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Tova H. Rosen
San Jose State University

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DEVELOPMENT OF AN AQUATIC MUSCLE TEST
FOR PERSONS WITH NEUROMUSCULAR DISORDERS

A Thesis

Presented to

The Faculty of the Department of Human Performance

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

By

Tova H. Rosen

May 1999

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APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE

Emily H. Wughalter, Ed.D.

Nancy L. Megginson, Ph.D.

Emily Dunlap, P.T.

APPROVED FOR THE UNIVERSITY

ABSTRACT

DEVELOPMENT OF AN AQUATIC MUSCLE TEST FOR PERSONS WITH NEUROMUSCULAR DISORDERS

by Tova H. Rosen

The purpose of this study was to develop and to establish reliability and validity of 3 Aquatic Muscle Test (AMT) items: hip abduction, shoulder flexion to 90°, and trunk rotation. Participants were 14 men and 9 women, aged 24 to 65 years, and diagnosed with neuromuscular disorders. Five experts in the field of aquatic rehabilitation established face validity and supported the need for the AMT with a few suggested modifications. Stability reliability was established by comparing AMT results on two different days. The coefficients indicated high stability reliability for each of the 3 AMT items. Concurrent validity was established by comparing the AMT results to a standardized land manual muscle test. The correlation indicated high validity for the AMT shoulder flexion test item, good validity for the AMT hip abduction test item, and low validity for the AMT trunk rotation test item. It was concluded that AMT hip abduction and shoulder flexion to 90° are reliable and valid measures of muscle strength within range of motion and can be used with persons with neuromuscular disorders in aquatic environments. Further development of AMT items and other aquatic assessment tests are recommended.

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CHAPTER I

Introduction

In recent years, the pool has become significant place for the rehabilitation of individuals with disabilities. Aquatic exercise provides potential benefits for physiological and psychological conditions (Hurley & Turner, 1991; Levin, 1991; Meyer & Hawley, 1994; Triggs, 1991). Water presents a unique modality for rehabilitation since responses to exercise in the water are different than those on land. Research has demonstrated the benefits of aquatic rehabilitation for individuals with neuromuscular disorders (Gehlsen, Grigsby, & Winant, 1984; Gorvey, 1991; Prins, Hartung, Merritt, Blancq, & Goebert, 1994). In water, the buoyancy effect decreases joint compression and body weight perception, reducing the need for muscle guarding, and reducing the presence of muscle spasm and pain. Therefore, strengthening exercises can begin in the water before they are even possible on land (Hurley & Turner, 1991; Lewis, 1985; Prins et al., 1994). The warmth of the water provides relaxation, facilitates pain management, stimulates awareness, and provides an ideal medium for muscle re-education (Ruoti, Morris, & Cole, 1997). For individuals with disabilities, water provides a medium to gain independence, and to facilitate the performance of activities of daily living (Levin, 1991; Meyer & Hawley, 1994; Triggs, 1991; Weinstein, 1986). Group exercises can also encourage social interaction, and provide mental support improving a client's morale and confidence (Levin, 1991).

With the increasing popularity of aquatic rehabilitation, practical knowledge and skills are necessary to design an appropriate aquatic program. An effective aquatic program begins by gathering information regarding the functional ability demonstrated by clients. The physical evaluation produces measurable data necessary for developing program goals and objectives (Bates & Hanson, 1996).

Assessments in adapted physical activity are essential in the process of making decisions for (a) screening and referral, (b) diagnosis and placement, (c) instruction and student progress, and (d) sport classification (Sherrill, 1998). As Heward and Orlansky (1988) indicated, "assessment is coming to be seen not as an isolated exercise, but as an inseparable part of a student's ongoing educational program" (p. 55). Bricker (1986) indicated that an assessment tool should be ecologically valid, which means that a test should be sensitive to the environment. Bailey and Wolery (1989) refer to this as a curriculum referenced test. Curriculum referenced testing involves the assessment of a student's ability in the instructional environment. The interpretation of a curriculum referenced test should correspond closely to curricular objectives (Zittel, 1994).

When assessing individuals with neuromuscular disorders, evaluating muscular performance is essential in making diagnoses, determining functional impairment, planning a therapeutic program, and measuring improvement (Wadsworth, Krishman, Harrold, Sear, & Nielsen, 1987). Manual muscle testing (MMT) has become an integral part of the evaluation of neuromotor performance for those with interrupted or disrupted motor patterns (Cole, Furness, & Twomey, 1988). MMT is a subjective measurement of muscle strength, and is

based on a grading system of movement against the force of gravity and examiner's resistance (Wadsworth et al., 1987). MMT has been found to be a reliable measurement tool (Florence et al., 1992; Lilienfeld, Jacobs, & Willis, 1954; Silver, McElroy, Morrow, & Heafner, 1977; Wadsworth et al., 1987). In addition, Allsop and Ziter (1981) indicated that MMT is the most valid method of monitoring disease progression in clients with neuromuscular deficits and must be included in clients' assessments.

Assessment tests in the aquatic environment are extremely limited. In fact, no standard tests to evaluate the physical performance of individuals with disabilities in an aquatic program were found in the literature. The development and validation of an aquatic muscle test should provide an ecologically valid instrument to meet the need for assessment in aquatic rehabilitation.

Significance of the Study

The increasing popularity of aquatic rehabilitation for individuals with disabilities must lead to practical knowledge and skills necessary to develop and implement aquatic programs. Central to this process is consideration of how clients are assessed before and after aquatic treatment. Presently, assessments for aquatic rehabilitation are conducted on land and translated from land to be used in the aquatic environment. Thus, they are not ecologically valid instruments as indicated for effective assessment and instructional planning (Bailey & Wolery, 1989; Bricker, 1986; Zittel, 1994).

Dulcy (1981) investigated the problems in aquatic programs for disabled children. Based on a survey of educational needs of persons working in aquatics for the handicapped.

she found that professionals functioning in the aquatic program did not have the practical knowledge and skills necessary to design and implement an aquatic program (Dulcy, 1976). She referred to the fact that aquatic therapists were unable to provide skill adaptations, and to incorporate prescribed exercises into the pool programs. Dulcy (1993) stated that aquatic therapists were deficient in "...knowledge of evaluation techniques for individuals in aquatic program; ability to incorporate treatment goals and methods into pool programs; knowledge of treatment progression methods..." (p. 10).

Prins et al. (1994) conducted a study to measure the improvement in muscle strength after 8 weeks of an aquatic exercise program for poliomyelitis individuals. They found that no previous studies of aquatic exercise had attempted to measure changes in strength as a result of various water activities with these individuals. They suggested that "...this may be due to the absence of a convenient method of recording the applied force in the water for specific movements..." (p.38).

Since movement and the mechanism of its production is a central component for human activity, evaluating muscle strength for individuals with neuromuscular disorders is of major importance to professionals who are concerned with rehabilitation (Cole et al., 1988). However, in light of the fact that water has been used extensively as a therapeutic modality in a wide range of disabilities, no evidence of a standardized assessment test to measure muscle strength in the aquatic environment exists.

Three selected aquatic muscle test items, shoulder flexion to 90°, hip abduction, and trunk rotation, were developed for the purpose of this study. These items have been chosen to

test a variety of muscles groups affected by individuals with neuromuscular disorders, as well as to represent a variety of common positions used in aquatic rehabilitation.

The aquatic muscle test (AMT) is deliberately constructed to gather information about a client's muscle strength within available range of motion while in the aquatic environment. AMT is based on modifications of Manual Muscle Testing on land (Daniels, Williams, & Worthingham, 1980). Performance of the AMT should reflect a client's performance in the water. This direct examination is valuable for developing individualized client objectives and goals, as well as evaluating a client's progress throughout the aquatic program. It is important to note that the AMT is recommended in conjunction with land diagnosis and evaluation. While evaluation on land has an emphasis on functional land-based goals, AMT is designed to apply directly to instructional planning in the water.

AMT considers the force of buoyancy when evaluating muscle performance. Buoyancy reduces the effect of body weight and allows clients to perform movements that may be impossible on land. This brings the focus to the client's ability, which in most cases, improves the client's morale and encourages further participation in the aquatic program.

The validity and reliability of AMT will provide aquatic professionals with a practical and ecologically valid assessment test to be used in aquatic programs. Since no previously recorded studies of an aquatic assessment test for this special population exists, the development of AMT can serve to initiate follow-up studies to meet the needs of aquatic professionals and clients.

Statement of Purpose

The purposes of this study are multifold:

1. To develop three aquatic muscle test items for the measurement of muscle strength within range of motion for individuals with neuromuscular disorders;
2. To establish face validity of the aquatic muscle test items from five experts in the field of aquatic rehabilitation;
3. To estimate the concurrent validity of the aquatic muscle test items by comparing it to a standardized manual muscle test on land;
4. To evaluate the stability reliability of the aquatic muscle test items by comparing AMT test results on two different days.

Operational Definitions

The following terms will be used in this study and are presented here for clarification.

Neuromuscular disorders. Neuromuscular disorders are defined as disturbances in muscle and nerve units usually resulting in impairment of the efferent nervous system (Anderson, 1994). Typically, neuromuscular impairments include weakness, hypertonicity, voluntary movement deficits, limited range of motion, sensory loss, incoordination, and postural instability (Morris, 1994).

Muscle strength. Muscle strength is the force output of a contracting muscle that is directly related to the amount of tension that a contracting muscle can produce (Kisner & Colby, 1996).

Muscle testing. Muscle testing is a method of evaluating the muscles, tendons, and associated tissue, of a moving part of the body (Anderson, 1994). Muscle testing uses the technique of manual examination and can be performed in water or on land.

Manual Muscle Testing (MMT). MMT measures the amount of tension that contracting muscle can produce against gravity and examiner manual resistance. MMT evaluates isometric muscle contraction.

Manual resistance. The pressure used to denote the outside force applied by the examiner to determine the strength of the muscle being tested. The amount of pressure is the determining factor in maximum, moderate, and light manual resistance. For the purpose of the study, maximum manual resistance determines when the examiner applies a great amount of force to “break” the resistance exerted by the client. Moderate manual resistance determines when the examiner applies medium amount of force to “break” the resistance exerted by the client. Light manual resistance determines when the examiner applies minimal amount of force and can easily “break” the resistance exerted by the client.

Break test. When a client actively holds a body part in a prescribed position, while an examiner attempts to “break” the hold by a manual counterforce (Wadsworth et al., 1987).

Full available range of motion. The amount of angular motion allowed at the joint between any two bony levers (Kisner & Colby, 1996).

Muscle strength within range of motion. Based on the above definitions and specifically for this study, this is the contraction of a muscle that moves the body part throughout the range of motion permitted by the joint.

Buoyancy. The force experienced as an upthrust that acts opposite the direction of gravity. It can be assisted, supported or resisted. Buoyancy assisted is when movement is towards the surface of the water. Buoyancy supported occurs when movement is horizontal to the water surface. Buoyancy resisted is when movement is toward the bottom of the pool.

Delimitations

The following delimitations were used for the purpose of the study:

1. Participants range in age from 24 to 65 years.
2. The AMT was used with individuals with neuromuscular disorders.
3. Specific conditions within the board definition of neuromuscular disorders were not controlled.

Limitations

The following limitations were recognized in the current study:

1. Changes in participants' physical condition from day to day could not be controlled and may have affected the results of the study.
 2. Participant motivation could not be controlled.
 3. The effects of medication on participants' performance could not be controlled.
 4. All types of neuromuscular disorders were not included.
 5. Individuals with contraindications to water therapy were not able to participate in the study.
- Individuals without isolated mobility were disqualified from the study.

Summary

The physical properties of the water offer many advantages in rehabilitation settings. Some of the major therapeutic benefits of warm water exercise are the reduction of pain sensitivity, reduction of muscle spasm, improvement of range of motion, increase in muscle strength, improvement of body awareness, balance, and the promotion of relaxation, morale and confidence (Bates & Hanson, 1996).

Assessment lies at the heart of individualizing physical activity for persons with special needs. Manual muscle testing, as traditionally conducted on land, is a common tool to assess muscle strength in individuals with neuromuscular disorders (Florence et al., 1992). The need for more ecologically valid assessment tests led to this study. An aquatic muscle test was developed through modification of manual muscle testing on land. Its purpose is to measure muscle strength within the range of motion in the aquatic environment. Shoulder flexion to 90°, hip abduction, and trunk rotation were used as the test items. The purpose of this study was to develop an aquatic muscle test and to establish the validity and reliability of 3 aquatic muscle test items for individuals with neuromuscular disorders.

CHAPTER II

Review of Literature

Aquatic rehabilitation is becoming more and more popular for individuals with neuromuscular disorders. However, there are a limited number of research studies on the use of a water assessment test. The AMT was developed to meet this need.

The review of literature is divided into three areas: a) the development, validity, reliability, and current use of manual muscle testing of individuals with physical conditions, (b) the effectiveness of aquatic rehabilitation for individuals with neuromuscular disorders, and (c) assessment and evaluation in aquatic rehabilitation.

Manual Muscle Testing: Development, Reliability, Validity, and Current Use

Manual Muscle Testing (MMT) is the traditional method used for routine clinical assessment of strength (Griffin, McClure, & Rertorini, 1986). Therapists frequently use MMT to clinically assess patients with neuromuscular deficits (Florence et al., 1992). MMT is based on a system of grading movement against gravity or examiner resistance (Wadsworth et al., 1987). This technique has been revised, advanced, and promoted resulting in several methods from which to choose. Each method has differing scales symbols to represent grading. All methods appear to be based on a similar principles with factor defining the criteria for the varies muscle strength grades. The difference between the methods includes positioning, stabilization, application of force, and extent of subdivision among the major categories of grades (Florence et al., 1992).

MMT developed by Lovett in 1912. The first published article describing the procedures, which include the use of an outside force, was written by Wilhmina Wright who assisted Dr. Lovett (Daniels et al., 1980).

Beginning with 1951, MMT played a vital part in the evaluation of agents designed to combat paralytic poliomyelitis (Daniels et al., 1980). Lilienfeld et al. (1954) reported the first field trial study carried out to determine whether Gamma Globulin would protect paralysis resulting from poliomyelitis. Grading was done by using the Lovett system of gravity and manual resistance as criteria of muscle strength into six categories of Normal, Good, Fair, Poor, Trace, and No Power.

Iddings, Smith, and Spancer (1961) reported the development of a numerical index for clinical research in muscle testing. A detailed form that included the addition of plus and minus to the standard grade was used.

Kendall and McCreary (1983), and Daniels et al. (1980) described the most common used methods for manual muscle testing. In 1976, neurologists reported that they most often used the scale proposed by the Medical Research Council (MRC) of the United Kingdom (1976). All three methods have six categories for grading of muscle strength. Daniels et al. (1980) used words (Normal, Good, Fair, Poor, Trace, or Zero) to symbolize their basic grading categories. They added the use of a plus or minus sign to the basic grade to denote greater or lesser amount of resistance or range through the motion. Kendall and McCreary (1983) used percentages (from 100% as normal to 0% as zero) to define their grading criteria.

The MRC scale used the numeral grades 0 to 5, and plus and minus within grades 4, and 5 (MRC, 1976).

Few research studies provide information regarding the reliability, validity, and reproducibility of the various MMT techniques. Several studies published during the poliomyelitis era address the role of physical therapist and MMT in drug trials and the standardization of reliability of MMT grades in the clinical research setting (Florence et al., 1992). Lilienfeld et al. (1954) addressed the interrater reliability of MMT grades in evaluating an agent (Gamma Globulin) in preventing or modifying the severity of paralytic poliomyelitis. The examiners in the study were 43 physical therapists, 23 physicians, and 8 nurses. All the examiners had five days orientation course at which the same instructor instructed them with the method of examination. A total of 45 individuals with poliomyelitis were examined and a total of 65 muscles per patient were graded. The findings indicated that the average difference in scores between examiners was approximately 3 percent. When the compression is analyzed in terms of individuals' muscle grades, it was found that two examiners agreed completely in a grading of a muscle or muscle group in about 70 percent of instances, and approximately 95 percents agreed within plus or minus one grade. The results of this study indicated that the system of muscle testing used in the Gamma Globulin evaluation program has a high degree of reproductively by different examiners (Lilienfeld et al., 1954).

Iddings et al. investigated the reliability of examiners performing the manual muscle test in order to utilize the procedures for clinical use (1961). Thirteen physical therapists participated in this study. Their clinical experience varied from 1-13 years. No standard

method of muscle testing was established for this study. Two patients with anterior poliomyelitis were selected for this muscle testing study. The interrater reliability was reported as 45.3% for complete agreement and as 90.6% for agreement within one muscle grade. Two of the 13 physical therapist re-tested the same patient, with intra rater reliability being 54% and 65% for complete agreement, and 98% agreement within one muscle grade. The results of this study indicated that manual muscle testing used in a clinical situation can be reliable in spite of different training of the physical therapist and use of different techniques of testing (Iddings et al., 1961).

Silver et al. (1977) described the MMT for use in clinical research setting with patients with renal disease. The standardized test was administrating to 20 non-disabled subjects by three evaluators who assess 12 muscle groups per subject using the MMT method of Daniels et al. (1980). There was complete agreement among evaluators for 67% of muscle tested and 97% agreement within half of a muscle grade.

Ziter, Allsop, and Tyler (1977) used the MMT to assess muscle strength in patients with Duchenne's Muscular Dystrophy (DMD), and document muscle strength over time. The evaluators described the MMT as a useful measure for documenting disease progression and suggested it be incorporate into clinical studies and therapeutic trials. Reliability of the MMT was not address in this study.

Allsop and Ziter studied the clinical tests of strength and function of 27 patients with DMD (1981). Every 3 months for 2.5 years, they measured the muscle strength of nine pair of muscle, using the grading system described by Daniels et al. (1980) with minor

modifications. They concluded that MMT remains the most valid method of monitoring disease progression and must be included in patient assessment.

Few studies have attempted to characterize the relationship between MMT and a hand-held dynamometer (DMT). Beasley (1961) reported a very low correlation between these two methods in terms of accuracy of results. He found that muscles qualified at 50% of normal strength by objective techniques could be rated as "normal" by MMT. On the other hand, Wadsworth et al. (1987) designed a study to determine the intrarater reliability of MMT and DMT muscle testing (DMT). A physical therapist performed the MMT and DMT of the same five muscle groups on 11 patients and then repeated the tests two days later. The results reflected that the test-retest reliability coefficients for the MMT ranged from 0.63 to 0.98 and were statistically significant for the shoulder abduction and hip flexor muscles. These results, therefore, suggested that the MMT is a consistent evaluation tool. Wadsworth et al. (1987) found that MMT is less sensitive than the DMT to variability in strength of muscle in "Fair" to "Normal" range. They concluded that both MMT and DMT are reliable testing methods supporting the work of Schwartz, Cohen, Herbison, and Shah (1992) who evaluated the relationship between MMT and DMT as accurate methods for measuring muscular strength. One hundred and twenty two individuals with spinal cord injuries were measured for upper extremity strength. It was found that 22 of the 24 correlations obtained between MMT and DMT were significant. (correlations ranged from 0.59 to 0.94). At the same time, they found that MMT below 4 seemed to correlate better with their respective myometry scores, whereas muscles with MMT scores within the normal range of function tend to

produce a wide range of myometry values, leading to low correlation. They concluded that for “good” to “normal” grades (4 to 5), MMT might not be sufficiently sensitive.

Florence et al. (1992) conducted a study to document the intrarater reliability of MMT grades in assessing muscle strength of patients with Duchenne’s Muscular Dystrophy (DMD). A total of 18 muscle groups were tested on each patient (102 boys) using a modification of the MRC scale. Intrarater reliability ranged from 0.65 to 0.93. It was concluded that: (a) the reliability varied among individual grades, with grades in the gravity eliminated position having the highest reliability values, and (b) grades of proximal muscle group were more reliable than grades of muscle group located distally.

In recent years, numerous mechanical and electronic devices of varying complexity and applicability to clinical muscle testing have been developed. This development provides valuable information regarding muscle function and they are essential for research purposes. However, MMT remains readily available and inexpensive tool for both clinical and research purposes (Daniels et al., 1980).

Aquatic Rehabilitation for Individuals with Neuromuscular Disorders

Currently, there is an increased use of aquatic exercise as a therapeutic modality (Gorvey, 1991; Triggs, 1991). Many research studies have demonstrated the efficacy of aquatic rehabilitation for individuals with neuromuscular disorders (Gehlsen et al., 1984; Hurley & Turner, 1991; Lewis, 1985; Prins et al., 1994).

Aquatic rehabilitation is currently being used for individuals with neuromuscular disorders who have abnormal sensation, impaired motor control or weakness, poor

coordination, impaired balance or equilibrium reaction, decreased functional ability, abnormal gait pattern, decrease endurance, and depression or poor motivation. The characteristics of water (buoyancy, increased resistance, and natural warmth) help the therapist and the patient to achieve the rehabilitation goal in a more conducive environment (Hurley & Turner, 1991). Aquatic therapy is recommended because buoyancy reduces the effect of body weight on the limbs and joints (Prins et al., 1994). Buoyancy is the most valuable aspect of water therapy. It allows the patient to perform exercises that would normally be impossible on land (Lewis, 1985). Ataxia or lack of muscle coordination can be encountered in different neurological diagnoses. The buoyancy of the water helps provide trunk stabilization so that limb movements are easier (Hurley & Turner, 1991). The buoyancy effect of the water decreases joint compression force by supporting the body. Decreasing the amount of body weight on joints eliminates the need for muscle guarding and spasms that lead to symptoms of pain. Reduced level of pain allows for tolerance to increase functional activities such as ambulating in water that may be intolerable on land (Tovin, Wolf, Greenfield, Crouse, & Woodfin, 1994).

The use of water resistance has proven to be a suitable medium for designing strengthening exercises for recovery from a variety of debilitating orthopedic conditions and injuries (Prins et al., 1994). In the aquatic environment, the decrease in compressive force means decreased pain with activity and thus allows many more options for strengthening exercises. Aquatic strength training is beneficial for strengthening the muscles and reducing tendons and ligaments stress around the joint. Gehlsen et al. (1984) measured muscular

strength and endurance of patients with Multiple Sclerosis (MS). The subjects participated in a 10-week exercise program consisting of freestyle swimming and shallow water calisthenics exercises. The results indicated that an aquatic program might induce positive changes in muscular strength and power in patients with MS. The findings of this study are similar to findings in a study by Prins et al. (1994). Prins et al. investigated the effects of aquatic exercise training on dynamic force production during specific limb movement in persons with residual poliomyelitis weakness. Eight weeks of aquatic exercise training using swimming and resistance devices resulted in significant improvement of muscle strength in certain upper body limb movements in persons with weakness resulting from poliomyelitis. Prins et al. suggested that the advantage of water exercises is that the movements primarily incorporate concentric muscle contraction. This movement is desired since eccentric muscle contraction has been shown to be related to increased muscle stress.

Many individuals with neuromuscular disorders suffer from impaired motor control and weakness. Water therapy is an excellent medium for treating these conditions. Weaknesses of facial muscles can be addressed in the pool by having the patient blow bubbles with a straw. Neck and trunk weakness can be strengthened as the patient moves his or her leg from side to side while being supported in the supine position. Sitting activities strengthen the neck and trunk, promote maintenance of good postural alignment, and assist the progression to activities that assist anterior, posterior, and lateral weight shifting (Hurley & Turner, 1991). The main exercises involve working on extensor muscles and improving muscle strength in the legs and arms. The extensor exercises are especially important for the

individual who sits in the flexed position in a wheel chair most of the day (Lewis, 1985). A study by Routi, Troup, and Berger (1994) showed significant improvement in muscle endurance with an older adult population.

Using the water to restore range of motion and flexibility is the most traditional application. Released from the effect of gravity, the injured area can move more freely (Levin, 1991). Prins et al. (1994) found that range of motion was also improved in response to the aquatic training program. Chronically fatiguing exercise seems to be related to an increase in atrophy and strength loss in poliomyelitis subjects. Water therapy facilitates passive movement, range of motion, assertive exercise, and very mild active exercise. These types of exercises are suitable for increasing exercise work rate without developing unusual fatigue (Prins et al., 1994). Perhaps, the most universal symptom of individuals with MS is fatigue. Gehlsen et al. (1984) quantified the effects of the aquatic fitness program on the muscular strength and endurance of patients with MS. The results of this investigation indicated that muscular work and endurance could be dramatically improved in patients with MS.

The pool provides a medium in which the patients can increase sensory awareness of an extremity through tactile and temperature pathways (Triggs, 1991). The sensory stimulation of the water helps to increase the patient's awareness of the affected body part. Splashing on the affected side of the patient with hemiplegia can increase sensation through the turbulence of the water, as the extremity is moved (Hurley & Turner, 1991). The water provides a useful proprioceptive cue that can help in the feedback of body positioning (Levin,

1991). The Bad Ragaz Ring Method which incorporates the use of some proprioceptive neuromuscular facilitation (PNF) can be used when the aim of treatment is general mobilization (Boyle, 1981).

A patient who has a balance and equilibrium impairment benefits from the support of the water around the trunk. This support allows for more reaction time to shift the center of gravity during ambulating (Hurley & Turner, 1991). Ambulating in the pool is useful in gradually increasing the patient's walking and weight bearing abilities (Triggs, 1991). The buoyancy of the water can aid in transfers, gait training, and stair climbing (Gorvey, 1991).

Relaxation of spastic or contracted muscles can be achieved through the natural warmth of the water (Hurley & Turner, 1991). The typical temperature of therapy pool is approximately 92-94 degrees Fahrenheit. The physical properties of warm water are utilized to gain relaxation and freedom of movement (Hall, Bisson, & O'Hare, 1990).

One of the most important benefits of aquatic therapy, especially in patients with chronic pain, is improvement in psychological status (Triggs, 1991). Perhaps, one of the biggest advantages of aquatic therapy might be in keeping the person motivated during rehabilitation (Levin, 1991).

Water is an excellent medium for helping patients gain independence and functional ability (Hurley & Turner, 1991). The decrease in perceived pain and stiffness with improvement in joint flexibility, muscle strength, and coordination facilitate the ability to perform activities of daily living. This increases the levels of independence and improves self-esteem (Weinstein, 1986). In their study, Meyer and Hawley (1994) found that patients

who participated in community-based water exercise programs reported reduced anxiety and depression, improvement in pain perception, as well as in sleeping, relaxation, and activities of daily living. Sanders et al. (1997) also found that functional water exercise programs significantly improved the activities of daily living of sedentary older adults.

The need for socialization is of great importance for individuals with disabilities. Participation in aquatic programs enhances social interaction and encourages group support of each other (Triggs, 1991). Weinstein (1986) indicated that swimming was found to be a mood elevator, helping to decrease feelings of depression and isolation. Water activity is particularly good for people who may not be able to participate in other activities. The social interaction allows them a chance to be with others in a positive activity.

In conclusion, the unique properties of water, particularly buoyancy, water temperature, and water viscosity, allow rehabilitation therapists design effective and versatile treatment program. The specific benefits of weight relief and reduce pain perception allow movement exploration, strengthening, and functional activity of daily living training, often before clients can perform the same on land (Morris, 1994).

Assessment and Evaluation in Aquatic Rehabilitation

Assessment and evaluation in rehabilitation has four main purposes: (a) defining the individual's problems and needs; (b) helping clinicians classify patients into groups; (c) providing data for planing and implementing treatment; and (d) evaluating the value and effectiveness of the therapeutic program (Charness, 1994).

Rothstein (1985) stated that therapists who prescribe treatments must be able to justify their decisions and discuss the accuracy of measurement tool. In order to generate and control a treatment plan, a therapist must use assessment tools.

Bricker (1986) indicated that assessment and evaluation procedures should be linked into the intervention program. If an instrument does not yield information necessary to developing an effective training, it lost its value.

Research in the area of aquatic rehabilitation was described in the previous section. In order to show the instruments (land versus water) that have been used to evaluate effectiveness of aquatic treatment, few studies were selected to review the measurement tools used to evaluate the effectiveness of an aquatic rehabilitation.

Prins et al. (1994) designed a study to evaluate the effect of aquatic exercise training on people with poliomyelitis disability. Dynamic muscle force and range of motion was measured before and after an 8-week aquatic exercise intervention. An Aquanex Hydrodynamic Measurements System was attached to the participants' hand, foot or resistive device, and used to measure dynamic force production in the water. Range of motion of several selected joint movements was measured on land.

Tovin et al. (1994) evaluated the effects of exercise in the water and on land using rehabilitation patients with intra-articular anterior cruciate ligament reconstruction. The data that was collected included muscle performance measurements, passive range of motion measurements, girth measurements and a functional questionnaire. All measurements were conducted on land.

Woods designed a study to evaluate the physical benefits of aquatic exercises and modified swimming strokes in the treatment of low back pain and dysfunction (1989). A Functional Ability Assessment Checklist, developed by the author, was used to measure subjects' physical performance. The physical assessment included strength and flexibility tests. All measurements were performed on land before and after the aquatic treatment.

Gehlsen et al. (1984) conducted a study to quantify the effect of an aquatic program on muscle strength and endurance, work, and power of patients with MS. Two types of isokinetic dynamometers were used to assess the muscular variables studied. A Cybex II dynamometer (on land) was used to measure peak torque, work, and fatigue in the lower extremities and biokinetic swim-bench (in water) was used to measure the upper extremities. The swim-bench data indicated a significant improvement in the components of strength (force, work, and power) for all experimental trials. However, all flexor and extensor peak torque for the lower extremities indicated no significant differences. Gehlsen et al. (1984) discussed the reason strength component gains were evident for the upper extremities and not for the lower extremities. They suggested that specificity of training (water testing followed by water training) might be the key factor influencing the outcome of the force and torque measurements.

Routi et al. (1994) conducted the only study in which all measurements were administered in the water. They designed a study to determine the effects of non-swimming water exercises on muscular endurance and aerobic work capacity in an older adult population. The tests for muscle endurance were performed while standing in water at a

depth just above shoulder level and included shoulder abduction, adduction flexion, horizontal flexion, and extension. The number of repetitions were recorded and compared before and after aquatic training.

The review of literature revealed that most of the measurements used to evaluate the effectiveness of aquatic programs were conducted on land. There is little evidence for research using aquatic assessment tests. Furthermore, none of the above studies discuss the validity and reliability of the tools used to measure aquatic program effectiveness.

Research in aquatic rehabilitation is needed not only to document treatment effectiveness, but also to develop patient classification system and practice guidelines Few studies were conducted to investigate the value of water assessment tests to prescribe aquatic exercise.

Mercer, Jensen, and Fromme (1994) found that significant multiple regression models were built using the veritable treadmill heart rate and gender to predict deep water running (DWR), VO_{2peak} , and heart rate (HR) peak. They suggested that if DWR is the mode of exercise, the prescribed HR should be based on a DWR maximal test. Otherwise, HR should be adjusted to prevent overproduction of training HR. In addition, Kaminsky et al. (1993) suggested that due to the growing popularity of water exercise programs there is a need to establish water assessment test. Following this statement they developed shallow water run test to predict peak aerobic power. They concluded that a 500-yard shallow water run test, especially when used with the descriptive measures of percent body fat and height, can be a

reasonable estimate of an individual's cardiorespiratory fitness. They concluded that shallow water run test could be capable of classifying an individual's fitness level in aquatic programs.

Sazakalidou (1994) developed the water exercise VASA test for the estimation of muscular endurance of the lower body. To estimate the test validity, he tested 30 health participants for knee flexion and extension. It was concluded that the water-exercise test provided a valid estimation of muscular endurance and can be used as assessment tool for water exercise class. Sazakalidou suggested that subsequent studies should examine the reproducibility of the VASA test for special population.

Another aspect of evaluation in aquatic rehabilitation refers to quantitative measurement of strengthening exercises used in aquatic rehabilitation. Hillman, Methews, and Pope (1987) designed a study to quantify the load on different sized bats being moved at different speeds through the water. The procedure of the study involved subjects standing in the pool with their backs against the pool wall, holding the bat with the arm extended and fully immersed in water. The subjects moved the bat through the water 180 degrees horizontally and 90° vertically (in both upward and downward directions). The load on the bat during the movement, and the time between starting and ending the movement were recorded. The results of this investigation showed the average load on the bat at different speeds and with bats of varying widths. For example, a subject taking 3.5 seconds to move an 18-cm bat 180 degrees resulted in an average load of 1.5-kilogram force. Similarly, a subject taking 4 seconds to move a 24-cm bat 180 degrees resulted an average load of 2 Kilograms force. The data presented in this study allowed the aquatic therapist to determine the force

generated by a patient by measuring the time taken to move the bat and thus, allowed planning of progressive resistance exercise.

Harrison, Hillman, and Bulstrode (1992) conducted a study to explore the relationship between the loading of the lower limbs when a subject is standing and walking at varying speeds while partially immersed at different levels. Participants' weight on dry land was measure and compared with their weight at varying levels of immersion while walking or standing by using a force-measuring platform. This comparison is referred to as percentage weight bearing. Measurements were made while standing, slow walking, and fast walking. Levels of immersion were cervical (C7) to ground, Xiphisternum to ground, and waist (ASIS) to ground. It was found that the lower the level of immersion the greater the percentage weight-bearing, and that fast walking pace can be greater than those when static by as much as 76%. The data that provided in this study allows the aquatic therapist to plan a progressive weight bearing exercise program.

Bad Ragaz Ring Method (BRRM) is a common technique for resistance exercises in pool therapy (Boyle, 1981). It is similar to PNF in that the therapist guides the patient through specific patterns of movement to increase strength and range of motion (Morris, 1994). Even though, BRRM technique provides a mean for progressive resistance exercise, only one research study was found in the literature. Harrison and Allard (1982) attempted to quantify the resistance produced using the BRRM. Measurements were taken during maximum resistance generated during the performance of 6 different PNF patterns. Measurements performed in water were: (a) with the supporting floats fully inflated, and (b)

with the supported floats partly deflated. A third measure was made on dry land. The results of this investigation indicated that BRRM exercises used as a strengthening exercise vary depending on the pattern: whereas some patterns may be used until normal strength is acquired, others produce relatively little resistance and are suitable only for the early stage of rehabilitation.

In conclusion, as found in the literature, assessment and evaluation in aquatic rehabilitation are necessary to plan a progressive exercise program. It was also found to be valuable to determine the effectiveness of that program.

Summary

The review of literature presented in this chapter indicated the following:

Manual Muscle Testing used in a clinical setting demonstrated high intrarater reliability (Florence et al., 1992; Iddings et al., 1961; Lilienfeld et al., 1954; Wadsworth et al., 1987). Other studies concluded that MMT remains the most valid method used in individuals with neuromuscular disorders (Allsop & Ziter, 1981; Florence et al., 1992).

Benefits of aquatic programs for individuals with neuromuscular disorders are: reduced pain sensitivity, improved coordination, increased in muscle strength, improved range of motion, and sensory awareness, improved proprioceptive stimulation, enhanced gait training, muscle reeducation, relaxation, increased self-esteem, better motivation, and independence (Hurley & Turner, 1991; Levin, 1991; Prins et al., 1994; Tovin et al., 1994; Triggs, 1991).

Literature on assessment and evaluation of aquatic rehabilitation demonstrated that (a) measurement tools used to evaluate an aquatic program's effectiveness are usually conducted on land while there is a need for specificity of training and ecologically valid measurements (Bricker. 1986; Gehlsen et al. 1984); (b) few studies that investigated the use of aquatic assessment tests indicated the significance of these tests in prescribing aquatic exercises (Mercer et al., 1994); and (c) a quantitative approach to strengthening exercises in water is necessary to improve the ability of the therapist in planning a progressive aquatic program (Harrison et al., 1992; Hillman et al., 1987).

CHAPTER III

Method

In this chapter, the methods used to measure the validity and reliability of the aquatic muscle test items will be presented. Explanations of the recruitment and characteristics of participants, the study design, testing procedures and data analysis will be provided.

Participants

Following permission and approval from the Human Subjects-Institutional Review Board of San Jose State University, participants were recruited from two local aquatic therapy and recreational centers in the Bay Area of California. A proposal (Appendix A) requesting facility use as well as permission to recruit volunteers from their client base was submitted and approved was granted by each of the centers. A poster (Appendix B) calling for volunteers to participate in the study was placed at both centers. The poster included information regarding the purpose of the study as well as required characteristics for participants (individuals 20 to 65 years old, diagnosed by a licensed physician with a neuromuscular disorder). In addition, the researcher attended meetings of a few local neuromuscular disorders support groups (Parkinson's Disease, Brain Injury, and Multiple Sclerosis). At these meetings the researcher explained the purpose of the study and requirements for participation as well as handing out informative flyers calling for volunteers (Appendix C). The poster and flyers were also distributed at the Adapted Physical Education Programs of 4 local colleges.

Individuals interested in participation signed an informed consent (Appendix D), including an informational letter explaining in detail the testing procedures; the required characteristics for inclusion in the study; and the benefits of knowing muscle strength within range of motion in the water and on land. Participants were informed that they might experience fatigue at the end of the testing session. In addition, participants filled out a medical information form (Appendix E) describing their neuromuscular disorders and physical conditions. This form assisted in screening those with conditions that are contraindicated in aquatic therapy. Confidentiality was maintained by adding a separate personal information sheet (Appendix D) which included a participant code number. A waiver releasing the aquatic centers from any liability was also included (Appendix F).

Upon reviewing the above information, the researcher selected 23 participants (14 males, and 9 females, $M = 51.2$ years, $SD = 2.5$) that met the requirements of the study. The following number and type of diagnosed neuromuscular disorders were included in the study: 8 - Stroke, 4- Parkinson's Disease, 1 - Guillain-Barre Syndrome, 1 - Neuropathy, 1 - AV Malformation, 1 -Cerebral Palsy, 2 - Brain Injury, 1 - Muscle Movement Disorder, 1- Polymyocytis, 1 - Post Polio Syndrome, 1 - Multiple Sclerosis, and 1 - Friedreich's ataxia. A copy of the informed consent signed by the researcher was mailed back to the participants. At a later date, participants were scheduled for the research.

Study Design

Hip abduction, shoulder flexion to 90°, and trunk rotation were tested using MMT on land and AMT in the water. These muscle test items were selected for two reasons. First,

since different parts of the body may be affected in individuals with neuromuscular disorders, movements in lower extremity, upper extremity, and trunk may be required to perform the functional activities in their daily lives. Second, in the aquatic program, a variety of positions are needed to apply the force of buoyancy to assist, resist, or support a movement. When testing different planes of movement (frontal, sagittal, and transverse), standing, sitting, supine, and side lying positions are required. Since these positions are used in aquatic rehabilitation it was important to include them in the study.

Two measures of validity were applied in the study. Face validity (Appendix G) was measured by sending the AMT test items for review by 5 experts in the field of aquatic therapy and adapted aquatics. The two experts in aquatic physical therapy were: a head of University Physical Therapy Division, and an aquatic physical therapy professional. The three experts in adapted aquatics were: two Adapted Physical Education Directors and a Professor of Biomechanics. A short questionnaire with open-ended questions and a rating scale using a modified Likert-type scale were included in the face validity package (Appendix G).

Concurrent validity was measured by comparing AMT in water with a standard land test. Since Manual Muscle Testing (Daniels et al., 1980) has been found to be reliable and is commonly used when assessing muscle strength for individuals with neuromuscular disorders (Florence et al., 1992); it was selected as the comparison test. For measuring the reliability of AMT, stability reliability was established by comparing AMT items results on two different days.

Testing Procedures

Validity and reliability of AMT were measured as follows: two testing sessions (A and B) were performed on two different days, 2-7 days apart. For session A, aquatic muscle testing was performed in the water. For session B, aquatic muscle testing was followed by manual muscle testing on land. Three testing items - hip abduction, shoulder flexion to 90°, and trunk rotation - were tested respectively with AMT in water and MMT on land. Testing sessions (AB or BA) were performed in a counterbalanced order using a Latin Square Design. All testing sessions performed by the researcher of this study.

AMT Testing Procedure

Aquatic muscle testing (AMT) was performed in a therapeutic pool. Water temperature ranged from 88 to 92° F. and was 4 feet deep. Flotation devices were attached to participants to provide stabilization. However, no equipment was used on the tested limb. Water temperature and depth were consistent and the same equipment was used with the same participant in each testing session. Three test items - hip abduction, shoulder flexion to 90°, and trunk rotation - were tested respectively. Each of these tests was performed in three continuous sections: movement with buoyancy assisted, movement with buoyancy supported, and movement against manual resistance in the most stable position. At the beginning of each test, the examiner showed the participant an illustrated test protocol and explained the test procedures (Appendix H). The illustrated protocol was laminated to prevent it from getting wet. For each section, testing was performed on the left limb first, then the right limb. Participants were graded on a scale of 0 to 8 (Appendix I). Testing began in a buoyancy

assisted position, and continued to a buoyancy supported position, then to the most stable position with examiner's manual resistance. The highest grade achieved was recorded on an examination record sheet (Appendix J). In addition, an evaluative summary was written at the end of each testing session. Test modification or adaptation of equipment was documented on the record sheet.

MMT Testing Procedures

Manual muscle testing, using the examination technique described by Daniels et al. (1980) was conducted on land. The MMT was performed in a room adjacent to the pool. Hip abduction, shoulder flexion to 90°, and trunk rotation were tested, respectively. With each test item, testing began with the lowest grade (movement with gravity eliminated), and progressed to the highest grade achieved (movement against gravity and manual resistance). At the beginning of each test, the examiner showed the participant an illustrated test protocol and explained the test procedures (Appendix H). Testing was performed on the left limb first, then the right. No equipment was attached to the body during the test. However, a pillow to support the neck and material to prevent friction between the tested body part and the therapy table were used. Participants were graded on a scale of 0 to 5 in the trunk rotation test. For the hip abduction and the shoulder flexion tests, the 0 to 5 scale was expanded using plus (+) and minus (-) marks. For grades 1-3, plus and minus were used to indicate more than half or less than half ROM, respectively. For grades 4-5, plus and minus used to indicate a greater or lesser amount of manual resistance, respectively. However, for statistical use, grades were

marked on a scale of 0 to 10 (Appendix I). Any modifications were documented on the record sheet (Appendix J), and an evaluative summary was written at the end of the session.

Prior to all sessions, the examiner explained to the participants the testing procedures and answered any questions. In addition, participants were required to fill out a modified Rating of Perceived Exertion (RPE) scale (ACSM, 1991) to determine their physical condition on the day of the test (Appendix K). The RPE scale ranges from 1 (very, very weak) to 14 (very, very good) and was used to record acute changes in condition that may have affected the results. A difference of five grades between sessions was considered a radical change and was used as the criteria for disqualification from the study. Since actual results ranged from no change to 3 grades different, all participants qualified for participation.

Analysis of Data

Face validity was analyzed using qualitative and quantitative analysis. Concurrent validity was analyzed by comparing AMT and MMT. Pearson Product-Moment correlation coefficients were used to determine the correlation among AMT and MMT. Stability reliability coefficients were used by comparing AMT results on two different days. An Alpha Coefficient statistic was calculated to determine the reliability coefficient.

Summary

Twenty-three participants (14 males, 9 females) diagnosed with neuromuscular disorders, and ranging in age from 24 to 65 years, participated in the study. Participants were recruited from two local aquatic centers, local neuromuscular disorders support groups and Departments of Adapted Physical Education at 4 local colleges. Hip abduction, shoulder

flexion to 90°, and trunk rotation were tested using AMT and MMT. Each participant took part in two testing sessions. Session A included aquatic muscle testing and session B included manual muscle testing and aquatic muscle testing. Testing sessions were performed in a counterbalanced (rotation) order. Face validity was evaluated by sending the AMT test principles and procedures for review by 5 experts in the field of aquatic rehabilitation. Concurrent validity was measured by comparing AMT in water to MMT on land, using Pearson Product-Moment correlation statistics. Stability reliability was measured by comparing AMT results on two different days, using Alpha Coefficient statistics. The researcher performed all testing sessions following AMT and MMT protocols.

CHAPTER IV

Results

This study was conducted to establish the validity and reliability of AMT. To establish face validity, 5 experts in the field of aquatic rehabilitation reviewed the AMT manual. To establish concurrent validity, 3 AMT items were compared to established standardized manual muscle testing on land. To establish stability reliability, 3 AMT items were compared on two different days. The results of the study presented in this chapter include: descriptive data for all participants, face validity, concurrent validity, and stability reliability analyses.

Descriptive Data for all Participants

Participants' characteristics are presented in Table 1. Participants were 23 persons diagnosed with 12 different types of neuromuscular disorders. Diagnoses included: Stroke (n = 8), Parkinson's Disease (n = 4), Brain Injury (n = 2), Guillain-Barre Syndrome (n = 1), Neuropathy (n = 1), Polymyositis (n = 1), Post polio Syndrome (n = 1), Multiple Sclerosis (n = 1), Friedreich's Ataxia (n=1), Muscle Movement Disorder (n = 1), AV Malformation (n = 1), and Cerebral Palsy (n=1). Participants included 9 females, and 14 males, ranging in age from 24 to 65 years, with a mean age of 51.2 years (SD = 11.9). Eleven of the 23 participants required AMT test modification to complete the study.

Face Validity of the AMT

Five experts representing two aquatic rehabilitation disciplines, participated in the face validity aspect of the study. Experts 1, 2, and 3 represented adapted aquatics, while Experts 4

and 5 represented aquatic physical therapy. A face validity package, including the AMT manual and a questionnaire, was sent to the experts for their review. The results from the face validity reviews are presented through qualitative and quantitative analyses.

Table 1.

Participants' Characteristics

Participant #	Age (in years)	Gender (M= male, F= female)	Diagnosis	Modification (Y= yes, N= No)
1	62	M	Stroke	Y
2	60	F	Parkinson's Disease	N
3	46	M	Guillain-Berre Syndrome	Y
4	63	M	Neuropathy	N
5	24	F	AV Malformation	N
6	32	M	Cerebral Palsy	N
7	54	F	Brain Injury	N
8	41	F	Muscle Movement Disorder	Y
9	52	M	Polymyocytis	Y
10	65	M	Post Polio Syndrome	N
11	63	F	Stroke	Y
12	51	M	Stroke	Y
13	65	M	Parkinson's Disease	N
14	65	F	Brain Injury	N
15	31	M	Friedreich's ataxia	N
16	36	F	Parkinson's Disease	N
17	53	F	Stroke	Y
18	59	M	Stroke	Y
19	47	F	Multiple Sclerosis	N
20	44	M	Stroke	Y
21	59	M	Parkinson's Disease	N
22	51	M	Stroke	Y
23	55	M	Stroke	Y

Based on a face validity questionnaire (Appendix E), data analyses are divided into two sections: (a) questions 1-3 used a 5 point, Likert-type scale and were analyzed with

Quantitative analysis. (b) questions 4-6 were open-ended questions and were analyzed using qualitative analysis. In both sections, a table summarizing the results is followed by the researcher's response to the experts' critical comments.

Face Validity – Quantitative Analysis

A 5 point, Likert-type scale was used to evaluate questions 1, 2, 3a, 3b, and 3c. Participants ranked the questions using the following: 1 = Strongly Disagree, 2 = Disagree, 3 = Moderate, 4 = Agree, 5 = Strongly Agree. The means and standard deviations by expert and by question are presented in Table 2.

As illustrated in Table 2, experts on the average rated questions 1 and 3b the highest. Question 3b received a higher average rating than questions 3a and 3c. The average rating indicates experts scored from moderate to strongly agree. Based on the AMT results, the experts agreed that they would be able to evaluate a client's performance, and moderate to agree that they would be able to develop objectives for treatment and estimate the aquatic treatment effectiveness.

The five experts had the greatest range of scores for question 3c. The greatest spread of scores appeared between expert 5, and experts 2 and 4. Experts 2 and 4 strongly agreed that based on the AMT results one would be able to estimate the effectiveness of aquatic treatment, and expert 5 strongly disagreed with this statement. With regard to this statement expert 5 stated, "How would you know it was due to aquatic intervention?" This comment is irrelevant to the validity of the AMT. If a client gains strength due to aquatic intervention than strength measurement should be apply to assess the effectiveness of the program.

Table 2.

Means and Standard Deviations by Expert and by Question

Questions	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	<u>M</u>	<u>SD</u>
1. Is there is a need for aquatic assessment tests for designing an aquatic exercise program?	5	5	4	3	3	4.00	1.00
2. Is the proposed AMT procedure related directly to assessing muscle strength within range of motion in the aquatic environment?	4	5	3	5	2	3.80	1.30
3a. Based on the test results, would you be able to develop objectives for treatment (prescribe the appropriate aquatic exercises)?	3	5	3	4	2	3.40	1.14
3b. Based on the test results, would you be able to evaluate the client's progress?	3	5	4	5	3	4.00	1.00
3c. Based on the test results, would you be able to estimate the effectiveness of the aquatic treatment?	3	5	3	5	1	3.40	1.67
<u>M</u>	3.60	5.00	3.40	4.40	2.40		
<u>SD</u>	0.89	0.00	0.55	0.89	0.14		

All experts gave an average rating of agree to question 1. These responses suggest an overall agreement between aquatic professionals regarding the need for aquatic assessment

tests for designing aquatic exercise programs. This indicates the need for ecologically valid assessment tests in adapted physical activity and adapted aquatics. As Bricker (1986) indicated: "...assessment and evaluation procedures should be linked into the intervention program...strong relationship between program goals, assessment procedures, curricular content and subsequent evaluation of individual and group progress should exist" (p.335).

Face Validity – Qualitative Analysis

The second section of the face validity questionnaire included three open-ended questions. Experts were asked to state 3 advantages and 3 disadvantages of the use of the AMT and any other comments, recommendations, and concerns. Some experts added their comments in the AMT manual.

Table 3 summarizes the experts' responses to questions 4 through 6. Some experts expanded their comments in the AMT manual. The experts' overall responses are meaningful to the understanding of the AMT strengths, weaknesses, and any necessary revisions. The following section presents an analysis of the experts' critical comments.

AMT advantages. Some of the advantages described by all experts related to the fact that the AMT was designed for use in the aquatic environment. Their comments were "good start", "good idea", "can perform during aquatic session", and "provides clinical picture on what clients can do in the water". These comments corresponded with the relatively high scores given by all experts to question number 1 (the need for an aquatic assessment test).

Table 3.

Summary of Experts' Response to Questions 4, 5, and 6

Questions	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
4a Advantage	Quick	Easy direction	It's a start	More sensitive than land evaluation	Provides clinical picture on what clients can do in water
4b Advantage		Great photos	Usable for most disabilities	Done during aquatic session	Same information as land based test
4c Advantage		Helpful for pre-post testing		Usable with very weak clients	
5a Disadvantage	Doesn't test full ROM	Trunk flexion Grades 3-0 need to be changed	Not quantifiable	Not universally known	Doesn't provide information on land function
5b Disadvantage	Warm water is not possible in all situations	More detailed information on equipment	Can't compare results		Doesn't tell anything different than land test
5c Disadvantage	Doesn't provide enough information	Objectiveness of grading	Verbal description not accurate		Doesn't use the principles of drag effect to increase reduce resistance
6 General comments, recommendation, and concerns Comments in AMT manual	Doesn't provide enough information for a large group of older adult with disabilities AMT provides subjective measurement upon which a program can be based Great idea	Used incorrect language in the protocol Be more aware of test description	The AMT is not standardized across testers Need standard definition for maximum, moderate, and light resistance	Good idea Need standard definition	Have the same problems as in MMT (subjective, non-functional movement) Inadequate stabilization The relative density of a specific limb will affect the results Drag related resistance is not considered

Experts 3 and 4 emphasized the applicability of the AMT. Expert 3 said, “the AMT can be used for most disabilities”. When evaluating clients with a variety of disabilities, it is very important to have an instrument that can be used with weaker clients as well.

Using different assessment tools for each type of disability may require a therapist to be familiar with variety of instruments, protocols, and testing techniques. Conversely, AMT can be used to test muscle strength with most clients, regardless of the type of disability. Expert 3 stated, “the AMT appears to be more sensitive than land-based, as weaker subjects can be evaluated”. Hurley and Turner (1991), and Lewis (1985) reported that aquatic rehabilitation is extremely beneficial for those individuals who have difficulties walking on land. For these individuals, land evaluation will provide the examiner with information that will not be applicable in the water. Moreover, in some cases, it is difficult or impractical to test weaker clients on land. Lack of an appropriate assessment instrument is a barrier to effective assessment (Bailey & Wolery, 1989). Thus, the sensitivity of the AMT to test weak muscles benefits both the client and the examiner in an aquatic environment.

AMT disadvantages. Experts 2 and 3 expressed major disadvantages of the AMT. Expert 3 stated, “...the AMT is not quantifiable and results cannot be comparable between testers”. In subjective tests, the concern of interrater reliability always exists. With manual examination, there is difficulty in determining what constitutes light, moderate, and maximum resistance. These values vary from one tester to another and also with the same tester during serial tests. However, as indicated by Florence et al. (1992), “intrarater reliability of manual

examination (MMT) ranged from 0.65 to 0.93, with grades in the lowest grades (gravity eliminated) having the highest reliability values” (p.115).

In addition, manual examinations do not require the use of special equipment. Although mechanical and complex devices may be applicable to clinical muscle testing, manual muscle testing remains a readily available and inexpensive tool for both clinical and research purposes (Daniels et al., 1980).

Some comments focused on the information gained by using the AMT. Expert 1 stated, “the AMT does not test full range of motion”. It is not the purpose of the AMT to provide the tester with information regarding a client’s ROM. Rather, the AMT provides information on the client’s muscle strength within their available range of motion. In other words, ROM is a factor used to define the criteria for grading strength rather than a factor that is being measured. Determining full or partial range of motion during buoyancy assisted position is done by visual observation and the palpation of the muscle being tested. In addition, if a client is not able to perform full available ROM, a passive ROM test is performed to determine if the joint is restricted. If passive ROM is available but the client cannot actively perform full available ROM, muscle weakness is indicated.

In spite of the fact that the AMT does not measure ROM, it does provide the tester with information as to why movement is limited. Factors other than muscle weakness such as spasticity, soft tissue restriction or inadequate proximal stabilization can limit full ROM. In this case, testers should document the limitation on the examination record sheet and another measuring tool should be used to determine ROM and the reason for the limitation.

Expert 3 also expressed a concern regarding the pool temperature during testing. The pool temperature where expert 3 works is 84-86°F, however, the test manual recommended using a warmer pool (88-92°F) for testing. One reason a warm pool is necessary for the AMT is that cold water could cause muscle contraction that would affect the results. However, in a practical setting the AMT could be performed at colder temperatures as long as clients are comfortable and the same water temperature is maintained and recorded throughout all tests with clients.

Expert 5 expressed another concern stating, “the AMT does not provide information on land function”. The AMT is not intended to provide information on land function. One advantage of the AMT is that it is performed in the same environment (aquatic) in which training programs will be designed and implemented. Note also that the AMT was recommended to be used in conjunction with and not instead of land-based evaluation. Although the goal of treatment may be to improve a client’s condition on land, it is supported in the literature that the treatment plan should begin with evaluation of the client’s performance in relation to the instructional environment (Baily & Wolery, 1989).

Expert 5 also stated that “the AMT lowest grades (0, 1) and the highest grades (6, 7, 8) can be conducted on land and have the same results as in the water”. It seems that expert 5 means that if AMT produces the same results as MMT, why use the AMT? It is true that for grades 6, 7, and 8 (in the most stable position and against manual resistance) the manual resistance given by the examiner is similar in both environments. But, when testing in the water, a client can benefit from the water properties, such as pain-free position, or the use

of buoyancy to assist in regaining limited movement (mainly where the limiting factor is muscle spasm). Also, the examiner can use the test positions as a guideline for developing the client's aquatic exercises. For the lowest grade (buoyancy assisted), applying the force of buoyancy in the AMT affects the movement differently than gravity eliminated would affect performance on land. If a client does not have muscle contraction, then no difference will be found. However, when muscle weakness is found, buoyancy will assist movement while gravity eliminated (the lowest MMT grade) will not. Furthermore, one could ask if the warmth of the water, an actual muscle contraction, or the difference in pain sensitivity affects a client's performance in the water. Regardless, it must be considered that aquatic examination may provide different results than land examination.

Experts' General Comments, Recommendations, and Concerns

The general comment section allowed experts to express any concerns, recommendations or suggestions regarding the AMT. Expert 3, 4, and 5 suggested the use of operational definitions for light, moderate, and maximum manual resistance. The need for operational definitions is clear and essential to guide an examiner through the testing process. Based on the experts' recommendations, operational definitions were used with these terms and are now presented in Chapter 1 of the thesis

Expert 1 suggested that "the AMT does not provide enough information for a large group of students". It is always a challenge to assess individuals in a class setting. However, in a small class setting or when attendants work with students, the teacher can give more personal attention and the AMT can be used. Yet, the AMT is designed to be administered

individually and should not be used if it can not be done correctly. Expert 1 said, “...the AMT is a great idea for helping assess students abilities and progress and for developing individualized education programs”.

Expert 5 raised an important concern regarding testing in a “buoyancy assisted” position. Expert 5 explained that a relative density (RD) of an object is the property that determines whether the object will float or sink. Thus, if a tested limb has RD less than 1 (RD of water = 1), the limb would always rise to the surface even with no muscle activation. In contrast, a client with RD greater than 1 will have to activate a muscle contraction in order to perform the movement. The difference between two clients is not a concern in a criterion-reference test like the AMT, because a client’s performance is measured in comparison to certain criteria rather than to another client. This also exists in MMT, while the weight of the limb and the work required to perform a movement against gravity is different from client to client. Yet, the question remains as to how the examiner knows if the muscle is doing the movement or if the movement occurs because of the RD value. This is a valid concern and until further tests are done, must be considered a weakness of the AMT.

Expert 5 noted that it might be a problem determining whether turbulence-related drag is affecting the test. When examining movement through water, two kinds of flows should be considered. The flow of a liquid may be either streamlined or turbulent. The resistance to turbulent flow is greater than the resistance to streamline flow. The quicker the movement and the greater the frontal area, the greater the turbulence and therefore the greater the resistance (Duffield, 1983). With the AMT (grades 0 to 5), the movement is performed in

slow motion creating streamline flow and the frontal area of the limb is relatively small. Thus, the streamlined flow generates an insufficient force to allow resistance and the drag related resistance should not be a concern for the examiner.

Another concern was related to the inability to provide adequate stabilization in the water. It is extremely important to apply proximal stabilization when testing an isolated movement. Since gravity is greatly reduced in the water and does not serve as a fixation force as it does on land, stabilization in the water relies largely on the examiner's counter balance against the client body and the fixation of the client to a stable place, usually the wall.

Expert 5 also maintained that like manual muscle testing on land, AMT measures non-functional movements. Obviously, there is a place for functional assessment tests when evaluating client's performance. The AMT, however, is intended to determine a client's current level of performance in a specific movement (strength within range of motion) and not the overall level of motor functioning.

Summary of Face Validity of AMT

Face validity was established by sending the AMT manual and questionnaire for review by 5 experts in the field of aquatic rehabilitation. A total of 6 questions were included in the questionnaire. For questions 1 through 3, a 5 point, Likert-type scale was used with quantitative analysis. Participants ranked the questions using the following: 1 = Strongly Disagree, 2 = Disagree, 3 = Moderate, 4 = Agree, 5 = Strongly Agree. For questions 4 through 6, open-ended questions were used with qualitative analysis.

Findings from quantitative analysis (Table 1) indicated that all experts agreed that there is a need for an aquatic assessment test. All experts rated between moderate to agree on the use of the AMT results to develop program objectives, evaluate the client's progress, and estimate treatment effectiveness. Also, all experts moderately agreed that the AMT related directly to assessing muscle strength within range of motion in the aquatic environment. In conclusion, results from quantitative analysis showed an average rating of 3.76 by all experts. This rating indicates that experts had a tendency to agree on the validity of the AMT

Qualitative analysis indicated that all experts were positive on the need for an aquatic assessment test. They recognized the applicability of the test to the aquatic program and to clients with a variety of disabilities. Most experts stated a concern regarding the subjectivity of the AMT and suggested the use of operational definitions for light, moderate, and maximum manual resistance. Only one expert expressed concern for drag related effect, relative density of the limb, and inadequate stabilization while administering the test in the aquatic environment.

Stability Reliability of AMT

Stability reliability was established by comparing the results of 3AMT items from left and right sides on two different days. The two tests took place no less than 2 and no more than 7 days apart. Three items - hip abduction, shoulder flexion to 90°, and trunk rotation - one on each side, were compared with AMT1 and AMT2. Participants were graded on a scale from 0 to 8. Raw data for AMT1 and AMT2 are presented in Table L1 in Appendix L.

Coefficient Alpha correlation was used to determine the stability reliability coefficient among AMT1 and AMT2 (see Table 4). A correlation of $r = 0.96$ was found between AMT1 hip left and AMT2 hip left. A correlation of $r = 0.98$ was found between AMT1 hip right and AMT2 hip right. A correlation of $r = 0.99$ was found between AMT1 shoulder left and AMT2 shoulder left. A correlation of $r = 0.97$ was found between AMT1 shoulder right and AMT2 shoulder right. A correlation of $r = 0.98$ was found between AMT1 trunk rotation left and AMT2 trunk rotation left. A correlation of $r = 0.98$ was found between AMT1 trunk rotation right and AMT2 trunk rotation right. All correlations were found to be statistically significant.

Table 4.

Stability Reliability – Coefficient Alpha Correlation (r)

AMT1 AMT2	AMT1HL AMT2HL	AMT1HR AMT2HR	AMT1SL AMT2SL	AMT1SR AMT2SR	AMT1TL AMT2TL	AMT1TR AMT2TR
Stability Reliability (r)	0.96**	0.98**	0.99**	0.97**	0.98**	0.98**

Note. AMT1HL = AMT1 hip left; AMT2HL = AMT2 hip left; AMT1HR = AMT1 hip right; AMT2HR = AMT2 hip right; AMT1SL = AMT1 shoulder left; AMT2SL = AMT2 shoulder left; AMT1SR = AMT1 shoulder right; AMT2SR = AMT2 shoulder right; AMT1TL = AMT1 trunk rotation left; AMT2TL = AMT2 trunk rotation left; AMT1TR = AMT1 trunk rotation right; AMT2TR = AMT2 trunk rotation right.

** $p < 0.01$

Summary of Stability Reliability of AMT

Stability reliability was established by comparing AMT test results on two different days. Coefficient Alpha statistic was used to determine the reliability of the AMT. Correlation was found to be statistically significant for all test items. Based on this correlation, AMT test items were found to be highly reliable.

Concurrent Validity of AMT

Concurrent validity was established by comparing the AMT results with the MMT results. Three AMT items - hip abduction, shoulder flexion to 90°, and trunk rotation - one on each side, were compared to the MMT test. Participants were graded on a scale from 0 to 8 with the AMT. For the MMT, a scale from 0 to 10 was used with hip abduction and shoulder flexion to 90° test items, and a scale from 0 to 5 with the trunk rotation test item. Raw data for AMT1 and MMT are presented in Table L2 in Appendix L.

Pearson Product-Moment Correlation Coefficients were used to determine the relationship between AMT1 and MMT. A coefficient of determination (r^2) was calculated for every correlation found to be statistically significant. These are presented in Table 5.

A correlation of $r = 0.78$ was found between AMT1 hip left and MMT hip left ($p < 0.01$). Approximately 61% of AMTHL can be explained by knowing MMTHL. A correlation of $r = 0.82$ was found between AMT1 hip right and MMT hip right ($p < 0.01$). Approximately 67% of AMTHR can be explained by knowing MMTHR. A correlation of $r = 0.92$ was found between AMT1 shoulder left and MMT shoulder left ($p < 0.01$). Approximately 84% of AMTSL can be explained by knowing MMTSL. A correlation of

$r = 0.92$ was found between AMT1 shoulder right and MMT shoulder right ($p < 0.01$).

Approximately 84% of AMTSR can be explained by knowing MMTSR. A correlation of

$r = 0.44$ was found between AMT1 trunk rotation left and MMT trunk rotation left ($p < 0.05$).

Approximately 19% of AMTTTL can be explained by knowing MMTTL. A correlation of

$r = 0.29$ was found between AMT1 trunk rotation right and MMT trunk rotation right. No

Coefficient of determination was calculated for this correlation since it is not statistically significant.

Table 5.

Concurrent Validity – Pearson Product-Moment Correlation Coefficient (r) and Coefficient of Determination (r^2)

AMT1 MMT	AMT1HL MMTHL	AMT1HR MMTHR	AMT1SL MMTSL	AMT1SR MMTSR	AMT1TL MMTTL	AMT1TR MMTTR
Pearson Correlation Coefficient (r)	0.78**	0.82**	0.92**	0.92**	0.44*	0.29
Coefficient of Determination (r^2)	0.61	0.67	0.84	0.84	0.19	

Note. AMT1HL = AMT1 hip left; MMTHL = MMT hip left; AMT1HR = AMT1 hip right;

MMTHR = MMT hip right; AMT1SL = AMT1 shoulder left; MMTSL = MMT shoulder left;

AMT1SR = AMT1 shoulder right; MMTSR = MMT shoulder right; AMT1TL = AMT1 trunk

rotation left; MMTTL = MMT trunk rotation left; AMT1TR = AMT1 trunk rotation right;

MMTTR = MMT trunk rotation right. ** $p < 0.01$, * $p < 0.05$

Summary of Concurrent Validity of AMT

Concurrent validity was established by comparing the results of 3 AMT items, one on each side, to the 3 items of the MMT on land. Pearson Product-Moment correlation statistics were used to determine the validity of the AMT by comparing it to the established MMT. Hip abduction and shoulder flexion were significantly related. Trunk rotation on the left side was found to be significantly related. Trunk rotation on the right side was found to be not significant. The highest coefficient of determination calculated was on the left side shoulder flexion test item. The lowest coefficient of determination was calculated was the right side trunk rotation test item.

Summary of Results

Twenty-three participants diagnosed with 12 different types of neuromuscular disorders participated in this study. Participants ranged in age from 24 to 65 years (9 females and 14 males). Face validity, concurrent validity, and stability reliability were established for the AMT. Face validity was established by sending the AMT manual and questionnaire to 5 aquatic rehabilitation experts for their review. The results were subjected to qualitative and quantitative analyses. Experts agreed on the need for aquatic assessment test and rated the AMT with a good face validity with few modifications and concerns regarding its subjectivity. Stability reliability was established by comparing the AMT test results on 2 different days. A Coefficient Alpha statistics were used to determine the reliability of the 3 AMT items on the left and right sides. All correlations among AMT items were found to be statistically significant with high stability reliability. Concurrent validity was established by

comparing the AMT results to the established MMT on land. Pearson Product-Moment correlation was used to determine the validity of the AMT. Results show that the AMT hip abduction and shoulder flexion test items were significantly related to the MMT test items. The AMT trunk rotation test item did not significantly related with the MMT trunk rotation test item.

CHAPTER V

Discussion, Conclusion, and Future Recommendations

The purposes of this study are as follows: (a) to develop an aquatic assessment test by developing three AMT items (hip abduction, shoulder flexion to 90°, and trunk rotation); (b) to establish face validity of AMT items by five experts who reviewed the AMT manual and answered a questionnaire; (c) to estimate the concurrent validity of AMT items by comparing AMT test results on two different days; and (d) to evaluate the stability reliability of AMT items by comparing AMT results with MMT results.

The development of the AMT is discussed in terms of test modifications and recommendations for practical use. Face validity, concurrent validity, and stability reliability as applied to the study are discussed. Finally, the chapter includes conclusions and recommendations for future study.

AMT Modification and Recommendations for Practical Use

Eleven out of 23 participants performed the AMT with some modifications and adaptations for their specific needs. Although there was not a need for adaptation of equipment, modification of test positions for specific conditions was required. Modifications were used mainly with the shoulder flexion to 90° test item. With this test, side lying position was required for grades 4 and 5 (movement while buoyancy supported). It was found that side lying position was not only an uncomfortable position for many participants, but was also impossible to perform by individuals who did not have the ability to hold the wall with one arm. Modification required the examiner to stabilize the participant's body against the wall

while standing in front of them. If participants were uncomfortable even in this modified position, the side lying position was not used at all and a grade was given based on performance of the remainder of the tests. For the same reasons, it is also necessary to question the use of assisted, supported, or resisted buoyancy. If a position requiring buoyancy use is uncomfortable or impossible for the client, it must be assumed that the results will be inaccurate and the position must be eliminated from the tests. It is suggested that alternative positions should be developed for these cases.

When testing hip abduction, the issue of active stabilization with participants lacking upper extremity strength was more pronounced in participants diagnosed with stroke. With these individuals, the lack of mobility and strength on one side reduced their ability to hold the wall when standing with their side to the wall. Thus, they performed the test while facing the wall, holding with the unaffected hand. This problem was encountered in the supine position, where participants were required to stabilize their upper body by holding the wall with both hands. A variety of modifications were used to overcome this problem. In some cases, an attendant stabilized the participant's upper body. The attendant stood in chest deep water, back stabilized against the wall, and held the participant under armpits. In other cases, sufficient stabilization was achieved by having the participant hold the wall with only the unaffected hand. This was possible due to the fact that the examiner added additional stabilization by holding their body against the participant's body while holding the pelvis.

Some potential problems were also found with the trunk rotation test item. The issue of both hands holding was solved with a modification similar to the one used in the hip

abduction supine position. Also, since manual resistance was given while the participant held the thigh at a 90-degree angle to the trunk, the strength of the legs was involved in the test. If participants could not hold their legs in this position, the test could not be completed. For example, when a stroke participant with an affected left side performed trunk rotation to the left, the lack of strength, muscle control, and coordination interfered with the ability to hold trunk rotation. This was even more noticeable when manual resistance applied to the legs.

Adequate stabilization to isolate movement correctly is of particular importance when testing manual muscle strength (Cole et al., 1988). To ensure adequate stabilization when using the AMT, the following recommendations are made: When testing shoulder flexion to 90° (grades 0-3, 6-8), the examiner's elbow and forearm was stabilized on horizontal surface of the pool gutter while placing her hand on the participant's shoulder. The participant's trunk was held against the pool wall. This not only stabilized the shoulder but the whole trunk as well, preventing the participant from extending their trunk to assist shoulder extension. It also provided greater stability for the examiner. In the trunk rotation test (grades 4-8), the examiner should place his or her leg against the wall. This will improve the examiner's body mechanics so they may apply correct and safe resistance.

To allow recording the results of each test while in the water, a laminated master examination record sheet was developed. The data were written on this sheet with a wax pen and later transferred to the client's file. The sheet could then be erased and used again.

Face Validity of AMT

Five experts in the field of aquatic rehabilitation reviewed the AMT. Based on the experts' comments and recommendations, face validity was established for the AMT. Experts agreed that there is a need for an aquatic assessment test to be used with individuals with physical disabilities. Experts 1, 2, 3, and 4 agreed that, based on the AMT results, the therapist would be able to develop objectives for treatment, evaluate the client's progress and estimate the effectiveness of the aquatic program. Experts acknowledged the adaptability of the AMT, expressing that not only can it be used with a variety of physical conditions but with very weak clients too. Disadvantages of the AMT as viewed by the experts are that (a) it is a subjective test, (b) it cannot be used with a large group of clients, (c) warm water (88-92°F) is not always available, (d) it does not provide information on land function, and (e) the relative density of the limb may affect the results. The above disadvantages may be viewed as the AMT weaknesses and limitations.

Some of the comments were used to revise the AMT and some were used as recommendations for future study. Comments were added in Chapter 3 regarding the need for operational definitions for maximum, moderate, and light manual resistance. Comments regarding the use of correct language were added to the AMT manual (Appendix G).

Concurrent Validity of AMT

Concurrent validity was established by comparing the results of 3 AMT items to those of the established MMT on land. The shoulder flexion to 90° AMT test item had the highest values of correlation with a coefficient correlation (r) of 0.92 for both sides. It is interesting

to note that this high value was achieved even though this test item required the most modifications. This may be due to the similarity of the two tests. In both AMT and MMT, manual resistance was applied in the same line of direction (from above) and participants were in the same body position (sitting). The validity established for the AMT hip abduction test item was lower than that of the AMT shoulder flexion test item ($r = 0.78$ for hip abduction left side, $r = 0.82$ for hip abduction right side). This may be due to the different way manual resistance was applied to participants and/or their body position. With the AMT hip abduction test item, manual resistance was applied from the side while it was applied from above in the MMT test. The participants' body position in the AMT was supine and for MMT it was side lying which may have affected the ability of the participant to generate muscle contraction and also the ability of the examiner to give resistance.

A low concurrent validity was established for the AMT trunk rotation test item. Baumgartner and Jackson (1996) stated that "a crucial step in establishing the concurrent validity of a test is the choice of a suitable criterion measure" (p. 124). It is possible that MMT was not a suitable measure for establishing concurrent validity to the AMT trunk rotation test item. In the MMT trunk rotation test, the oblique muscles work to rotate the upper trunk towards the legs, while in the AMT test the oblique muscles work to rotate the legs towards the trunk. Even though both tests measure trunk rotation strength, different parameters are involved in each test. When flexing the legs towards the chest in the AMT test, the mobility of the legs plays a part in achieving the desired movement. In the MMT test, the arms play a part in achieving the desired movement. These limitations not only affect the

test itself but also the correlation established between the two tests. Thus, it is concluded that concurrent validity cannot be established between the AMT trunk rotation test and that of the MMT.

Stability Reliability of AMT

Stability reliability was established for the AMT by comparing the results of 3 AMT test items on two different days, 2-7 days apart. The correlation among AMT1 test items and AMT2 test items was statistically significant. It was concluded that the hip abduction, shoulder flexion to 90°, and trunk rotation AMT test items are highly reliable. Baumgartner and Jackson (1996) stated that “most physical measures are stable from day to day, exhibiting test-retest reliability coefficients between 0.80 and 0.90” (p. 98). A few factors may have contributed to the high stability reliability established for the AMT. First, the examiner maintained a standardized testing procedure. Second, as indicated by a modified RPE scale, all participants perceived little or no change in their physical condition in both sessions. Third, the short interval between the AMT1 and AMT2 measurements (2-7 days apart) may have contributed to a bias factor as the examiner may have remembered the grades given to the participants on the first test and thus affected grades given on the second day. Even though the examiner did not have access to AMT1 results when conducting AMT2, it is still possible that the time between measurements was not sufficient to reduce forgetting and to avoid bias. Finally, the high stability reliability established for AMT may simply indicate that it is a stable measurement of muscle strength within range of motion and can be used as an assessment tool in the aquatic environment.

Conclusions

The development, validity, and reliability of AMT were established in this study. Tests for hip abduction, shoulder flexion to 90°, and trunk rotation were developed for the purpose of the study. Based on the results, the following conclusions were reached:

1. Based on the experts' review, there is a need for aquatic assessment tests. Experts also agreed that based on the AMT results the examiner would be able to develop objectives for aquatic treatment, evaluate the client's progress, and estimate the effectiveness of the aquatic treatment.
2. Based on the experts' review, the weaknesses and limitations of the AMT are that (a) it is a subjective test, (b) it cannot be used with a large group of clients, (c) it is not applicable to cold water pool, (d) it does not provide information on land function, and (e) the relative density of the limb may affect the results.
3. The major modification of the AMT to adapt to clients needs was having them use one hand instead of both for stabilization. This modification did not effect the stability reliability of the AMT.
4. The AMT hip abduction test item had high stability reliability and high concurrent validity.
5. The AMT shoulder flexion to 90° test item had high stability reliability and high concurrent validity. However, side lying position during this test was found to be uncomfortable for the participants and should be eliminated from the AMT test protocol.
6. The AMT trunk rotation test item had high stability reliability and low concurrent validity. Based on this finding, it should be eliminated from the AMT test protocol.

Recommendations for Future Study

The unique properties of the water must be considered when designing and implementing an aquatic rehabilitation program. The development of an aquatic assessment test was prompted by the fact that the performance of a movement in the water is rather different than the performance of the same movement on land. This leads to the conclusion that the aquatic treatment plan should be followed by an aquatic assessment test. This is also supported in the literature and is referred to as the need for ecologically valid assessments and curriculum referenced instruments (Bailey & Wolery, 1989; Bricker, 1986).

In addition, assessment tests for individuals with disabilities are needed for use in a practical setting as well as for research purposes (Lavay & Lasko-McCarthy, 1992). Lavay and Lasko-McCarthy also stated that professionals in adapted physical activity must address the challenge of developing valid, reliable, and commercially available test instruments and protocols specific to individuals with disabilities.

A large variety of client populations and diagnoses are being treated today in the aquatic environment (Ruoti et al., 1997). Two valid problems in rehabilitation programs are: (a) the limited number of assessment tests for individuals with disabilities, and (b) the lack of aquatic assessment tools. As indicated in the literature, "it is important to document how one is advancing in the program with regard to the use of the water" (Styer-Acevedo & Cirullo, 1994, p.174). Since the AMT designed to be used in aquatic rehabilitation and especially for individuals with disabilities, it addresses both of the problems mentioned above.

The development of the AMT in this study should serve as a starting point for other aquatic rehabilitation professionals to continue and further develop aquatic assessment tests. Based on the findings of this study, the following recommendations should be considered in future study:

1. Interrater reliability must be conducted to insure that the developed AMT items are stable across two different examiners.
2. In this study, the hip abduction and the shoulder flexion to 90° test items were found to be reliable and valid. However, for practical use of the AMT, more AMT items should be developed and tested for their validity and reliability. In addition, AMT trunk rotation test item should be either compare to another standardize trunk rotation strength test or should be redevelop.
3. The results of this investigation are based on research done with clients diagnosed with neuromuscular disorders. However, since aquatic rehabilitation is used with individuals with a wide variety of conditions, a replication study should be conducted with participants with as many of these other disabilities as possible. On the other hand, even with the neuromuscular disorders categories, a more specific groping should be used. In addition, AMT should be conducted with children with disabilities to generalize the test results for children
4. Pool temperature recommended for AMT use and as applied in this study ranged from 88 to 92° F. Since this exact temperature may not be available in all therapeutic pools, it is important to test clients at the same water temperature as that in which their program is conducted. AMT should also be tested in a cooler temperature range of 82 to 88° F. It would

also be interesting to find out if there would be different results if the same participants were tested at different pool temperatures.

5. AMT is not intended to test functional movement. However, functional tests are very beneficial to rehabilitation programs. Ultimately, the performance of the client in the pool must be eventually linked to his or her functional performance on land. Hence, functional aquatic assessment tests (e.g., walking, balance) administered in the water should be developed and standardized.

6. A major concern expressed by the experts was that AMT is a subjective test. An objective aquatic assessment tool (e.g., hand dynamometer) should be modified for the aquatic environment and tested for validity and reliability.

7. Many techniques are used in the water to improve clients' ROM. However, there are no tests to measure the effectiveness of the techniques or to justify the rationale of using the water as a modality to improve ROM. For this reason, effective ROM measurements should be developed for use in the water.

8. One weakness of the AMT was related to the buoyancy assisted position and the question of whether movement occurs because the relative density of the limb is less than 1. Further research would be required to make this determination.

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APPENDIX A

PROPOSAL FOR FACILITY USE
(EXAMPLE: EASTER SEALS AT TIMPANY CENTER)

Proposal

Requesting the use of Easter Seals at Timpany Center facilities for a research study

By

Tova Rosen

Graduate Student

Department of Human Performance

San Jose State University

Presently, I am working on my Master's thesis work "Development of an Aquatic Muscle Test (AMT) for Persons with Neuromuscular Disorders".

The purposes of the study

- 1) To develop a new assessment tool to be used with physically challenged individuals in the aquatic environment.
- 2) To validate AMT by measuring aquatic muscle test items and manual muscle test items on land and then comparing the tests results.
- 3) To establish the reliability of AMT by measuring AMT results on two different days.

Methods and procedures

Thirty individuals diagnosed with a neuromuscular disorder, ranging in ages 20 to 65 will participate in the study.

Testing procedures will require volunteers to participate in two testing sessions on two different days. In session A (day 1), aquatic muscle testing in the water will be performed. In session B (day 2) aquatic muscle testing in the water will be followed by Manual Muscle Testing (by Daniels et al., 1980) on land. The order of the testing for session A and B will be counter balanced to participants.

Volunteers recruitment

Volunteer recruitment will be conducted in two ways. First, a poster calling for volunteers will be placed on the center's bulletin board. Second, The investigator of the study will contact different neuromuscular disorders support groups. Volunteers that meet the requirements will sign an Informed Consent explaining the research procedures and their rights as research participants. In addition, each participant will sign a waiver releasing Easter Seals at Timpany Center from any responsibility.

Facility and equipment needs

1. Pool – Shallow water area (approximately 4 feet deep) close to the wall.
2. Land - A therapy table
3. Equipment – one neck floatation, one buoyancy vest, one pair of ankle floats, one water chair and one ski belt.

Schedule

Volunteer recruitment will start at the end of May 1998. Data collection will start at the end of June 1998 and will continue to the end of January 1999.

Test sessions will be performed during pool hours and access will be arranged with the pool manager so as to avoid interference with community and physical therapy programs. Any changes in the schedule will be rearranged with the persons in charge.

I truly appreciate your consideration to assist me in my research. I hope that together we will greatly improve the way we care for the disabled population and at the same time improve our practical knowledge in aquatic rehabilitation.

Thank you,

Tova Rosen
Graduate student
San Jose state University

.....

Easter Seals at Timpany Center (Please circle one):

I **Approve** / **Disapprove** the proposal for using the center facilities for a research study by Tova Rosen.

Name: _____ Position: _____

Date: _____

Signature: _____

APPENDIX B

POSTER CALLING FOR PARTICIPANTS

Aquatic Session

Free

Land Session

Muscle Testing

**Volunteers needed to participate in a
research study design to test
a newly developed**

Aquatic Muscle Test

Requirements:

- Ages 20 to 65
- Diagnosed Neuromuscular Disorders

**For information: Call Tova
(Graduate Student @ San Jose State University)
(408) 377 - 8295**

APPENDIX C
INFORMATIVE FLYER

Aquatic Muscle Testing

San Jose State University graduate student, Tova Rosen, is conducting a research study in the area of aquatic rehabilitation.

The study will be conducted at The Betty Wright Swim Center in Palo Alto or at Easter Seals at Timpany Center in San Jose
(Water temperature: 89 to 92°)

Volunteers Needed !

The purpose of this study is to measure the validity and reliability of a newly developed Aquatic Muscle Test, an assessment tool designed especially for planning programs in an aquatic setting. The Aquatic Muscle Test measures muscle strength within range of motion in the pool. It is a manual examination to be used with individuals with neuromuscular disorders and is based on a modification of a standard land test, Manual Muscle Testing (Daniels et al., 1980).

Requirements

Diagnosed with a neuromuscular disorder

(neuromuscular disorder is defined as a disturbance in muscle and nerve units):

Range in age 20 to 65 years.

Study procedures

You will be asked to attend the center on **two** different days, for two testing sessions. On the first visit you will be tested with the Aquatic Muscle Test in water. After 2 to 4 days you will be tested with Manual Muscle Test on land and with Aquatic Muscle Test in the water. Each session will last for about one hour.

For more information
Call Tova at (408) 377-8295

APPENDIX D
INFORMED CONCENT
&
PERSONAL INFORMATION SHEET

San José State
UNIVERSITY

College of Applied
Sciences and Arts

Department of Human
Performance

One Washington Square
San Jose, CA 95192-0054
Voice: 408-924-3010
Fax: 408-924-3033

INFORMED CONSENT

Dear volunteer:

San Jose State University graduate student, Tova Rosen, is conducting a research study in the area of aquatic rehabilitation. Tova is a therapeutic aquatic instructor at Easter Seals at Timpany Center and The Betty Wright Swim Center at C.A.R.

The purpose of the study

The purpose of this study is to measure the validity and reliability of a newly developed Aquatic Muscle Test, an assessment tool designed especially for planning program in an aquatic setting. The Aquatic Muscle Test measures muscle strength within range of motion in the pool. It is a manual examination to be used with individuals with neuromuscular disorders and is based on a modification of a standard land test, Manual Muscle Testing (Daniels et al., 1980).

Who can participate in the study?

You will be selected to participate in the study if you are diagnosed by a licensed physician with a primary neuromuscular disorder (neuromuscular disorder is defined as a disturbance in muscle and nerve units), range in age 20 to 65 years, and qualify for aquatic programs (See contraindication to pool therapy in the attached Medical Information Form). If you are unclear whether you have a neuromuscular disorder or about contraindications to the pool therapy, contact Tova Rosen or just complete the form and we will notify you.

Procedures and requirement for participation

If you decide to participate, you will be asked to complete the medical information form, personal information, waiver of release, and to sign the informed consent. Please mail (every thing) to **Tova Rosen 2274 Starbright Drive, San Jose CA 95124** as soon as possible. Upon review, you will be notified regarding your participation and will be contacted to be scheduled for the study.

You will be required to attend the center on two different days, for two testing sessions. During session A, you will be tested with the Aquatic Muscle Test in water. During session B you will be tested on the items of the Manual Muscle Test on land and with Aquatic Muscle Test items in the water. For both land and water testing, hip abduction (lower extremities), shoulder flexion (upper extremities) and abdominals (trunk) will be tested. Before the testing session begins, you will be asked to complete a written scale to determine your physical condition on the day of the test. All testing will be performed by the investigator of this study.

.....Participant's initials

The California State University:
Chancellor's Office
Bakersfield, Chico, Dominguez Hills,
Fresno, Fullerton, Hayward, Humboldt,
Long Beach, Los Angeles, Maritime Academy,
Monterey, San Bernardino, Pomona,
Sacramento, San Bernardino, San Diego,
San Francisco, San Jose, San Luis Obispo,
San Marcos, Sonoma, Stanislaus

San José State
UNIVERSITY

College of Applied
Sciences and Arts
Department of Human
Performance

One Washington Square
San Jose, CA 95192-0054
Voice: 408-924-3010
Fax: 408-924-2055

During session A, you will meet with the investigator to receive more detailed information regarding the testing procedures and will be able to ask any questions regarding the test. Following, you will proceed to the water to participate in the test. To perform the hip abduction muscle test you will first be standing in a water depth of 4 feet, holding the pool wall. Then, you will be in a supine position supported with floatation devices at the ankle, waist and neck. For the shoulder flexion test, you will be in a sitting position, either leaning against the wall or in a water wheel chair. Then you will be in a side lying position supported by the wall and floatation devices at the neck and waist. To perform the abdominal test you will first be in a vertical position at a 5-6 feet depth and will be supported with a floatation device around your upper trunk. Then, at a 4-foot depth, you will be placed in a supine position supported by the investigator. In all testing positions you will be asked to perform a movement with buoyancy assisted, buoyancy supported and against manual resistance. During all testing positions you will be supported by the investigator and/or floatation devices as needed. If you feel discomfort at any time, the test will be discontinued. The session will last for 30 minutes. At the end of the session you will be informed of the results.

In session B, you will meet with the investigator to receive information regarding the testing procedures for that day. Manual muscle testing will be performed first in a quiet room and will last for 30 minutes. The land testing will include sitting, standing and side lying positions on a therapy table. After the land test, you will enter the water for the Aquatic Muscle Test that will last for 30 minutes with the same procedures as in session A. In session A you will be required to spend about 1 hour for the aquatic muscle test and on session B for about 1.5 hours for both tests. The order of sessions A and B, and the testing items (hip abduction, shoulder flexion and trunk rotation) will be interchangeable.

Both the land and water tests will take place at Easter Seals at Timpany Center in San Jose or at The Betty Wright Swim Center in Palo Alto. The study will be conducted during the months of June through January of 1999.

Benefits

The anticipated benefits from participating in this study include increased knowledge regarding your physical performance (muscle strength) in the aquatic environment and on land. In addition, you will be able to identify variation in muscle strength of one side to the other. Based on this knowledge you will be able to place emphasis on a training program that may improve muscle strength and general performance.

.....Participant's initials

The California State University:
Bakersfield, Chico, Dominguez Hills,
Fresno, Fullerton, Hayward, Humboldt,
Long Beach, Los Angeles, Maritime Academy,
Merced, San Bernardino, Pomona,
Sacramento, San Bernardino, San Diego,
San Francisco, San Jose, San Luis Obispo,
San Marcos, Sonoma, Stanislaus

San José State
UNIVERSITY

College of Applied
Sciences and Arts

Department of Human
Performance

One Washington Square
San Jose, CA 95152-0054
Voice: 408-924-3010
Fax: 408-924-3055

Risks

The risks from participating in the study include the possibility of some discomfort that you may feel during the testing sessions or fatigue at the end of the sessions.

Confidentiality

Any information that is obtained in connection with this study that can be connected with you will remain confidential and will be disclosed only with your permission or as required by law. You will not be personally identified in any reports or publications that may result from this study. Identities will be kept confidential by numbering the participants and by keeping data in the files of the investigator. Only the investigator will have access to these files.

Right to refuse or withdraw

If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty. Your decision of whether or not to participate will not effect the relationship with the investigator, your therapy environment, or San Jose State University.

Questions

If you have any questions, please feel free to ask at any time. You can contact Tova Rosen at home: (408) 377 8295. For any questions or concerns regarding your rights as a research participant or research-related injury, you may contact Serena Stanford, Ph.D., Associate Academic Vice President for graduate studies and research, at (408) 924-2480, or the Human Performance Department Chair Dr. James Bryant at (408) 924-3010, and the Committee Chair Dr. Emily Wughalter at (408) 924-3043.

Your signature indicates that you have read and understand the information provided above, that you willingly agree to participate, that you may withdraw your consent at any time and discontinue participation without penalty, that you will receive a copy of this form, and that you are waiving any legal claims, rights or remedies

Participant's Signature

Date

Investigator's Signature

Date

The California State University
Chancellor's Office
Bakersfield, Chico, Dominguez Hills,
Fresno, Fullerton, Hayward, Humboldt,
Long Beach, Los Angeles, Maritime Academy,
Merced, San Bernardino, Pomona,
Sacramento, San Bernardino, San Diego,
San Francisco, San Jose, San Luis Obispo,
San Marcos, Sonoma, Stanislaus

Personal Information

(Please print!)

Name: _____
(First) (Last)

Address: _____
(Street # or P.O. Box)

_____ (City) (State) (Zip code)

Phone Number: Home # _____

Work # _____

Participant code: _____

APPENDIX E

MEDICAL INFORMATION FORM

Medical Information Form

Participant Code: _____ **Date:** _____

Please check in the most suitable space. be accurate. specific and clear.
Information is confidential and will be used only for the research purposes.

General Information:

Date of Birth: _____ Height: _____ Weight: _____

Medical Information:

Primary diagnosis: _____

Year diagnosed: _____

Associate conditions: _____

Physician name and telephone number: _____

Mobility and assisted needed: Check one that apply to you in each category:

Walking: ()Independent ()Minimal ()Moderate ()Maximum assist.

Transfer: ()Independent ()Minimal ()Moderate ()Maximum assist.

Wheelchair: ()Not applicable ()Minimal ()Moderate ()Maximum assist.

Assistive devices: ()Braces R , L ()Prostheses ()Crutches ()Canes
()Walker ()Others _____

Can you move your arms and legs in all different directions? ()Yes ()No

Medications:

() No

() Yes: What kind? _____

When Taking? _____

What time in the day do you perform the best? _____

Communication:

Understanding English: () Yes () No

Verbally: () Verbal () Nonverbal

Hearing: () Good () Low

Aquatic experience

Attending aquatic program? () Currently () In the past () Never

Program attending: () Easter Seals at Timpany Center

() The Betty Wright Swim Center

Needs assistance in the pool? () Yes () No

Comfortable with water in the ears? () Yes () No

Contraindication conditions to water therapy: Check any of the following that apply to you:

() Chronic urinary infection

() Open wounds

() Infectious diseases

() Contagious skin rashes

() Excessive fear of water

() Unstable medical condition () Seizures () Cardiac () Respiratory

() Menses without internal protection

() Bowel incontinence

Please maintain other medical information that you think we should know about it:

In case of emergency, please contact:

Name: _____ Phone Number: _____

APPENDIX F

WAIVER OF RELEASE

WAIVER OF RELEASE

I, _____ willingly volunteer to participate in the research study of "Aquatic Muscle Testing for Individuals with Physical Disabilities" conducted by Tova Rosen (graduate student at San Jose State University) and thereby release The Betty Wright Swim Center at C.A.R of any / all responsibility of my well being.

Signature: _____

Date: _____

APPENDIX G
FACE VALIDITY PACKAGE

*Aquatic Muscle Test (AMT)
for Individuals with Physical
Disabilities*

Face Validity Package

*Presented by
Tova Rosen
Graduate Student
Department of Human Performance
San Jose State University*

May, 1998

Tova Rosen
P.O. Box 872
Saratoga, CA 95071
Home phone: (408) 868-9589
Work phone: (408) 295-0228 ext.222
E-mail: trosen@email.sjsu.edu

Expert address:

Dear Expert:

I am a graduate student majoring in Adapted Physical Activity in the Department of Human Performance at San Jose State University, California. Presently, I am working on my Master's thesis research, "Development of Aquatic Muscle Test (AMT) for Persons with Neuromuscular Disorders".

In my research, there will be two types of measurement validity. The first will be concurrent validity, measured by comparing AMT in water to a standard land muscle test (Manual Muscle Testing [Daniels, et al., 1980]). The second type will be face validity and will be measured by sending a description of the AMT tests for review by five experts in the field of aquatic therapy and adapted aquatics. I have selected you as one of these experts. I hope you will consider reviewing my work.

Enclosed is a package of information with descriptions of the AMT test protocols and principles. I ask that you review three muscle tests: hip abduction, shoulder flexion and trunk rotation. These muscle tests have been chosen to represent movements of the upper / lower extremities and trunk in three different planes of movement that require various positions in the water.

For effective feedback, I have also enclosed a short questionnaire. Please feel free to E-mail or call me if you have any questions regarding the test items.

I truly appreciate your time and cooperation. If it is convenient for you, it would be very helpful if I could receive your review within the next week.

Thank you.

Tova Rosen

Aquatic Muscle Test (AMT) for Individuals with Physical Disabilities

Introduction

Aquatic rehabilitation is frequently used as a medium in the physical rehabilitation of individuals with progressive and non-progressive disabling conditions. An aquatic setting provides an ideal environment that encourages freedom of movement and the attainment of mobility skills by these individuals.

With the increasing popularity of aquatic rehabilitation, practical knowledge and skills are necessary to design an appropriate aquatic program. This begins by gathering information regarding a client's functional ability. An aquatic assessment test should be used to evaluate a client's performance for developing program goals and objectives. Since there is no such a test, Aquatic Muscle Test (AMT) was developed to fill this need.

What is Aquatic Muscle Test?

AMT is currently in the field-development stage. It is an assessment tool that measures **muscle strength within range of motion** in the aquatic environment. It is a Criterion-Referenced test to be used with physically challenged individuals.

AMT is based upon modifications of "Manual Muscle Testing" on land (Daniels et al., 1980). AMT is a subjective test based on a grading system from 0 to 8. Movement performed in progressive order from buoyancy assisted to buoyancy supported, and lastly in the most stable position and against examiner manual resistance.

The Purposes of the AMT

To gather accurate information about the client's muscle strength within their range of motion in the aquatic environment.

Based on the test results the aquatic therapist / instructor can:

1. Develop objectives of treatment (treatment program);
2. Evaluate the client's progress throughout the program; and
3. Estimate the effectiveness of aquatic rehabilitation.

It is important to note that AMT is intended to be used in conjunction with a land evaluation. While land evaluation provides land-based goals, AMT results apply directly into instructional planning.

Finally, AMT is designed to provide immediate feedback from which individuals with disabilities can experience success, thus improving their confidence, morale, and increasing participation in aquatic rehabilitation.

AMT Grading System

AMT is based on a numerical grading system from 0 to 8.

Movement (active assisted ROM) while buoyancy assisted

- 0 – No ability or evidence of muscles contraction.
- 1 – The ability to initiate a flicker movement that is visual or palpable.
- 2 – The ability to move the body part into partial available range of motion while buoyancy assisted
- 3 – The ability to move the body part into full available range of motion while buoyancy assisted.

Movement (active ROM) while buoyancy supported

- 4 – The ability to move the body part into partial available range of motion while buoyancy supported.
- 5 – The ability to move the body part into full available range of motion while buoyancy supported.

Movement against manual resistance and buoyancy in the most stable position*

- 6 – The ability to move the body part into full available range of motion while buoyancy assisted / supported / resisted, holding it for less than 3 sec against light manual resistance.
- 7 – The ability to move the body part into full available range of motion while buoyancy /assisted / supported / resisted, holding it for 3-5 sec against moderate manual resistance.
- 8 – The ability to move the body part into full available range of motion while buoyancy assisted / supported / resisted, holding it for 3-5 sec against maximum manual resistance

The highest grade achieved is marked on an examination record sheet

* In grades 6,7, and 8 muscle strength is measured against examiner manual resistance. This requires adequate stabilization for both the examiner and the client.

To ensure accuracy of results for each muscle testing, a test protocol was designed with the most stable position (assisted / supported / resisted). We found that once manual resistance is applied to the body part, the effect of buoyancy is unimportant.

Strength Test

Without manual resistance, AMT measures isotonic muscle action. However, when manual resistance is given, an isometric contraction is being tested. AMT is defined as a “break test” during which a client actively holds the body part in a prescribed position while the examiner attempts to “break” the hold by a manual counter force.

When interpreting the test result for instructional planning, it is important to be aware of the type of muscle contraction being tested.

Subjective Test

Since AMT is a subjective test the test grading relies largely on the examiner's judgment. To ensure accurate measurements the examiner should develop an in-depth knowledge of kinesiology as well as hands-on skills such as muscle and tendon palpation, detection of compensatory movements and also awareness of how positioning influences the effects of the water on the body.

Criterion - Referenced Test

AMT is a Criterion – Referenced test. This is described by Werder and Kalakain (1985) as "A test to compare a student's motor performance to some predetermined criterion, rather than to the performance of other student" (p.59). AMT intends to measure the client's muscle strength at the beginning of the program and evaluate his/her progress throughout the aquatic rehabilitation. Also, AMT compares deviation in performance of one side of the body to the other, hence, allowing the therapist to gather valuable information for instructional planning

Ecological Valid Instrument

AMT is designed to meet the need for an ecologically valid test. Bricker (1989) indicated that such a test should be sensitive to the testing environment. The interpretation of this measurement should correspond closely to the curriculum objectives (Zittel, 1994). AMT test results link directly into instructional planning.

AMT Principles and Guidelines

To ensure that the findings of the examination are reproducible, AMT requires attention to positioning, stabilization, trick movements and application of resistance. Standardization of the test procedures and principles is important for meaningful results during serial testing of a client.

How to Apply the Resistance?

Manual resistance is applied to determine grades 6, 7, and 8. It is most important that the examiner is familiar with how to apply the resistance. Application of resistance in any other way will significantly affect the validity and reliability of the test.

Guidelines for application of resistance are:

- 1) Resistance is given at the end of range of motion.
- 2) Pressure should be exerted in the opposite direction to the line of pull of the muscle being tested.
- 3) Resistance is given near the distal-end of the segment to which the muscle inserts.

- 4) Pain should not be elicited (in case of discomfort or pain the resistance should be discontinued).
- 5) The amount of resistance applied by the examiner should be gradual to the force exerted by the client.
- 6) The amount of resistance required for the higher grades vary with the client's age and gender as well as the muscle is being examined.
- 7) Resistance should be given for 3-5 seconds.

Trick Movements

When a muscle or muscle group attempts to compensate for the lack of function of a weak or paralyzed muscle the result is a substitution movement, or what is called a trick movement. Trick movements can be caused by either 1) muscle substitution (for example, lateral rotation of the hip during hip abduction may be assisted by the Tensor fasciae latae muscle) or, 2) mechanical compensation (for example, leaning backwards during a shoulder flexion test to generate momentum transfer to help the muscle do the movement).

For accurate muscle examination, no trick movements should be permitted. In cases when trick movements cannot be eliminated, it must be documented in the client's test report. In some cases it is an indication of functional postural deviation or factors other than muscle weakness.

Positioning

Attention to position is important in two respects: 1) to best accomplish the desired test with concern to rules and principles related to testing, and 2) to ensure the comfort and safety of a client.

Stabilization

Stabilization should be of great concern when assessments are made in the aquatic environment. Fixation and support proximally to the tested part are necessary to isolate the desired action. The stationary segment must be fixed by muscle tension or by external pressure. For example, when the examiner applies counter-pressure on a client towards the pool wall when in side lying position, stabilization will prevent synergist action and muscle substitution. For effectiveness stabilization and personal safety the examiner must stand close to the client, stay low and keep his/her body stable.

Standardization of Procedures

To ensure that the findings of the test are reproducible, standardization of the test procedures must be maintained.

Standardization of procedures include:

- 1) **Water temperature.** The ideal water temperature for AMT is 88-92° F. The warmth of the water has tremendous effects on the body's capabilities, thereby, it is important to

record any change in water temperature during serial testing. Testing are not recommended in cold water as it creates discomfort and causes the clients to respond by tensing their muscles.

- 2) **Speed of the movement.** The speed of the movement may affect the ability to move the body part through range of motion. Instructions should be given to perform a slow movement in order to overcome the influences of water resistance.
- 3) **Equipment.** There is no use of equipment on the body part being tested. Equipment may be used to stabilize the body in the test position. Any kind of equipment that meets this need is appropriate. However, the same equipment should be used in serial testing of a client to prevent discomfort that may affect the results.
- 4) **Depth of the water.** Water depth should be at waist level for the shallow water tests. At this depth, the examiner is better able to stabilize the body and to give resistance. All body parts being tested should be immersed in water.
- 5) **Timing.** The day of the test, the time of day and, whether the test is given after physical activity can influence the test results. The examiner should be consistent in timing during a serial testing
- 6) **Instruction.** Prior to entering the water it is necessary to explain to the client the purpose of the tests and to give some general instructions regarding test procedure. Since the pool environment can be very noisy and distracting, instructions should be given loudly and clearly and kept simple. The examiner should encourage the client to demonstrate her/his best performance. If needed, allows three repetitions of each action and record the best one.
- 7) **Modifications.** When testing persons with disabilities, adaptation and modification may be necessary. One such case would be when a client is required to stabilize his/her upper body by holding the pool wall while the examiner tests the lower body extremities. If the client lacks the upper body strength to do this, an attendant may stabilize the client's body. It is important that such modifications be done in a way that will not affect the test results. Any/all modifications must be documented.

Aquatic Muscle Testing

(AMT)

Test Protocols

- *Hip Abduction*
- *Shoulder Flexion to 90°*
- *Trunk Rotation*

*Photographs by
Carl D. Johnson*

*Please note: Pictures were taken with able-body person for better demonstration
of the test protocols*

Hip Abduction – Test Protocol

Muscle = Gluteus Medius

ROM = 0 to 45 degrees

AMT – hip abduction

Movement while Buoyancy Assisted

Test position: Standing, with side to the wall, holding the wall with one hand. Tester stands behind the client, stabilizing pelvis, with hand on muscle being tested.

Test action: client abducts leg through range of motion (without allowing rotation).

Test grades:

0. No evidence of muscle contraction (hip abduction).
1. Client initiates a flicker movement of hip abduction that is visual or palpable.
2. Client abducts leg into *partial* range of motion while buoyancy assisted.
3. Client abducts leg into *full* range of motion while buoyancy assisted.

If client achieves grades in buoyancy assisted position, continue testing in buoyancy supported position. Otherwise, discontinue the test and mark the highest grade achieved.

Cont... AMT – hip abduction

Movement while Buoyancy Supported

Test position: Supine, holding pool wall above the head. Flotation device supporting neck/pelvis and left ankle (when testing right leg). Tester stands at the client's left side and stabilizes his/her pelvis.

Test action: The client abducts right leg into full range of motion while buoyancy supports the leg. Tester gives resistance on lateral side above the knee.

Test grades:

4. Client abducts right leg into *partial* range of motion while buoyancy supported.
5. Client abducts right leg into *full* range of motion while buoyancy supported.

If client achieves grades in buoyancy supported position, continue testing in buoyancy supported with manual resistance position. Otherwise, discontinue the test and mark the highest grade achieved.

Movement Against Manual Resistance while Buoyancy Supported

Test position: Supine, holding pool wall above the head. Flotation device supporting neck pelvis and left ankle (when testing right leg). Tester stands at the client left side and stabilizes his/her pelvis.

Test action: The client abducts right leg into full range of motion while buoyancy supports the leg. Tester gives resistance on lateral side above the knee.

Test grades:

6. Client abducts right leg into full range of motion and holds it less than 3 seconds, while buoyancy supported, against *light* manual resistance.
7. Client abducts right leg into full range of motion and holds it for 3-5 seconds, while buoyancy supported, against *moderate* manual resistance.
8. Client abducts right leg into full range of motion and holds it for 3-5 seconds, while buoyancy supported, against *maximum* manual resistance.

Hip Abduction – Test Notes

Trick movements:

- Lateral rotation of the hip (hip flexor and abdominal may substitute).
- Pelvis moves towards thorax (contraction of lateral trunk muscles).
- Abduction of the opposite leg (when stabilization is not maintained).

Shoulder Flexion to 90°–Test Protocol

Muscles = Deltoideus (anterior fibers) & coracobrachialis

ROM = 0 to 90°

AMT – shoulder flexion to 90°

Movement while Buoyancy Assisted

Test position: Sitting in a water wheel chair or Semi-sitting against the wall. Tester stands to the client's tested side to stabilize scapula.

Test action: client flexes arm to 90° range of motion (palm is facing down).

Test grades:

0. No evidence of muscle contraction (shoulder flexion).
1. Client initiates a flicker movement of shoulder flexion that is visual or palpable.
2. Client flexes arm into *partial* range of motion while buoyancy assisted
3. Client flexes arm into *full* range of motion while buoyancy assisted.

If client achieves grades in buoyancy assisted position, continue testing in buoyancy supported position. Otherwise, mark the highest grade achieved and discontinue the test.

Cont... AMT – shoulder flexion to 90°

Movement while Buoyancy Supported

Test position and action:

Side-lying, back to the wall, holding pool wall with the upper hand. Flotation device supporting neck and pelvis. Tester stabilizes downward shoulder to the wall. Client flexes arms to 90 degrees with thumb pointing up.

Test grades:

4. Client flexes arm into *partial* range of motion while buoyancy supported.
5. Client flexes arm into *full* range of motion while buoyancy supported.

If client achieves grades in buoyancy supported position, continue testing in buoyancy supported with manual resistance position. Otherwise, discontinue the test and mark the highest grade achieved.

Cont... AMT – shoulder flexion to 90°

Movement Against Manual Resistance while Buoyancy Assisted

Test position: Client sits in a water chair or semi-sitting against the wall. Shoulder immersed in water. Tester stands to the client's tested side to stabilize the scapula.

Test action: Client flexes arm into full range of motion while buoyancy assisted. The palm is facing down. Client should not be allowed to rotate or abduct the arm. Tester gives resistance above the elbow.

Test grades:

6. Client flexes arm into full range of motion and holds it less than 3 seconds, while buoyancy assisted, against *light* manual resistance.
7. Client flexes arm into full range of motion and holds it for 3-5 seconds, while buoyancy assisted, against *moderate* manual resistance.
8. Client flexes arm into full range of motion and holds it to 3-5 seconds, while buoyancy assisted, against *maximum* manual resistance.

Shoulder Flexion to 90° - Test Notes

Trick movements:

- With external rotation of the arm, the long head of the biceps muscle is helping to achieve shoulder flexion.
- Leaning backward or arching the trunk to achieve shoulder flexion.

Trunk Rotation– Test Protocol

*Muscles = Rotation to right: left External Oblique & right Internal Oblique.
Rotation to the left is brought about the opposite muscles.*

ROM = 45 degrees rotation with knees 90° bend to chest.

AMT – trunk rotation

Movement while Buoyancy Assisted

Test position: Client vertically supported by flotation device around the shoulders in the deep-end, holding the wall with both hands (corner preferred). Tester is standing behind the client, holding the trunk to feel the movement.

Test action: Client flexes both legs to 90 degrees. Then rotates trunk toward shoulder. (Instruction: “bring both knees toward chest and rotate toward right shoulder” when left external oblique and right internal oblique being tested).

Test grades:

0. No evidence of muscle contraction (trunk rotation).
1. Client initiates a flicker movement of trunk rotation that is palpable.
2. Client rotates trunk into *partial* range of motion while buoyancy assisted.
3. Client rotates trunk into *full* range of motion while buoyancy assisted.

If client achieves grades in buoyancy assisted position, continue testing in buoyancy supported position. Otherwise, discontinue the test and mark the highest grade achieved.

Cont... AMT – trunk rotation

Movement while Buoyancy Supported

Test position: Supine, both hands holding the pool wall above the head. Flotation device supports the neck. Tester stands behind the client's tested side, holds the trunk and ensures movement under water.

Test action: The client flexes both legs to 90 degrees (towards the chest). Then, rotates the trunk into full available range of motion while buoyancy supported

Test grades:

4. Client rotates trunk into *partial* range of motion while buoyancy supported.
5. Client rotates trunk into *full* range of motion while buoyancy supported.

If client achieves grades in buoyancy supported position, continue testing in buoyancy supported with manual resistance position. Otherwise, mark the highest grade achieved and discontinue the test.

Cont... AMT – trunk rotation

Movement Against Manual Resistance while Buoyancy Supported

Test position: Supine, both hands holding the pool wall above the head. Flotation device supports the neck. Tester stands behind the client's tested side, holds the trunk and ensures movement under water.

Test action: The client flexes both legs to 90 degrees (towards the chest). Then, rotates the trunk into full available range of motion while buoyancy supported. Resistance is given at the thighs of both legs closer to the abdominal muscles.

Test grades:

6. Client rotates trunk into full range of motion and holds it less than 3 seconds, while buoyancy supported, against *light* manual resistance.
7. Client rotates trunk into full range of motion and holds it for 3-5 seconds, while buoyancy supported, against *moderate* manual resistance.
8. Client rotates trunk into full range of motion and holds it to 3-5 seconds, while buoyancy supported, against *maximum* manual resistance.

Name..... Date.....

Aquatic Muscle Test Review Face Validity Questionnaire

Direction: please rate and fill out the following questions using this scale:
1 = Strongly Disagree; **2** = Disagree; **3** = Moderate; **4** = Agree; **5** = Strongly Agree.

1. There is a need for aquatic assessment tests for designing an aquatic exercise program.

1 2 3 4 5

.....

2. The proposed AMT procedure is related directly for assessing muscle strength within range of motion in the aquatic environment.

1 2 3 4 5

.....

3. Based on the test result, you would be able to:

a) Develop objectives for treatment (prescribe the appropriate aquatic exercises);

1 2 3 4 5

.....

b) Evaluate the client progress;

1 2 3 4 5

.....

c) Estimate the effectiveness of the aquatic treatment.

1 2 3 4 5

.....

4. State 3 advantages in the use of the AMT.

1.....
 2.....
 3.....

5. State 3 disadvantages in the use of the AMT.

1.....
 2.....
 3.....

6. Do you have any comments, recommendation or other concerns in regard to the AMT?.....

.....

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APPENDIX H
ILLUSTRATED PROTOCOLS

AMT - Hip Abduction**Muscle = Gluteus Medius****ROM = 0 to 45 degrees**

- 0. No evidence of hip abduction.
- 1. Subject initiates a flicker movement of hip abduction that is visual or palpable.
- 2. Subject abducts leg into **partial** ROM.
- 3. Subject abducts leg into **full** ROM.

Buovancy assisted **Buovancy supported**

- 4. Subject abducts leg into **partial** ROM.
- 5. Subject abducts leg into **full** ROM.

Buovancy supported & manual resistance

- 6. Subject abducts leg into full ROM and holds it less than 3 seconds against **light** resistance.
- 7. Subject abducts leg into full ROM and holds it for 3-5 seconds against **moderate** resistance.
- 8. Subject abducts leg into full ROM and holds it for 3-5 seconds against **maximum** resistance.

AMT – Shoulder flexion to 90°

Muscles = Deltoides (anterior fibers) & coracobrachialis
ROM = 0 to 90 degrees

0. No evidence of shoulder flexion.
1. Subject initiates a flicker movement of shoulder flexion that is visual or palpable.
2. Subject flexes arm into **partial** ROM.
3. Subject flexes arm into **full** ROM.

Buoyancy assisted

Buoyancy supported

4. Subject flexes arm into **partial** ROM.
5. Subject flexes arm into **full** ROM.

Buoyancy assisted & manual resistance

6. Subject flexes arm into full ROM and holds it less than 3 seconds against **light** resistance.
7. Subject flexes arm into full ROM and holds it for 3-5 seconds against **moderate** resistance.
8. Subject flexes arm into full ROM and holds it for 3-5 seconds against **maximum** resistance.

AMT – Trunk Rotation

Muscles = Rotation to right: left Obliquus externus & right Obliquus internus. Rotation to the left is brought about the opposite muscles.

ROM = Rotation with hip bent to 90 degrees.

Buovancy assisted

0. No evidence of trunk rotation.
1. Subject initiates a flicker movement of trunk rotation that is visual or palpable.
2. Subject rotates trunk into **partial** ROM.
3. Subject rotates trunk into **full** ROM.

Buovancy supported

4. Subject rotates trunk into **partial** ROM.
5. Subject rotates trunk into **full** ROM.

Buovancy supported & manual resistance

6. Subject rotates trunk into full ROM and holds it less than 3 seconds against **light** resistance.
7. Subject rotates trunk into full ROM and holds it for 3-5 seconds against **moderate** resistance.
8. Subject rotates trunk into full ROM and holds it for 3-5 seconds against **maximum** resistance.

MMT - Hip Abduction

Muscle = Gluteus Medius

ROM = 0 to 45 degrees

Gravity Eliminated

- 1: 0. No evidence of hip abduction.
- 2: 1. Subject initiates a flicker movement of hip abduction that is visual or palpable.
- 3: 1+. Subject abducts leg **less than** ½ ROM.
2-. Subject abducts leg **more than** ½ ROM.
- 4: 2. Subject abducts leg into **full** ROM.

Against Gravity

- 5: 2+. Subject abducts leg **less than** ½ ROM.
3-. Subject abducts leg **more than** ½ ROM.
- 6: 3. Subject abducts leg into **full** ROM.

Against Gravity & Manual Resistance

- 7: 3+. Subject abducts leg into full ROM and holds it against **minimal** resistance.
- 4-. Subject abducts leg into full ROM and holds it against **less than moderate** resistance.
- 8: 4. Subject abducts leg into full ROM and holds it against **moderate** resistance.
- 9: 4+ Subject abducts leg into full ROM and holds it against **more than moderate** resistance.
- 5-. Subject abducts leg into full ROM and holds it against **less than maximum** resistance.
- 10: 5. Subject abducts leg into full ROM and holds it against **maximum** resistance.

MMT - Shoulder flexion to 90°

Muscles = Deltoides (anterior fibers) & coracobrachialis

ROM = 0 to 90 degrees

Gravity Eliminated

- 1: 0. No evidence of arm flexion.
- 2: 1. Subject initiates a flicker movement of arm flexion that is visual or palpable.
- 3: 1+. Subject flexes arm **less than** ½ ROM.
2-. Subject flexes arm **more than** ½ ROM.
- 4: 2. Subject flexes arm into **full** ROM.

Against Gravity

- 5: 2+. Subject flexes arm **less than** ½ ROM.
- 3-. Subject flexes arm **more than** ½ ROM.
- 6: 3. Subject flexes arm into **full** ROM.

Against Gravity & Manual Resistance

- 7: 3+. Subject flexes arm into full ROM and holds it against **minimal** resistance.
- 4-. Subject flexes arm into full ROM and holds it against **less than moderate** resistance.
- 8: 4. Subject flexes arm into full ROM and holds it against **moderate** resistance.
- 9: 4+ Subject flexes arm into full ROM and holds it against **more than moderate** resistance.
- 5-. Subject flexes arm into full ROM and holds it against **less than maximum** resistance.
- 10: 5. Subject flexes arm into full ROM and holds it against **maximum** resistance.

MMT – Trunk Rotation

Muscles = Rotation to right: left Obliquus externus & right Obliquus internus. Rotation to the left is brought about by the opposite muscles.

ROM = rotation of thorax is possible until scapula on side of forward shoulder is raised from table.

Gravity Eliminated

0: No evidence of trunk rotation.

1: Subject attempts to approximate thorax on left and pelvic on right that is visual or palpable.

2: Subject rotates thorax.

Against Gravity

3: Scapula on forward shoulder is only raised from table

4: Scapula on forward shoulder is raised from table and other partially raised.

Against Gravity

5: Subject rotates and flexes thorax to one side

APPENDIX I
GRADING SYSTEM

AMT Grading System

AMT is based on a numerical grading system from 0 to 8.

Movement (active assisted ROM) while buoyancy assisted

0 – No ability or evidence of muscles contraction.

1 – The ability to initiate a flicker movement that is visual or palpable.

2 - The ability to move the body part into partial available range of motion while buoyancy assisted

3 – The ability to move the body part into full available range of motion while buoyancy assisted.

Movement (active ROM) while buoyancy supported

4 – The ability to move the body part into partial available range of motion while buoyancy supported.

5 – The ability to move the body part into full available range of motion while buoyancy supported.

Movement against manual resistance and buoyancy in the most stable position*

6 - The ability to move the body part into full available range of motion while buoyancy assisted / supported / resisted. holding it for less than 3 sec against light manual resistance.

7 - The ability to move the body part into full available range of motion while buoyancy /assisted / supported / resisted. holding it for 3-5 sec against moderate manual resistance.

8 – The ability to move the body part into full available range of motion while buoyancy assisted / supported / resisted. holding it for 3-5 sec against maximum manual resistance

The highest grade achieved is marked on an examination record sheet

* In grades 6, 7, and 8 muscle strength is measured against examiner manual resistance. This requires an adequate stabilization for both the examiner and the client.

To ensure accuracy of results for each muscle testing, a test protocol was designed with the most stable position (assisted / supported / resisted). We found that once a manual resistance applies to the body part, the effect of buoyancy is unimportant.

MMT Grading System
(Daniels et al., 1980)

1	0. <u>No contraction</u>
2	1. <u>Slight contraction (flicker movement) visual or palpable</u>
3	1+ With gravity eliminated, less than half ROM
2- With gravity eliminated, more than half ROM
4	2. <u>With gravity eliminated, full ROM</u>
5	2+ Against gravity, less than half ROM
3- Against gravity, more than half ROM
6	3. <u>Against gravity, full ROM</u>
7	3+ Against gravity, minimal manual resistance
4- Less than moderate manual resistance against gravity
8	4. <u>Moderate manual resistance against gravity</u>
9	4+ More than moderate manual resistance against gravity
5- Less than maximum manual resistance against gravity
10	5. <u>Maximum manual resistance against gravity</u>

Grading principles

In grades 4 and 5, for a greater or lesser amount of resistance plus or minus grades will be used. In grades 3, 2, and 1, more than half ROM will be marked with plus, less than half ROM will be marked with minus.

APPENDIX J

EXAMINATION RECORD SHEET

AMT - EXAMINATION RECORD SHEET

Participant #: _____ Date: _____ Time: _____
Muscle testing: **AMT** Session: _____ Number on RPE scale: _____ Water temperature: _____
Equipment use: _____
Adaptation: _____

<u>LEFT</u>	<u>Hip Abduction</u>	<u>RIGHT</u>
0 1 2 3 / 4 5 / 6 7 8		0 1 2 3 / 4 5 / 6 7 8
<u>Comments:</u>		

<u>Shoulder Flexion to 90°</u>
0 1 2 3 / 4 5 / 6 7 8
<u>Comments:</u>

<u>Trunk Rotation</u>
0 1 2 3 / 4 5 / 6 7 8
<u>Comments:</u>

MMT - EXAMINATION RECORD SHEET

Participant #:	Date:	Time:
Muscle testing: MMT	Session:	Number on RPE scale:
Equipment use:		
Adaptation:		

<u>LEFT</u>	<u>RIGHT</u>
<u>Hip Abduction</u>	
0 1 1+2- 2 / 2+3- 3 / 3+4- 4 4+5- 5	0 1 1+2- 2 / 2+3- 3 / 3+4- 4 4+5- 5
1 2 3 4 / 5 6 / 7 8 9 10	1 2 3 4 / 5 6 / 7 8 9 10
Comments:	

<u>Shoulder Flexion to 90°</u>	
0 1 1+2- 2 / 2+3- 3 / 3+4- 4 4+5- 5	0 1 1+2- 2 / 2+3- 3 / 3+4- 4 4+5- 5
1 2 3 4 / 5 6 / 7 8 9 10	1 2 3 4 / 5 6 / 7 8 9 10
Comments:	

<u>Trunk Rotation</u>	
1 2 3 4 5	1 2 3 4 5
Comments:	

APPENDIX K

MODIFIED RPE SCALE

MODIFIED RPE SCALE

Participant Number:

Grade	Physical Condition	Date	Date	Date
1				
2	Very, very weak			
3				
4	Very, weak			
5				
6	Fairly weak			
7				
8	Somewhat good			
9				
10	Good			
11				
12	Very good			
13				
14	Very, very good			

Note. Modified from Guidelines for exercise testing and prescription (4th ed.). (p. 70). by American College of Sport Medicine, 1991. Philadelphia: Lea & Febiger.

APPENDIX L

RAW DATA

Table L1.

Raw Data – AMT1 and AMT2

Participant #	AMT1						AMT2					
	Hip		Shoulder		Trunk		Hip		Shoulder		Trunk	
	L	R	L	R	L	R	L	R	L	R	L	R
1	7	1	7	1	4	4	7	1	7	1	4	4
2	8	8	8	7	7	7	7	8	8	8	7	7
3	7	7	7	6	2	2	7	7	7	6	2	2
4	7	8	7	7	7	7	6	7	7	7	7	7
5	8	8	7	7	7	7	8	8	7	7	7	7
6	7	8	8	8	8	8	7	8	8	8	8	8
7	7	6	6	7	7	6	7	6	6	6	7	6
8	5	6	5	6	5	6	5	6	5	6	5	6
9	8	7	7	7	7	6	8	7	7	7	7	6
10	8	8	7	7	7	7	8	8	8	7	7	7
11	6	7	2	7	4	4	6	7	2	7	5	5
12	6	7	6	8	6	7	6	7	6	7	6	7
13	7	7	7	6	7	7	7	7	7	6	7	7
14	6	7	7	7	7	7	7	7	7	6	7	7
15	7	8	7	7	7	7	8	7	6	6	7	7
16	7	7	7	6	7	6	6	7	7	6	6	6
17	7	6	7	6	5	5	7	6	7	6	6	6
18	7	4	7	2	4	4	7	4	7	2	4	4
19	7	7	7	7	7	7	7	7	7	6	7	7
20	7	6	7	6	7	6	6	7	6	6	7	7
21	7	6	6	7	7	7	7	6	6	6	7	7
22	7	6	8	4	6	4	7	6	8	2	7	5
23	2	5	1	6	4	4	1	6	1	6	4	4

Table L2.

Raw Data - AMT and MMT

participant #	AMT1						MMT					
	<u>Hip</u>		<u>Shoulder</u>		<u>Trunk</u>		<u>Hip</u>		<u>Shoulder</u>		<u>Trunk</u>	
	L	R	L	R	L	R	L	R	L	R	L	R
1	7	1	7	1	4	4	8	2	9	2	4	4
2	8	8	8	7	7	7	9	8	9	8	4	4
3	7	7	7	6	2	2	7	7	7	7	3	3
4	7	8	7	7	7	7	8	9	9	9	4	4
5	8	8	7	7	7	7	10	10	9	9	4	4
6	7	8	8	8	8	8	9	10	10	10	5	5
7	7	6	6	7	7	6	7	5	7	7	3	3
8	5	6	5	6	5	6	6	6	6	6	1	2
9	8	7	7	7	7	6	8	8	8	7	4	4
10	8	8	7	7	7	7	8	8	8	7	4	4
11	6	7	2	7	4	4	5	8	2	8	3	4
12	6	7	6	8	6	7	6	8	6	8	3	4
13	7	7	7	6	7	7	8	8	8	7	5	4
14	6	7	7	7	7	7	7	6	8	8	3	3
15	7	8	7	7	7	7	7	7	7	7	5	5
16	7	7	7	6	7	6	5	5	7	7	3	3
17	7	6	7	6	5	5	9	6	9	7	3	3
18	7	4	7	2	4	4	9	5	9	2	4	4
19	7	7	7	7	7	7	8	7	7	8	4	4
20	7	6	7	6	7	6	7	8	7	7	4	4
21	7	6	6	7	7	7	8	7	9	9	5	5
22	7	6	8	4	6	4	7	6	10	2	5	5
23	2	5	1	6	4	4	3	6	1	7	3	3

IMAGE EVALUATION TEST TARGET (QA-3)

APPLIED IMAGE, Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989

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