the roll. The patient is instructed to move the far hand and head in the direction of the roll, turning onto the belly, and continue to back float. Repeat this movement to the other side. Note – if the patient cannot maintain static supine float, he will not have more than a score of

1 in this item.

Prone gliding for 5 sec. (head immersed) (BIS) Patient to immerse head/face in the water and change to a straight prone position, while hands are straight forward, looking down for 5 seconds. Starting position can be the “Chair (box) Position.”

Static back float for 5 sec. (BIS) Patient is instructed to count to five while floating on his back. The therapist can assist the patient to reach the required position.

Combined rotation (Change position from standing in the water or sitting on deck to prone and longitudinal rotation to back) (CRC) *The patient should begin this task by standing in the water or sitting on the edge of the pool and instructed to change position to prone float and then straight onto a back float. The head can be above the water throughout the task.*

Combined rotation (change position from back to prone floats to standing position) (CRC) The patient is instructed to change position from back to prone float with head immersed in the water and then stand up.

Progression along pool edge using hands (3m) (MA) The patient holds onto the edge of the pool, feet must be off the floor but may be up against the wall. Move at least 3 meters along the pool edge. This task is performed in water deeper than the patient’s height.

Walking across the pool (6m) (MA) Water reaches the patient’s chest. He is instructed to walk 6 meters across the pool. Support should be given from a position facing the patient by supporting his trunk or holding his hands, or from behind by supporting his trunk or pelvis.

Jumping across the pool (6m) (MA) Water reaches the patient’s chest. He Jumps 6 meters across the pool. Support should be given from a position facing the patient by supporting his trunk or holding his hands, or from behind by supporting his trunk or pelvis.

Jumping and ducking in and out of water (5 times) (MA) Water reaches the patient's chest. Eyes should be immersed in the water at each jump. He is instructed to jump up and duck in the water 5 times, immersing the head/face in the water each time. He is supported at trunk or hands, or from behind by supporting the trunk or pelvis.

Balance Control and Movement

Submerging – touch pool floor with both hands (Patient starts at chest water level, feet disengaged from the floor) (Up-Thrust) *The patient stands in chest-level water. Then he should dive down to touch the pool floor with both hands and come back up. Feet do not touch the pool floor when submerging.*

Entering the water (sit on deck, arms & hand) (MA) The therapist stands in the pool facing the wall. Instructing patient to sit on the edge of the pool, stretch hands forward towards the water and come forward with head until he is fully in the water.

Exiting the water (hands push body up on deck, rotate body to sit) (MA) Patient to stand with water at chest level. Pushes himself up onto the edge of the pool using hands, turn around and sit down with feet in the water.

Note: The abbreviations are explained in the table in Appendix 1.

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국문초록

재활치료를 위한 아쿠아 신체기능평가도구 개발

서론: 수중 치료는 신경 계통이나 정형 관련 및 기타 질환의 재활치료에 적합한 방법임이 입증되고 있다. 부력, 정수압, 점성(粘性), 응집력 등과 같은 물의 생물물리학적 특성에 의하여 물 속에서는 관절에 가해지는 하중을 줄이고 정맥울혈을 예방하면서 근육을 강화시킬 수 있다. 물 속에서의 신체기능이 실제 땅 위에서의 신체기능으로 전환될 수 있는지 알기 위해서는 물 속에서의 신체기능을 평가하기 위한 평가도구가 필요하다. 그러나 현재까지는 일반적으로 받아들여지고 있는 아쿠아 재활치료를 위한 평가도구는 없는 실정이다.

본 연구의 목적은 재활치료를 위한 아쿠아 신체기능평가도구를 개발하는 것이며 또한 개발된 평가도구가 수정바델지수, Medical Research Council (MRC) 총계지표 등과 같은 땅 위에서의 신체기능평가도구와 상관관계를 가지는지 여부를 조사하는 것이다.

방법: 2012년 1월부터 2017년 5월까지 근로복지공단 인천병원에서 치료를 받은 편측 마비(외상성 뇌손상 및 뇌졸중), 척추 손상 (척수손상 및 척추골절)환자들을 후향적으로 분석하였다. 대상자들의 수중기능평가, 도수근력검사, 및 수정바델지수 데이터 등을 수집하여 분석했다. 도수근력검사의 결과는 MRC 총계지표로 전환하여 분석에 사용하였다. 재활치료를 위한 아쿠아 신체기능평가도구를 개발하기 위하여 기존에 사용되었던 수치료 항목 중에서 수영과 관련된 16개 항목을 제외하고

분석하였다. 남은 21개 항목을 범주화하기 위하여 탐색적 요인분석을 시행하였다. 물 속에서의 신체기능과 땅위에서의 신체기능을 비교하기 위하여 개발된 평가도구와 수정바델지수 및 MRC 총계지표의 상관관계를 Spearmann 상관 분석을 사용하여 분석하였다.

결과: 환자 95명(여성 10명, 남성 85명) 대한 데이터를 분석하였다 .환자 25명은 뇌병변이 있었고 70명은 척추 손상이었다. 대상자들의 평균 연령는 53.4세였다(가장 젊은 환자는 27세, 가장 나이가 많은 환자는 73세). 21개 평가항목으로 구성된 아쿠아 재활치료를 위한 신체기능평가도구를 새로이 제안하였다. 이 평가도구의 항목들은 3개의 범주로 구분되었는데, 첫번째 요소는 체중이동, 두 번째 요소는 기본적인 기능 활동, 그리고 세 번째 요소는 점진적 기능활동 등이었다.

각각의 항목들은 0점에서 4점까지 5단계로 평가되었다. 이 평가도구측정값의 총합은 수정바델지수의 총합과 강한 상관관계 (r=0.636, p=0.000)를 보였고 MRC 총계지표와는 수정바델지수보다는 약한 상관관계 (r=0.298, p=0.01)를 보였다.

결론: 이 연구에서 개발한 평가도구는 아쿠아 재활치료의 진행을 기록하는 목적 뿐만 아니라 물속에서의 신체기능 향상이 땅위에서의 신체기능 향상으로 변환될 수 있음을 연구하기 위한 연구에 활용될 수 있을 것이다.

색인: 아쿠아치료, 할리윅, 신체기능,평가

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