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Role of an Aquatic and Non Aquatic Environment on Trunk Muscle Activation

Jeanne P. VandenBerg
Utah State University

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ROLE OF AN AQUATIC AND NON AQUATIC ENVIRONMENT ON TRUNK MUSCLE ACTIVATION

by

Jeanne P. VandenBerg

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Health and Human Movement

Approved:

Dr. Dennis Dolny Major Professor	Dr. Eadric Bressel Committee Member
Brian Larsen, DPT Committee Member	Byron R. Burnham Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

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ABSTRACT

Role of an Aquatic and Non Aquatic Environment on Trunk Muscle Activation

by

Jeanne P. VandenBerg, Master of Science

Utah State University, 2011

Major Professor: Dr. Dennis Dolny
Department: Health, Physical Education and Recreation

Low back pain (LBP) is a widespread problem affecting a number of people. Traditionally treated by nonoperative approaches the recent development of water currents and treadmills imbedded into pools has spurred physical therapists and athletic trainers to incorporate the use of aquatic therapy into their rehabilitation programs. OBJECTIVE: Determine if select trunk muscle activity levels are different in water-based exercises compared to land-based exercises. METHODS: 11 healthy male participants age 25.9 ± 5.53 years, whom did not have a history of and were not currently experiencing LBP or injury. Muscle activity was monitored via electromyography (EMG) at the rectus abdominis (RA), external oblique (EO), lower abdominals (LA), erector spinae (ES), and lumbar multifidis (MT). Each subject performed (1) maximum voluntary contractions (MVC's), (2) land-based exercises, and (3) water-based exercises. A paired samples *t* test was used to compare abdominal bracing (ABbrace), abdominal hallowing (ABhol), Anterior/Posterior pelvic tilts (APTilts), and lateral pelvic tilts (LatTilts) between comparable land and water conditions; general linear model-repeated measures was run to compare the 11 different water exercises; ABbrace, ABhol, APTilts, LatTilts, physioball push down (PBPushDown), PB lateral flexion, PB transverse rotations, stationary marching, leg abduction, and wall sits with sagittal and transverse plane arm movements. Follow-up multiple comparisons (LSD) were performed between water exercises using a Holm's corrected alpha level set at 0.05. RESULTS: Land-based exercises elicited greater EMG activity compared to water-based activities for all muscles (%MVC land vs. %MVC water): RA %MVC (8.3-19.3 vs. 2.1-9.7, P = .003-.029); LA %MVC (27-105 vs. 5.2-25, *P* = .001-.016); EO %MVC (13-59 vs. 4.8-24.5, *P* = .001-.303); ES %MVC (19.1-37.6 vs. 7.75-22.1, *P* = .001-.039) and MT %MVC (16-25.4 vs. 5.9-8.8, *P* = .00-.005). For water comparison ABbrace and PB exercises produced the most muscle activity while WallSitSag/Trans consistently produced the least muscle activity. CONCLUSION: Even with reduced muscle activity in the water, the calculated % mean MVCs were high enough (at or below 25% MVC) to provide muscle endurance and stability gains. With the information provided from the analysis of water exercise comparison, practitioners can effectively progress patients through a rehabilitation program.

(62 pages)

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Jeanne P. VandenBerg, LAT, ATC

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CHAPTER I

INTRODUCTION

Considered one of the leading causes of disability (Hayden, van Tulder, Malmivaara, & Koes, 2005), it has been reported that low back pain (LBP), lasting for one entire day, has afflicted at least 25% of the adult population in the United States within a 3 month time span, which may be why LBP is estimated as the fifth most common reason for persons to visit a physician (Chou et al., 2007). Researchers have identified three levels of LPB: acute, sub-acute and chronic (Akuthota, Ferreiro, Moore, & Fredericson, 2008; Hibbs, Thompson, French, Wrigley, & Spears, 2008) while analyzing muscle activation patterns, muscle activation during exercise performance, & the effects of treatment programs on pain and disability levels of patients compared to healthy participants (Akuthota et al., 2008; Dundar, Solak, Yigit, Evcik, & Kavuncu, 2009; Hibbs et al., 2008; Koumantakis, Watson, & Oldham, 2005; Santaella da Fonseca Lopes de Sousa, Orfale, Merieles, Leite, & Natour, 2009). Among these studies, variables were measured using a combination of different tools including; biofeedback, electromyography (EMG), force measurements, verbal feedback, journals and questionnaires. Recent research has concluded that core strength and core stability may help relieve/alleviate signs and symptoms of LBP (Akuthota et al., 2008; Hibbs et al., 2008; Koumantakis et al., 2005), thus it is generally accepted that the first step in treating patients with low back pain is through exercise whether through professional care or self-care options. Unfortunately research has also provided conflicting results regarding the proper exercise and lack the ability to establish a consensus for rehabilitation protocols for LBP sufferers. It is suggested, however, that a combination of endurance, strength and functional training (high and low threshold) exercises - depending on the patient's status – should be used as this leads to greater immediate and long term results (Akuthota et al., 2008; Hibbs et al., 2008; McGill, Grenier, Kavcic, & Cholewicki, 2003; Vezina & Hubley-Kozey, 2000).

Aquatic exercise has been gaining popularity in both the exercise and rehabilitation realms. In addition to offering traditional lap swimming, commercial, private and university facilities offer aqua aerobics and other aquatics classes. These classes are geared towards both men and women, of all ages. Recently, with the development of water currents and treadmills imbedded into pools, physical therapists and athletic trainers have increasingly incorporated the use of aquatic therapy into their rehabilitation programs.

There are many reasons why aquatic exercise may be beneficial. It offers variety from the traditional exercises and rehabilitation routine, is less intimidating, plus advancements in technology have allowed fitness personnel to expand its uses and reap greater rehabilitative benefits; for injured athletes, post operative rehabilitation and LBP rehabilitation (Dundar et al., 2009; Waller, Lambeck, & Daly, 2009). For rehabilitation professionals and researchers the greatest importance rests on the physiological and orthopaedic benefits that aquatic rehabilitation can offer; benefits that are possible due to two main characteristics of water, buoyancy and drag forces. Water provides buoyancy, which allows for a decrease in apparent body weight, while also providing resistance to movement through drag forces (Barela & Duarte, 2008).

Most of the current studies regarding aquatic therapy have focused on the cardiovascular effects and benefits of water and support the use of aquatic therapy as a rehabilitation tool in that regard (Hall, Macdonald, Maddison, & O’Hare, 1998; Reilly, Dowzer, & Cable, 2003; Rutledge, Silvers, Browder, & Dolny, 2007). Less research, however, has been done on the use and effects of aquatic therapy as a rehabilitation tool for patients suffering from LBP. Waller et al. (2009) reported that patients suffering from nonspecific LBP were able to decrease pain levels and increase function through aquatic rehab and reported a trend for higher motivation and rehabilitation adherence to aquatic rehabilitation. Similarly, Dziedzic, Jordan, and Foster (2008) reported that patient adherence was higher for aquatic therapy then land-based home exercises, and that long term effects of rehabilitation are partly dependent upon program adherence. Additionally, Dundar et al. (2009) saw better improvement in physical function and role limitations due to physical functioning in the aquatic exercise group compared to the land-based exercise group.

Since aquatic therapy is becoming more widely used and accepted as a rehabilitation tool, it is important to cover all facets of research in this area of rehabilitation so we can confidently answer the question: Does aquatic rehabilitation benefit the patient with LBP, not just anecdotally, but, more importantly, are there neuromuscular benefits? To date there is no research investigating EMG activity of core muscles during aquatic therapy, let alone the comparison of muscle activity while performing exercises on land and in the water. It is important to document and research EMG activity in the water and on land to determine if there is comparable, or at least beneficial amounts of, muscle activity between the two mediums for exercise. The first step in this research is to determine, in healthy adults, if the EMG activity of certain core/stabilizing muscles is, at minimum, able to provide beneficial amounts of muscle activation.

The primary purpose of this thesis research is to compare selected trunk muscle activity during the performance of a specific set of exercises in an aquatic environment compared to performing the same exercises on land. A secondary purpose is to compare the muscle activity among a series of water-based exercises.

CHAPTER II

REVIEW OF LITERATURE

This literature review on LBP addresses several topics: (1) theories of low back pain; (2) muscle activation and/or recruitment patterns in healthy participants and patients with LBP; (3) research on rehabilitation programs and outcomes for patients with LBP; (4) water as a medium for therapeutic exercises; and (5) recording electromyography in water versus land.

Theories of Low Back Pain

van Dieën, Selen, and Cholewicki (2003) reviewed over 30 studies with the intention of interpreting trunk muscle activity of persons experiencing LBP in terms of either adaptive and supportive or as contributing to an adverse cycle leading to chronicity. van Dieën et al. (2003) examined two models of back pain and muscle activity: the pain-spasm-pain model and the pain adaptation model. Originally proposed by Travell (as stated by van Dieën et al., 2003), the theory behind the pain-spasm-pain model is that initial injury (pain) will cause a muscle to spasm, causing more pain & more spasm. In this model it is believed that increases in muscle spindle output cause overexcitement of the alpha motor neuron pool. This hyper excitability is the basis for more sustained and intense muscle activity observed in patients with LBP as compared to healthy participants. On the contrary the pain-adaptation model theorizes decreased muscle activation when the muscle is acting as an agonist (shortening) and increased muscle activation with antagonistic (lengthening) activity. In reviewing the literature, van Dieën et al. (2003) concluded that patients with LBP showed altered muscle activation, and although there is evidence to support both models, neither model is an adequate explanation of the effects of back pain on muscle activation patterns. They propose that a change in trunk muscle recruitment is an adaptation required to stabilize the spine due to: decrease in passive stiffness of the spine as a consequence of disc or ligament damage, reduction in the ability to correct muscle perturbations because of reduced muscular force and disturbance of sensorimotor integration; and that such changes in recruitment patterns are often present after functional significance has disappeared and injured structures have recovered.

Muscle Activation/Recruitment Patterns

McGill et al. (2003) illustrated the importance, and vulnerability, of spinal stability by comparing the spinal column and its muscles to that of a fishing pole being held up by guy wires. Without the support of the guy wires the pole will bend under a minimal load. Once the guy wires are in place and uniformly tightened, the fishing pole will be able to support a much heavier load, but the slightest change in tension from just one guy wire will affect the amount of load the pole will be able to withstand. Putting this into terms of a person’s spinal stability the (supporting muscles) erector spinae, rectus abdominis, transverse abdominis & external oblique act as guy wires, a slight change in the ability of just one muscle to maintain the proper contraction/co-contraction will result in decreased spinal stability when a lesser load is placed on the spine. Similarly Reeves, Cholewicki, and Silfies (2006) stated that changes in muscle recruitments patterns will affect not only magnitude but also direction of load on intervertebral joints and spinal stability. Results from Arokoski, Valta, Kankaanpää, and Airaksinen (2004), McGill et al. (2003), and Reeves et al. (2006) indicate that without a coordinated muscle activation pattern a person will experience instability of the spine which may lead to tissue damage. This can be observed with persons suffering from LBP where compared to healthy subjects alterations in muscle patterns such as: muscle imbalances, co-contraction problems and delayed activation have been observed (Akuthota et al., 2008; Reeves et al., 2006; Silfies, Squillante, Maurer, Westcott, & Karduna, 2005; van Dieën et al., 2003).

Silfies et al. (2005) conducted a study on 20 patients suffering from LBP. These 20 participants were matched by age, sex, and body mass index with asymptomatic controls. Surface EMG electrodes were placed at the internal abdominal oblique (IO), external abdominal oblique (EO), rectus abdominis (RA), erector spinae (ES), and lumbar multifidus (MT) similar muscle sites have been used in research by Hubley-Kozey and Vezina (2002), Vezina and Hubley-Kozey (2000), and Stevens et al. (2006). Normalization of trunk flexor and extensor muscles was established through submaximal isometric contractions prior to performing a reaching task. In healthy participants a "normal" response to the reaching task is an increase in muscle co-contraction, as trunk stability is challenged. In patients with chronic LBP (CLBP), Silfies et al. (2005) reported overall higher muscle activation in patients with CLBP, especially of the RA and EO muscles. These results are comparable to results of Vezina and Hubley-Kozey (2000), Hubley-Kozey and Vezina (2002), and Stevens et al. (2006). Although this pattern of increased EO activation, compared to other trunk muscles has been reported in healthy participants (Vezina & Hubley-Kozey, 2000) the overall activation is significantly higher in patients with CLBP.

Using surface EMG to examine muscle activity of the RA, EO, IO (transverse fibers), lumbar multifidus (superficial fibers, sLM), and iliocostalis lumborum pars thoracis (ICLT) during usual and slumped sitting, Dankearts, O'Sullivan, Burnett, and Straker (2006) did not initially observe differences in trunk muscle activity between their pain free group (33 participants) and nonspecific CLBP group (34 participants). When the nonspecific CLBP group was divided into subclassifications, however, results indicated significant changes in muscle co-contraction patterns during usual and slumped sitting. According to observations as reported by O'Sullivan (2000), patients exhibiting flexion pattern (FP) disorders will, when seated, position themselves at the end range of flexion which will reduce the co contraction of the lumbo-pelvic stabilizing muscles. Whereas patients with active extension pattern (AEP) disorders position themselves in a more "active" hyperextension posture. Research conducted by Dankaerts et al. (2006) supports these observations. They observed that participants presenting with AEP had higher muscle activity of the sLM, ICLT and IO in both usual and slumped sitting when compared to FP subgroup and pain free group. Significant differences were also seen for both the sLM and ICLT, when comparing flexion relaxation ratios of the pain free and CLBP (pooled) groups; where the pain free group had a reduction in activity of the sLM and ICLT during slumped sitting. Additionally, when comparing subgroup flexion relaxation ratios separately, there was an increase in activity of the aforementioned muscles in the FP participants and an absence of relaxation for AEP participants (Dankaerts et al., 2006). This altered pattern of muscle contraction may be an adaption (Reeves et al., 2006), or compensatory reaction to a deficiency in the body's ability to adequately stiffen the joints of the spine as a result of tissue damage (McGill et al., 2003; van Dieën et al., 2003).

Reeves et al. (2006) compared over 200 varsity athletes with a history of LBP to determine if a change in muscle activation patterns is (1) associated with low back injury (LBI), (2) the cause of LBI, and (3) whether it is associated with duration of symptoms or frequency of injury (impairment or adaptation). Reeves et al. reported that muscle activation imbalances occurred between levels, and were not associated with length or frequency of LBI indicating these impaired activation patterns are a result of adaptation not impairment. van Dieën et al. (2003) is in agreement; concluding that altered muscle activity is a functional adaptation providing support to spinal instability initially created by an injury.

Since altered patterns of muscle activation can affect both the magnitude and direction of load on the intervertebral joints and spinal stability, Reeves et al. (2006) supports rehabilitation because an increase in muscle co-activation will intensify the shear forces and compressive load on the spine, increasing susceptibility to injury. van Dieën et al. (2003), on the other hand, advises that when initiating a rehabilitation program with the intention of restoring "normal" muscle activation patterns, it is important to differentiate between a patient who presents altered patterns of activation with and without lingering physiological disruptions. If physiological disruptions are present altered muscle activation patterns is the body’s way of stabilizing a physiologically instable spine (van Dieën et al., 2003).

Rehab Programs and Outcomes for Patients with LBP

In 2005 Koumantakis et al. investigated the effects of adding specific stabilization exercises to a general back and abdominal program for patients with subacute or chronic nonspecific back pain. There were 55 participants; 29 in the enhanced-exercise group and 26 in the general-exercise only group. Results demonstrated immediate improvements in both groups; Koumantakis et al. (2005) concluded that the enhanced program is no more beneficial than a general program for patients with LBP, whom show no clinical signs of spinal instability. While this study does not promote core stability as being advantageous over a general program for patients not experiencing spinal instability, rehabilitation professionals continue to incorporate core stability and core strength in their rehabilitation programs for LBP. Further research indicates such programs can improve muscular functioning and increase spinal stability in unstable patients (Akuthota et al., 2008; Filho, Santos, & Rocha, 2009; Hibbs et al., 2008). Hibbs et al. (2008) defined core stability as the ability to stabilize the spine as a result of muscle activity, while core strength is the ability of the muscle to produce force through contractile forces and intra-abdominal pressure. Research has examined the effects of both isolation exercises and co-contraction exercises; however, to date no consensus has been reached on which is the best for the patient. For example, research by McGill et al. (2003) concluded, since activation of multiple muscles is necessary for increased spinal stability muscle isolation exercises should not be emphasized. Hibbs et al. (2008) would argue that isolation exercises are important, especially in the introductory phase of rehabilitation; enabling patients to relearn proper activation of muscles that may be delayed or impaired. However exercises should progress as the patient improves in function and pain levels (Akuthota et al., 2008). Filho et al. (2009) support the use of both types of exercises. Their research observed long term improvements in a patient when incorporating both isolation exercises of the transverse abdominis (TA) and co-contraction exercises with TA and MT in their rehabilitation program. Similarly, Standaert, Weinstein, and Rumpeltes (2008) reviewed articles in which researchers reported improvements in participants' level of back pain and muscle activity when incorporating muscle isolation exercises and/or co-contraction and stabilization exercises. As McGill et al. (2003) have suggested, the sole use of isolation exercises in a low back program may not be beneficial to the patient as muscle recruitment to support the spine is dependent on the interaction between multiple muscles. Therefore, programs should also incorporate co-contraction stabilization exercises and continue to progress.

Although available research does not provide conclusive evidence on the increased benefits of incorporating stabilization exercises into general low back programs, there are no harmful effects of integrating such exercises into rehabilitation protocols for patients with LBP (Standaert et al., 2008). More research is needed and should, as suggested by Standaert et al. (2008) focus on: effective exercises, duration, frequency, and progression, which will vary depending on the type of back problem a patient is suffering.

Practitioners who continue to include stabilization exercises should individualize each program (Dziedzic et al., 2008) to the patient taking into account the type of injury, for example, chronic, recurring, acute, or if instability is present, then progressing the patient as they are able.

Water as a Medium for Therapeutic Exercises

One characteristic of water that lends to its inviting environment is buoyancy. Buoyancy allows for decreased axial load on the spine and weight bearing joints as well as decreased in ground reaction forces (Prins & Cutner, 1999; Rutledge et al., 2007) enabling patients to perform movements in water that they are normally hesitant to, or unable to perform on land (Waller et al., 2009). This can be especially beneficial when working with patients who continue to exhibit painful behaviors despite healing of their physiological deficiency for fear of movement or re-injury (van Dieën et al., 2003). According to Harrison, Hillman, and Bulstrode (1992), weight is decreased in proportion to the depth of water immersion. For example, when a patient is immersed in water to the level of the xiphoid process the percentage of weight-bearing is ~30% and water immersion at the level of the ASIS equates to a 57% unloading of body weight (Harrison et al., 1992). The ability to unload the body gives rehabilitation professionals the capability to gradually reintroduce patients to activities of daily living such as walking or running (depending on injury), which will also help to increase a patient’s range of motion. In addition to changing water level, rehabilitation professionals can incorporate strength training by taking advantage of the second characteristic of water: viscosity.

Sometimes referred to as drag or water resistance, the benefit of viscosity is that, the greater the movement through water “the greater the resistance to movement” (Barela & Duarte, 2008). Moreover, Rutledge et al. (2007) noted that water turbulence through the use of water jets may increase the degree of drag forces the body experiences. It would be expected that more movement during an exercise will increase water turbulence and resistance against the movement requiring increased muscle recruitment. This accommodating resistance not only decreases the risk for re-injury, but also provides functional neuromuscular adaptations as opposed to single muscle isolation that is generally trained when using machines and bar bells in a gym (Prins & Cutner, 1999).

Rehabilitation in an Aquatic Environment

Aquatic therapy is a new rehabilitation tool, and although it is widely practiced (Pöyhönen, Keskinen, Hautala, Savolainen, & Mälkiä, 1999), research on this topic is very limited. Most research is related to the cardiorespiratory benefits of aquatic rehabilitation (Hall et al., 1998; Reilly et al., 2003; Rutledge et al., 2007; Shono et al., 2000). Less is known regarding the benefits of performing exercises in the water. Dundar et al. (2009) assigned 65 patients suffering from CLBP to one of two groups; land-based or an aquatic based program. The land group was instructed on a 60-minute session of at home exercises (warm-up, flexion, extension, mobilization, stretching and strengthening exercises followed by a cool down) that were to be performed every day for 4 weeks. The aquatic group performed supervised exercises 60 minutes in the pool five times a week for 4 weeks. This program included a 15-minute pool side warm-up, followed by walking, aerobic, active ROM, stretching, and strengthening ending with a 5-minute cool down. The authors do not provide detailed explanations of the exercises performed. Results of their work indicate that aquatic exercises provide better improvement of disability and (physical) quality of life, as compared to the participants performing the land-based exercise protocol.

Waller et al. (2009) reviewed seven studies comparing the effects of aquatic exercise on low back pain. This review included studies on all types of LBP including pregnant women, but excluding post operative patients. Waller et al. reported difficulty in comparing outcomes across all studies as there was variety amongst all on frequency, duration, and exercises performed. While some studies claimed considerable improvements were observed over the control group, other studies showed little to no advantage of aquatic therapy over the control group; seeing improvements in both control and patient groups. Despite these conflicting results, no negative effects were seen with the use of aquatic therapy to treat low back pain patients and Waller et al. concluded that aquatic therapy is safe and effective, exhibiting high patient adherence. They further suggest that due to its high patient adherence, aquatic therapy can potentially be used as a motivator for patients with low treatment adherence and/or who feel a lack of improvement with their current program.

Electromyography in Water and Air (Land)

Surface electromyography (EMG) is accepted as a valid and reliable tool to measure muscle activity. However several factors may distort signal integrity such as subcutaneous fat thickness, electrode size and placement, skin impedance, cross talk from adjacent muscles, and electromagnetic interference from other nearby sources (Vera-García, Moreside, & McGill, 2010). Normalization of EMG signals can minimize inter-subject and inter-muscular variability, allowing for comparison between subjects and muscle sites (Vera-García et al., 2010).

With the introduction of aquatic therapy and the need to validate its use as a rehabilitation tool, questions have again arisen in regards to the accuracy of EMG readings while participants are immersed in water. da Silva Carvalho et al. (2010) and Silvers and Dolny (2011) examined the effect of waterproofing techniques on EMG electrodes and observed that their technique maintained the reliability of EMG recordings for both land and water conditions. In contrast, Pöyhönen, Keskinen, Hautala, Savolainen, and Mälkiä (1999) reported that pilot studies show additional protection is not required for accurate EMG signal analysis. Clarys et al. (1985, as reported in Pöyhönen & Avela, 2002) also observed such results.

From the interpreted results of these few studies it can be concluded that with or without the use of additional protection over EMG electrodes, muscle activity recorded in water is significantly lower than that which is recorded during land activation (Masumoto, Takasugi, Hotta, Fujishima, & Iwamoto, 2004; Pöyhönen & Avela, 2002; Pöyhönen et al., 1999). There is no clear explanation for the decreased muscle activation observed during muscle contractions in the water. Pöyhönen et al. (1999) took 20 healthy participants and compared EMG activity and force production of the knee extensor muscles, on land and in water, three times over a 2-week period. Their results show that despite a statistically significant decrease in muscle activity measured in water as compared to muscle activity measured on land, the force production was similar across all trials and sessions. Through this research Pöyhönen et al. (1999) hypothesized that the decreased muscle activation may be due to something other than EMG problems, such as altered neuromuscular function. In a follow-up study (Pöyhönen & Avela, 2002) measurements of maximum voluntary contractions (MVCs) of the medial gastrocnemius and soleus were measured in air and water using surface and fine wire electrodes. Additionally measurements of Hoffman and achilles tendon reflexes were taken. Results of this research showed decreases in EMG activity of these muscles with both types of electrodes, as well as changes in tendon reflex responses. Furthermore only minor, nonsignificant differences were observed for force values between air and water. Pöyhönen and Avela (2002) had suggested that water immersion can impair neuromuscular function up to 13%, as seen in their research, and that this impairment could be reflex related.

Similarly, Masumoto et al. (2004) reported a decrease in muscle activity in their participants when walking in water compared to land walking. Masumoto et al. placed surface electrodes on 8 trunk and lower extremity muscles. Masumoto et al., in contrast to Pöyhönen et al. (1999), and Pöyhönen and Avela (2002), elected to cover the electrodes once placed on the subject. Each subject performed the following three tasks; walking on dry land, walking in water with a current, and walking in water without a current, at three different pre selected speeds. For the water testing participants were immersed to the level of their xiphoid process. Percent MVC calculations show a significantly lower muscle activity in both water walking conditions, compared to dry land walking. From their results and literature review, Masumoto et al. and Pöyhönen et al. both suggest these decrease in muscle activity is a result of proprioceptive or neuromuscular functioning changes due to weightlessness and possibly hydrostatic pressure.

Summary

The current literature on low back pain and aquatic rehab is limited and in many cases inconclusive. Research is not able to provide rehabilitation professionals and patients with a set of exercises or frequency and duration time lines for rehabilitation programs. However patients do benefit from rehabilitation and it is important to use a variety of muscle isolation and functional exercises, as well as muscle strength and endurance goals. The literature shows that patients suffering low back injuries generally have altered muscle contraction patterns. In some cases, when pathology is still present, altered patterns of contraction are important to maintaining spinal stability. However when pathology is no longer present, altered patterns of muscle activation should be corrected via rehabilitation.   While many studies have provided evidence for the benefits of aquatic therapy for cardiovascular fitness and post surgical patients, its effects of aquatic therapy in the treatment of LBP is not as vastly studied. Although aquatic therapy is still a new rehabilitation tool; rehabilitation professionals currently use aquatic therapy in their practices and have anecdotally seen many positive results. Additional research is needed to validate or refute the use of aquatic therapy as a rehabilitation tool.

We chose to examine trunk muscle activity of participants while performing common LBP exercises in water and on land.

CHAPTER III

METHODS

Participants

Eleven healthy males with the following characteristics (mean ± SD) age 25.9 ± 5.53 years and mass 72.9 ± 9.95 kg, participated in this study. Participants were recruited from the University campus via word of mouth and filled out a questionnaire to ensure physical ability to perform the exercises in the study. For acceptance into the study participants were not currently experiencing symptoms of or had no history of LBP or injury. Prior to participation in the study, each participant read and signed a consent form approved by the university institutional review board (see Appendix A).

Procedures

Participants were seen on two separate occasions; day one comprised of introduction and supervised practice of the exercises to be performed during the data collection period. A written description of all exercises was given to participants as well, for further, at home practice. The second meeting was for the data collection. Participants had electrodes attached to skin for recording of muscle activity, then performed (1) MVCs, (2) land-based exercises, and finally (3) water-based exercises. Randomization of exercises occurred within each stage.

EMG Preparation

EMG electrodes were positioned to record activity at the rectus abdominis (RA), external oblique (EO), internal oblique (LA), erector spinae (ES), and lumbar multifidis (MT). It should be noted that while the electrodes were positioned along the muscle fibers to record internal oblique (IO) activation, the IO will be referred to as the lower abdominals (LA), since cross talk between the internal oblique and transverse abdominis make it difficult to differentiate between the two. The skin was first abraded with fine grit sandpaper to remove loose skin cells at attachment sites, then wiped clean with an alcohol prep pad and allowed to dry. Electrodes (BIOPAC #EL502) were placed on the prepared skin site, parallel to each other and along the line of the muscle fibers. Electrode collars were trimmed on one side to maintain a 2 cm inter electrode spacing. Electrode placement for abdominal muscles (Silfies et al., 2005), and back muscles (Dankaerts et al., 2006) was as follows: RA (1 cm above umbilicus, 2 cm lateral to midline), the EO (15 cm lateral to umbilicus), LA (2 cm medial to anterior superior iliac spine (ASIS) and 2 cm down), ES (6 cm lateral to midline at L1-L2) and MT (2 cm lateral to midline at L4-L5). A ground electrode was placed at the acromion process. Electrode leads (BIOPAC TD 109 3-meter leads) were attached to the electrodes and connected to the tethered telemetry BIOPAC system. Submaximal contractions were performed prior to waterproofing to ensure adequate muscle activity recording.

Preparing participants for data collection included a waterproofing technique (Silvers & Dolny, 2011) for the electrodes to prevent water from disrupting the integrity of the signal and reliability of recordings. To waterproof the electrodes, a rectangle of

OpSite ™ (approximately 12x15cm) was placed over electrodes, completely covering them. Holes punched in the OpSite ™ allow electrodes snaps to remain exposed. DAP® sealant (Alex Ultra 230, Premium elastomeric latex sealant) was applied to the non-metal portion of the lead prior to connecting to electrode snap. Once connected, DAP® sealant was also applied over the entire connection site. After approximately 15 minutes for curing, a second, larger rectangle of OpSite ™ was placed over everything, overlapping the first layer. This procedure was repeated for each of the five muscle sites. Cover the ground electrode with a single layer of OpSite ™ to prevent any unintentional contact with water. All lead wires from the electrodes are coiled and led back behind the subject so as not to inhibit performance of each exercise.

Participants performed three different MVC tests as described in Vezina and Hubley-Kozey (2000): (1) **Restrained sit-up**: participants are supine on a table with hips and knees bent and feet secured flat against the table by a tester. On a "ready, go" command the subject produces maximal effort against manual resistance, at the shoulders, by a tester (Dankaerts et al., 2006); (2) **IsoTrunk rotation:** requires the subject to be seated while producing a maximal trunk rotation to the left against manual resistance without trunk flexion (Hubley-Kozey & Vezina, 2002); (3) **Resisted back extension:** participants lay prone on a table, hands by head, with feet and torso secured via manual resistance by testers. When prompted participants extend against manual resistance applied at the scapula. Each MVC was held for 4 seconds and repeated after a 1 minute rest. Verbal encouragement was given (“push, push, push”) during the trials. MVC data were used as comparison data for normalization.

Exercises

The following is list of exercises with descriptions that each participant was asked to perform either on land, water or both. Each participant received a similar list as a handout on the familiarization day:

1. **Abdominal Bracing** (ABbrace). Also referred to as neutral spine. In an upright position participants were instructed to contract the entire abdominal wall, while maintaining a neutral lumbar spine (Monfort-Pañego, Vera-García, Sánchez-Zuriaga, & Sarti-Martínez, 2009). Position was held for 4 seconds, and repeated after a 1-minute rest.

2. **Abdominal Hollowing** (ABhol). Participants were instructed to stand with their back against a wall, allowing natural curvature of the spine, feet flat on ground shoulder width apart and away from the wall while knees were flexed to about 90 degrees. Once in this position participants were instructed to tighten their abdominals by drawing the navel up and in toward the spine, holding this position for 4 seconds. (Hubley-Kozey & Vezina, 2002; Monfort-Pañego et al., 2009). This exercise was performed twice. According to Monfort-Pañego et al. (2009), this neutral position will isolate the co-activation of the transverse abdominis and internal oblique muscles.

3. **Anterior/Posterior Pelvic Tilts** (APTilts). Participants were seated on a PhysioBall (PB) (65cm or 75cm ball, so that they could comfortably reach the floor, hips about 90degrees), feet flat on the ground, neutral spine activated. Participants wree instructed to rock their hips back and forth (A/P) so that the tailbone rotates forward and

backward. This was performed for a total of five repetitions. Water A/P tilts were performed in the same manner; however, instead of a PB, participants were seated on a kickboard, stabilized by a tester, in a water depth to the level of their xiphoid process.

4. **Lateral Pelvic Tilts** (LatTilts). Participants were seated on a PB (same size used for APTilts), feet flat on the ground, neutral spine activated. Participants were instructed to tilt hips from side to side by simultaneously dropping and lifting opposite hips (one repetition). Each participant was asked to complete a continuous five repetitions. In the water, participants are seated on a kickboard stabilized by a tester, with water at the xiphoid process.

5. **PhysioBall Lateral Flexion** (PBLatFlex). Participants were instructed to hold a PB against the right side of body, under the arm, stabilizing the ball in this position with the hand. Feet were just wider than hip width. Water level at the navel. Participants performed and maintained ABhol during the movement of the exercise. On the "go" command each participant laterally flexed, from the trunk, to the right side of the body until resistance was met. Participants were instructed to return to the starting position in a slow and controlled manner, once this resistance was met. Exercise was performed two times per side.

6. **PhysioBall Transverse Plane Rotations** (PBRoto). Participants held a PB (55cm) in their hands with arms outstretched at shoulder level, feet slightly wider than hip width, ABbrace engaged. Participants were instructed to maintain hip position and straight arms as they rotated through the exercise. Initial rotation was to the participants right side, towards, but not passed the right leg, then back through the center

of the body/start position, continuing to the left side of the body (again towards but not passed the left leg) and back towards the center of the body; this constituted one repetition. Each participant performed three continuous repetitions.

7. **Wall Sit with Upper Extremity Movement**. Participants placed their back against the wall, knees and hips at 90 degrees, feet shoulder width apart, with knees aligned over ankles. Participants were instructed to engage and maintain ABhol and wall sit position while they incorporate transverse (across body) and sagittal (up and down) arm movements. (a) For the transverse arm movement's (WallSitTrans) participants were instructed to hold fingers tight together, palms towards each other, halfway below water level. Each participant than alternately moved arms through the water at a moderate, controlled pace; right arm to left side, dropping it below water level prior to moving left arm across body to the right side. It is important to ensure that participants kept their shoulders against the wall during the arm movement. (b) For sagittal arm movements (WallSitSag), participants began with arms under water at his sides, fingers held tight and together, and palms facing the wall. When performing the exercise participants were instructed to alternately bring arms up to the surface of the water (keeping palms face down) and back down to the side of their body. One repetition was completed once both arms went through the motion. Each movement was performed for a total of two repetitions.

8. **Leg Abduction** (ABD). Participants were instructed to maintain ABbrace while raising the right leg out to side, no higher than hip level, without allowing forward motion. Participants were instructed to lower leg and repeat a total of three times,

continuously. This exercise was performed on the right leg only.

9. **Stationary Marching** (March). Participants were instructed to engage and maintain ABbrace, as they raised one leg up to hip height (hip and knee flexed to 90 degrees, while opposite foot remained planted on the ground), then lowered foot back down to ground. Alternating legs, participants repeated this exercise for a total of three marches per leg.

10. **PB Push Down** (PBPushDown). Each participant held a 55 cm PB between the hands, arms outstretched, elbows slightly bent, feet just wider than hip width apart. Participants were then instructed to engage and maintain ABhol during the performance of this exercise; bending forward at the waist, keeping shoulders and arms stiff, then returning to the start position once resistance from the water was met. Each participant performed three continuous repetitions in a slow and controlled manner.

Equipment

For muscle activity recordings electrodes (#EL502, BIOPAC Inc, Goleta, Ca) with 3m unshealed leads (TD 109, BIOPAC Inc). The leads were connected to a BIOPAC MP150 Data Acquisition System via a TEL100C 4-Channel Telemetry system. Data was collected via BIOPAC Acq*Knowledge*® data acquisition and analysis software version 4.1 for PC. Smith & Nephew OpSite ™ Flexifix Transparent Film Roll (UK) and DAP® sealant Alex Ultra 230, Premium elastomeric latex sealant (Baltimore, MD) were be used in the waterproofing procedure. Participants performed water-based exercises in a HydroWorx 2000 Series pool (Middletown, PA). In conjunction with EMG data collection two cameras (Creative Inc.) recorded above water and under water video. Light emitting diode (LED) lights were linked to EMG signal collection for later use to sink camera and EMG data for analysis. Other equipment used during exercises; kickboard and Physioballs sized 55 cm and 65 cm.

Data Recording

Video was recorded at 30Hz (as visibility allowed) and synched to EMG activity. EMG raw data were sampled at 1000 Hz. Signal amplification ranged from 1000 – 5000 Hz based on the specific muscle. Event markers were embedded in the data files during data collection to represent initiation and cessation of each exercise. Data were filtered using a digital band pass IIR filter of 20-500 Hz. The filtered signal was quantified with a root mean square (RMS). Average RMS values were computed for each muscle by taking the middle 3 s of EMG data collected for the MVC reference tests, ABbrace, and ABhol and computing for each repetition of dynamic exercises as designated by the event markers. The average RMS value computed for each muscle was then normalized to the average RMS value computed for the selected muscles MVC reference test.

Data Analysis

Descriptive statistics were calculated for all muscles across all exercises using IBM SPSS Statistics 19 (Somers, NY). A paired samples *t* test was used to compare the four comparable exercises between land and water (ABbrace, ABhol, APTilts, and LatTilts). General linear model-repeated measures analysis of variance was run on 11 water exercises for each of the five muscle sites. Follow-up multiple comparisons were calculated via least significant difference (LSD), using a Holm’s corrected alpha set at 0.05 to determine statistical significance.

CHAPTER IV

RESULTS

Land Versus Water Comparison

Descriptive data (mean ±SD) for each muscle during the four exercises: (1) ABhol, (2) ABbrace, (3) APTilts, and (4) LatTilts, performed in water and on land are displayed in Figures 1-5 (see Appendix B).

Rectus Abdominis (RA). RA activity was significantly greater between land & water conditions for ABhol (8.3 vs. 2.6% MVC), ABbrace (19.3 vs. 9.7% MVC), APTilts (11.0 vs. 2.1% MVC), and LatTilts (10.3 vs. 2.1% MVC) comparison (*P* = .003-.029; ES = .74-1.10) (Figure 1).

Lower Abdominals (LA). LA activity was significantly greater for all exercises examined (*P* = .016-.001; ES = .98-1.28) in land versus water conditions; ABhol (41.3 vs. 15.7% MVC), ABbrace (105.0 vs. 25.21% MVC), APTilts (30.5 vs. 6.8% MVC), and LatTilts (27.0 vs. 5.2% MVC). It was observed that the most LA muscle activity occurred during the perofrmance of ABhol and ABbrace exercises (Figure 2).

External Oblique (EO). EO muscle activity in Figure 3 displays significanlty greater muscle activation with land versus water conditions for ABhol (36.4 vs. 4.8% MVC), ABbrace (58.7 vs. 24.5% MVC), and APTilts (16.7 vs. 9.9% MVC) with *P* = .001-.005 and ES = .70-1.10. Although LatTilts did not reach a significant p value (*P* = .303) the calculated effect size (.58) may infer clinical significance. The oblique muscles as a whole (EO and LA) elicited greater muscle activation across all exercises, compared to RA.

Erector Spinae (ES). ES was significantly greater during land versus water conditions (*P* = .012-.003; ES = .54-1.04) for ABhol (21.2 vs. 10.7% MVC), ABbrace (37.6 vs. 22.1% MVC), APTilts (19.1 vs. 7.7% MVC), and LatTilts (20.5 vs. 8.8% MVC) (Figure 4).

Multifidus (MT). MT activity was significantly greater during land versus water conditions for all exercises (*P* = .005- <.001, ES = .83-1.3). The MT muscle group, when compared to the four other muscle sites, showed the most consistent range of mean values for land (16.5%-25.37% MVC) and water (5.8%-8.8%% MVC) conditions (Figure 5). For the land/water exercise comparison, RA produced the least amount of muscle activation during the performance of these four pairs of land and water exercises when compared to the remaining four muscle sites.

Water Comparison

Figures 6-10 (Appendix B) presents muscle activation (Mean ±SD) for each of the five muscles during the execution of the 11 water-based exercises. ABbrace and PB exercises consistently recorded the highest muscle activation for RA, LA, EO, ES, and MT. ABhol consistently recorded lower muscle activation across all muscle sites. For example, the RA muscle was most active during ABbrace (9.7% MVC), PBPushDown (8.7% MVC), and PBLatFlex (7.5% MVC) exercises (Figure 6). All three exercises evoke significantly more muscle activity as compared to the remaining 8 water exercises. In Figure 6 we again observe greatest EO muscle activity with ABbrace (24.5% MVC), PBPushDown (21.3% MVC), and PBLatFlex (27.7% MVC) as well as PBRoto (22% MVC). These aforementioned exercises are all statistically significant from water exercises 5-11 (Figure 7). For the LA muscle group ABbrace (23.0% MVC), PBRoto (11.3% MVC), and APTilts (6.8% MVC) all displayed significant differences from LatTilts (5.2% MVC). ABbrace was also significantly different from exercises 6-11 and PBRoto held statistical significance from exercises 9-11 (Figure 8). With the ES muscle site, statistical analysis showed higher mean muscle activity during the performance of ABbbrace (21.3% MVC), PBLatFlex (16.7% MVC), and PBPushDown (15.2% MVC), all with significantly more muscle activation then ABhol (8.5% MVC, *P* = .016-.046) (Figure 9). PBLatFlex was also significantly different from exercises 6-11(Figure 9). MT was only one of two muscles sites displaying top muscle activation with ABD (11.3% MVC). Along with, PBlatFlex (13.7% MVC), and PBroto (10.4% MVC) these three exercises had significantly higher muscle activation compared to the remaining 8 water exercises as displayed in Figure 10.

CHAPTER V

DISCUSSION

This study examined trunk muscle activation comparing (1) similar land and water exercises and (2) a set of 11 water exercises. Statistically significant differences were indentified among the five muscle sites for exercises performed in both conditions.

Land Exercises

In a study by Vezina and Hubley-Kozey (2000), it was reported that EO muscle activity (%MVC) was higher than both upper and lower RA muscle activity (%MVC) for the three exercises participants performed (abdominal hollowing, pelvic tilts and level 1 of the trunk stability test). In that study ABhol muscle activity for RA was approximately 6%, of MVC pelvic tilts about 14% and EO muscle activity averaged 18% and 28%, respectively. Drysdale, Earl, and Hertel (2004) and Vezina and Hubley-Kozey (2000) reported greater muscle activity during pelvic tilts compared to ABhol. The results of this study recorded higher muscle activity during pelvic tilts for the RA and MT only, but not the three other muscle sites. Differences in these results may be due to the method of how each exercise was performed. For both Vezina and Hubley-Kozey (2000) and Drysdale et al. (2004), pelvic tilts and ABhol were performed with the subject supine. In the current study, participants performed ABhol and pelvic tilts in an upright position so a similar body position could be replicated in water. Vera-García et al. (2010) researched muscle activity during a number of MVC techniques – one was maximal effort ABhol. While mean RA and EO muscle activation were below 25% and 40%, respectively, Vera-

García et al. observed the highest IO muscle activation during ABhol at 83.6% MVC. The current study reported RA and EO below 25% and 40%, respectively; IO activation (41%) was not as high as Vera-García et al. reported.

Land Versus Water Comparison

Statistically significant differences were observed in this study among the muscle sites observed during the performance of exercises on land and in water. When performed on land, ABbrace, ABhol, APTilts, and LatTilts consistently elicited greater muscle activation (8%-59% MVC) when compared to the muscle activity of water equivalent exercises (2%-24% MVC). Pöyhönen et al. (1999), Pöyhönen and Avela (2002), and Masumoto et al. (2004) have also reported decreased MVC muscle activation in water compared to land; decreases in activity by as much as 70%. Pöyhönen and Avela and Masumoto et al. agree that this decrease in muscle signaling is not due to a fault in EMG recording, but rather a proprioceptive or neuromuscular functioning change as a consequence of the weightlessness or the hydrostatic pressure experienced when a person is partially submerged in water. Pöyhönen and Avela and Pöyhönen et al. did not evaluate electrode recording integrity. Others (Masumoto et al., 2004; da Silva Carvalho et al., 2010) stated it is still necessary to cover electrodes to ensure recording fidelity during water exercises. In 2010 da Silva Carvalho et al. compared the effects of unprotected and protected electrodes on EMG recording in and out of water. They observed comparable EMG amplitude between the protected and unprotected electrodes in air and a decrease in EMG amplitude when comparing protected with unprotected electrodes in the water condition. Moreover, da Silva Carvalho et al. observed significantly greater muscle activity in land conditions compared to water conditions, with the greatest significance and sharpest decline in EMG amplitude in the unprotected water condition as compared to the air condition; concluding that it is necessary to protect electrodes when they are to be used in water conditions. Silvers & Dolny (2011) used a waterproofing technique to compare EMG during MVC's in water compared to land; their study demonstrated no difference between the two conditions using this protective technique.

Differences were observed between the two exercise conditions in this study. While the amount of muscle activation during the performance of exercises in the water condition were less as when performed on land, there was still activation detected. This is important clinically, as endurance benefits are associated with muscle activation at or below 25% MVC (Hibbs et al., 2008).

Water Exercises

There are two main characteristics of water that lend to its use as a rehabilitation tool; buoyancy and drag. Buoyancy reduces the effects of gravity on a person in water, which provides a decrease in axial load (Prins & Cutner, 1999). Harrison et al. (1992) observed that when submerged in water, the percent of weight bearing can range from 13%-70% depending on the water level. For the current research, the water level was at the xiphoid, giving a static percent weight bearing of about 30% (Harrison et al., 1992). Another benefit to this decrease load is the ability to gradually reintroduce a patient to, and ensure proper execution of, activities of daily living (Prins & Cutner, 1999). The drag force of water is an accommodating resistance (Prins & Cutner, 1999), not only is a person able to resistance train without the use of added weight, the amount of resistance experienced is related to the force and speed of the movement. Resistance can be further progressed with the incorporation of other rehabilitation tools. A PB can be used to increase resistance, and thus muscle recruitment, during movements such as rotation, or lateral and forward flexion. During the PBroto exercise in this study, the participant was instructed to hold the PB at the surface of the water, as the participant rotates through each repetition the agitated water intensifies the resistance requiring more muscle recruitment. This may explain why PB exercises elicited greater muscle activity than APTilts, LatTilts, WallSitSag, and WallSitTrans movements.

It is also important to note, that despite the lower activation observed during water performance, these findings do not negate the incorporation of aquatic therapy into rehabilitation programs. McGill et al. (2003) suggested that endurance training may be more important than strength gains as stability is an issue not of strength but of insufficient endurance and muscular control. The muscles in the current study recorded the following range of muscle activity presented as a %MVC: RA (1.8-9.7%), EO (4.6-27.7%), IO (4.3-56.5%), ES (8.5-21.3%), and MT (6.5-13.7%). While not at the minimum activation of 60% MVC required for strength gains, during certain exercises each muscle was active at or below 25% MVC required for endurance benefits (Hibbs et al., 2008). Stevens et al. (2006) concluded that activation as little as 1-3% MVC is sufficient enough to maintain dynamic spinal stability. Referring to Figures 6-10 even the least active muscle (RA) in the current study produced muscle activity above the 1-3% MVC level across all exercises and conditions.

Benefits of Aquatic Environment

Water is a valuable rehab tool because it enables patients to achieve adequate muscle activation in an environment comfortable to the patient. In their review article, Waller et al. (2009) found a higher motivation and rehabilitation adherence among patients performing rehabilitation in an aquatic environment. From the patient's perspective they are more motivated because of the reduction in pain, comfort of the water environment and the increased confidence of being able to do something that they were not previously able to do (Waller et al., 2009). From an anecdotal perspective, sometimes just getting moving can really boost a patient's confidence (if normally confined to crutches/locked brace). This is especially important among athletes as they have a hard time adjusting to activity restrictions because they are used to a high level of activity. With the ability to change the water level, practitioners can adjust the load placed on the spine. This feature is most beneficial to patients with LBP, as activity above 40% MVC may make patients susceptible to injury (Arokoski et al., 2004) and increases in axial load is contraindicated in patients with fragile disc pathology.

Properly progressing patients is a key factor in designing rehabilitation programs, for not only patients experiencing LBP (Akuthota et al., 2008), but all types of programs. With the results of the current study practitioners are better able to choose exercises that will safely and effectively progress patients with LBP through rehabilitation programs;

progressing not only within the aquatic environment, but in transition from water to land as well. For example, Monfort-Pañego et al. (2009) and Drysdale et al. (2004) reported exercises such as PB pelvic tilts, should be considered advanced exercises due to increased co-activation requirements, and incorporated later in the rehabilitation program. With the results of the current study, however, practitioners can comfortably incorporate pelvic tilts at the beginning of a patient's aquatic rehabilitation program because of the lower EMG activity observed. And later incorporate PB pelvic tilts on land. Another advantage to this is that the patient becomes familiar with proper execution of the exercise prior to performing it in a less controlled environment.

Previous research (Dundar et al., 2009; Dziedzic et al., 2008; Waller et al., 2009) has reported similar and better outcomes with aquatic based rehabilitation programs for patients with LBP compared to land-based programs. While no adverse effects have been reported ─Waller et al. (2009) reported aquatic rehabilitation is safe and effective ─ research is conflicting and has not overwhelmingly shown that aquatic rehabilitation is any more beneficial than land-based rehabilitation programs; but it is an effective alternative tool practitioners can use.

Conclusion

1. Results of this study show significantly greater EMG activity with land-based exercises as compared to equivalent water-based exercises.

2. When performed in water, ABhol, PBRoto, PBPushDown, and PBLatFlex continually elicited greater muscle activation compared to WallSitSag, WallSitTrans, and AP/LatTilts.
3. We promote the use of aquatic rehabilitation as an early phase in the progression of rehabilitation programs for patients with LBP.

REFERENCES

Akuthota, V., Ferreiro, A., Moore, T., & Fredericson, M. (2008). Core stability exercise principles. *Current Sports Medicine Reports, 7*(1), 39-44.

Arokoski, J.P., Valta, T., Kankaanpää, M., & Airaksinen, O. (2004). Activation of lumbar paraspinal and abdominal muscles during therapeutic exercises in chronic low back pain patients. *Archives of Physical Medicine and Rehabilitation, 87*, 823-832.

Barela, A.M.F., & Duarte, M. (2008). Biomechanical characteristics of elderly individuals walking on land and in water. *Journal of Electromyography and Kinesiology, 18,* 446-454.

Chou, R., Qaseem, A., Snow, V., Casey, D., Cross, J.T., Shekelle, P., & Owens, D.K. (2007). Diagnosis and treatment of low back pain: A joint clinical practice guideline from the American College of Physicians and the American Pain Society. *Annals of Internal Medicine, 147*(7), 478-491.

Dankaerts, W., O'Sullivan, P., Burnett, A., & Straker, L. (2006). Altered patterns of superficial trunk muscle activation during sitting in nonspecific chronic low back pain patients. *Spine, 31*(17), 2017-2023.

da Silva Carvalho, R.G., Amorim, C.F., Perácio, L.H.R., Coelho, H.F., Vieira, A.C., Menzel, H.K., & Szmuchrowski, L.A., (2010). Analysis of various conditions in order to measure electromyography of isometric contractions in water and on air. *Journal of Electromyoagraphy and Kinesiology, 20*(5), 988-993. doi10.1916/j.jelekin.2009.12.002

Drysdale, C.L., Earl, J.E., & Hertel, J. (2004). Surface electromyographic activity of the abdominal muscles during pelvic-tilts and abdominal hollowing exercises. *Journal of Athletic Training, 39*(1), 32-36.

Dundar, U., Solak, O., Yigit, I., Evick, D., & Kavuncu, V. (2009). Clinical effectiveness of aquatic exercise to treat chronic low back pain. *Spine, 34*(14), 1436-1440.

Dziedzic, K., Jordan, J.L., & Foster, N.E. (2008). Land- and water-based exercise therapies for musculoskeletal conditions. *Best Practice & Research Clinical Rheumatology, 22*(3), 407-418. doi:10.1016/j.berh.2007.11.002

Filho, N.M., Santos, S., & Rocha, R.M. (2009). Long-term effects of stabilization exercise therapy for chronic low back pain. *Manual Therapy, 14*(4), 444-447. doi:10.1016/j.math.2008.10.002

Hall, J., Macdonald, I.A., Maddison, P.J., & O'Hare, J.P. (1998). Cardiorespiratory response to underwater treadmill walking in healthy females. *European Journal of Applied Physiology, 77*(3), 278-284.

Harrison, R.A., Hillman, M., & Bulstrode, S. (1992). Loading of the lower limb when walking partially immersed: Implications for clinical practice. *Physiotherapy, 78*(3), 164-166.

Hayden, J.A., van Tulder, M.W., Malmivaara, A., & Koes, B.W. (2005). Meta analysis: Exercise therapy for nonspecific low back pain. *Annals of Internal Medicine, 142*(9), 765-775. Retrieved from MEDLINE database.

Hibbs, A.E., Thompson, K.G., French, D., Wrigley, A., & Spears, I. (2008). Optimizing performance by improving core stability and core strength. *Sports Medicine, 38*(12), 995-1008. doi:0112-1642/08/0012-0995

Hubley-Kozey, C.L., & Vezina, M.J. (2002). Muscle activation during exercises to improve trunk stability in men with low back pain. *Archives of Physical Medicine and Rehabilitation, 83,* 1100-1108.

Koumantakis, G.A., Watson, P.J., & Oldham, J.A. (2005). Trunk muscle stabilization training plus general exercise versus general exercise only: Randomized controlled trial of patients with recurrent low back pain. *Physical Therapy, 85*(3), 209-225.

Masumoto, K., Takasugi, S., Hotta, N., Fujishima, K., & Iwamoto, Y. (2004). Electromyographic analysis of walking in water in healthy humans. *Journal of Physiological Anthropology and Applied Human Sciences, 23*(4), 119-127.

McGill, S.M., Grenier, S., Kavcic, N., & Cholewicki, J. (2003). Coordination of muscle activity to assure stability of the lumbar spine. *Journal of Electromyography and Kinesiology, 13*(4), 353-359.

Monfort-Pañego, M., Vera-García, F.J., Sánchez-Zuriaga, D., & Sarti-Martínez, M.A. (2009). Electromyographic studies in abdominal exercises: A literature synthesis. *Journal of Manipulative and Physiological Therapeutics, 32*(3), 232-44.

O’Sullivan, P.B. (2000). Lumbar segmental ‘instability’: Clinical presentation and specific stabilizing exercise management. *Manual Therapy, 5*(1), 2-12. doi:10.1054/math.1999.0213

Pöyhönen, T., & Avela, J. (2002). Effect of head-out of water immersion on neuromuscular function on the plantarflexor muscles. *Aviation, Space and Environmental Medicine, 73*(12), 1215-1218.

Pöyhönen, T., Keskinen, K.L., Hautala, A., Savolainen, J., & Mälkiä, E. (1999). Human isometric force production and electromyogram activity of knee extensor muscles in water and on dry land. *European Journal of Applied Physiology, 80*, 52-56.

Prins, J., & Cutner, D (1999). Aquatic therapy in the rehabilitation of athletic injuries. *Aquatic Sports Injuries and Rehabilitation, 18* (2), 447-461.

Reeves N.P., Cholewicki, J., & Silfies, S.P. (2006). Muscle activation imbalance and low-back injury in varsity athletes. *Journal of Electromyography and Kinesiology, 16*, 264-272. doi:10.1016/j.jelekin.2005.07.008

Reilly, T., Dowzer, C.N., & Cable, N.T. (2003). The physiology of deep-water running. *Journal of Sport Sciences, 21*(12), 959-972. doi:10.1080/02640410310001641368

Rutledge, E., Silvers, W.M., Browder, K., & Dolny, D. (2007). Metabolic-cost comparison of submaximal land and aquatic treadmill exercise. *International Journal of Aquatic Research and Education, 1*, 131-146.

Santaella da Fonseca Lopes de Sousa, K., Orfale, A.G., Meireles, S. M., Leite, R. J., & Natour, J. (2009). Assessment of biofeedback program to treat chronic low back pain. *Journal of Musculoskeletal Pain, 17*(4), 369-377.

Shono, T., Fujishima, K., Hotta, N., Ogaki, T., Ueda, T., Otoki, K., … Shimizu, T. (2000). Physiological response and RPE during underwater treadmill walking in women of middle and advanced age. *Journal of Physiological Anthropology and Applied Human Science, 19*(4), 195-200.

Silfies, S.P., Squillante, D., Maurer, P., Westcott, S., & Karduna, A.R. (2005). Trunk muscle recruitment patterns in specific chronic low back pain populations. *Clinical Biomechanics, 20*, 465-473.

Silvers, W.M., & Dolny, D. (2011). Comparison and reproducibility of sEMG during manual muscle testing on land and in water. *Journal of Electromyography and Kinesiology, 21*, 95-101.

Standaert, C.J., Weinstein, S.M., & Rumpeltes, J. (2008). Evidence-informed management of chronic low back pain with lumbar stabilization exercises. *The Spine Journal, 8*, 114-120.

Stevens, V.K., Bouche, K.G., Mahieu, N.N., Coorevits, P.L., Vanderstraeten, G.G., &

Danneels, L.A. (2006). Trunk muscle activity in healthy subjects during bridging stabilization exercises. *BMC Musculoskeletal Disorders, 7,* 75. doi: 10.1186/1471-2474-7-75

van Dieën, J.H., Selen, L.P.J., & Cholewicki, J. (2003). Trunk muscle activation in low-back pain patients, an analysis of the literature. *Journal of Electromyography and Kinesiology, 13,* 333-351.

Vera-García, F.J., Moreside, J.M., & McGill, S.M. (2010). MVC techniques to normalize trunk muscle EMG in healthy women. *Journal of Electromyography and Kinesiology, 20,* 10-16.

Vezina, M.J., & Hubley-Kozey, C.L. (2000). Muscle activation in therapeutic exercises to improve trunk stability. *Archives of Physical Medicine and Rehabilitation, 81,* 1370-1379.

Waller, B., Lambeck, J., & Daly, D. (2009). Therapeutic aquatic exercise in the treatment of low back pain: A systematic review. *Clinical Rehabilitation, 23*(1), 3-14. doi:10.1177/0269215508097856

Wallwork, T.L., Stanton, W.R., Freke, M., & Hides, J.A. (2009). The effect of chonic low back pain on size and contraction of the lumbar multifidus muscle. *Manual Therapy, 14*(5), 496-500. doi:10.1016/j.math.2008.09.006

APPENDICES

Appendix A. Institutional Review Board Approval

Institutional Review Board
9530 Old Main Hill, Suite 214
Logan, UT 84322-9530
Telephone (435) 797-1821
Fax: (435) 797-3769

USU Assurance: FWA#00003308
Protocol # 2570

SPO #:

AES #: UTA00

MEMORANDUM

TO: Dennis Dolny Jeanne (Coby) Vandenberg
FROM: Kim Corbin-Lewis, IRB Chair,
True M. Fox, IRB Administrator

SUBJECT: A Comparison of Selected Trunk Muscle Activity Patterns During Lumbar Stabilization Exercises on Land and in Shallow Water

Your proposal has been reviewed by the Institutional Review Board and is approved under expedite procedure #4 .
X There is no more than minimal risk to the subjects.
There is greater than minimal risk to the subjects.
This approval applies only to the proposal currently on file for the period of one year. If your study extends beyond this approval period, you must contact this office to request an annual review of this research. Any change affecting human subjects must be approved by the Board prior to implementation. Injuries or any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Institutional Review Board.
Prior to involving human subjects, properly executed informed consent must be obtained from each subject or from an authorized representative, and documentation of informed consent must be kept on file for at least three years after the project ends. Each subject must be furnished with a copy of the informed consent document for their personal records.
The research activities listed below are expedited from IRB review based on the Department of Health and Human Services (DHHS) regulations for the protection of human research subjects, 45 CFR Part 46, as amended to include provisions of the Federal Policy for the Protection of Human Subjects, November 9, 1998.

4. Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. Examples: (a) physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject's privacy; (b) weighing or testing sensory acuity; (c) magnetic resonance imaging; (d) electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler blood flow, and echocardiography; (e) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual.

Appendix B. Figures

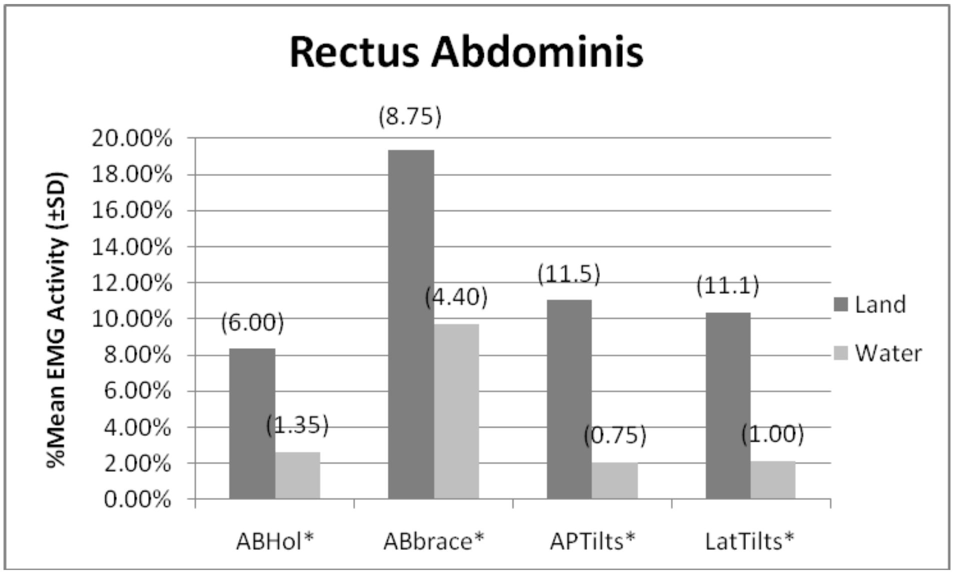

Figure 1. Land vs water comparison of normalized EMG amplitudes (±SD) for rectus abdominis. *Significant difference between the two conditions (*P* < .05).

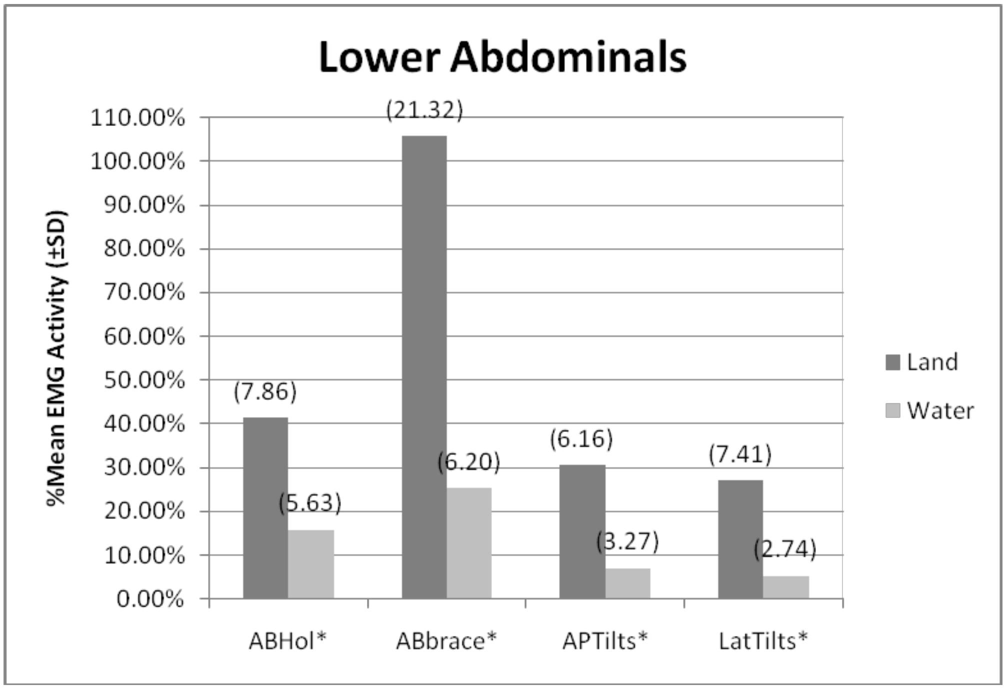

Figure 2. Land vs water comparison of normalized EMG amplitudes (±SD) for lower abdominals. *Significant difference between the two conditions (*P* < .05).

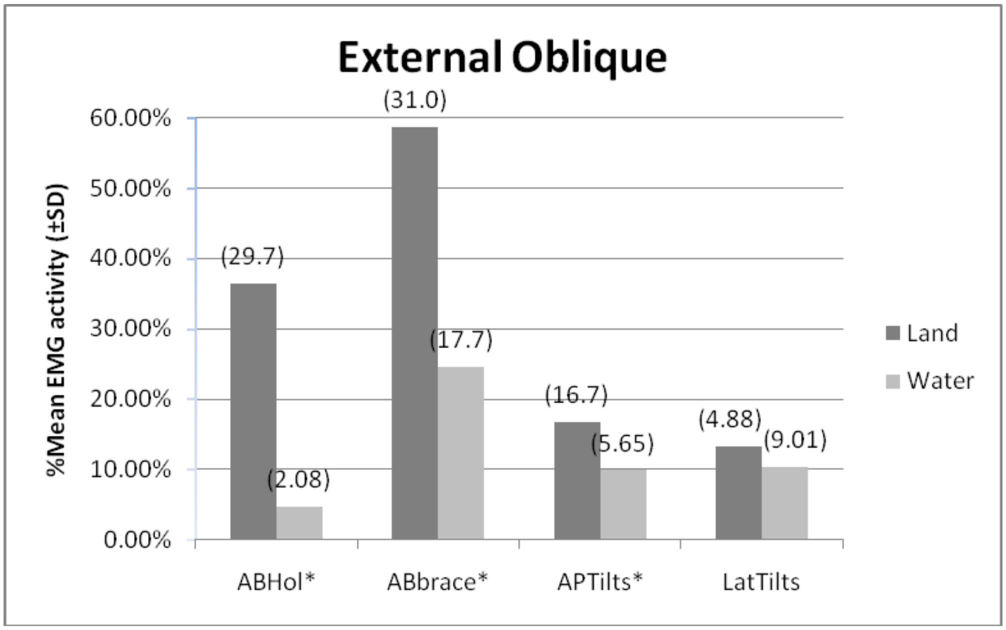

Figure 3. Land vs water comparison of normalized EMG amplitudes (±SD) for external oblique. *Significant difference between the two conditions (*P* < .05).

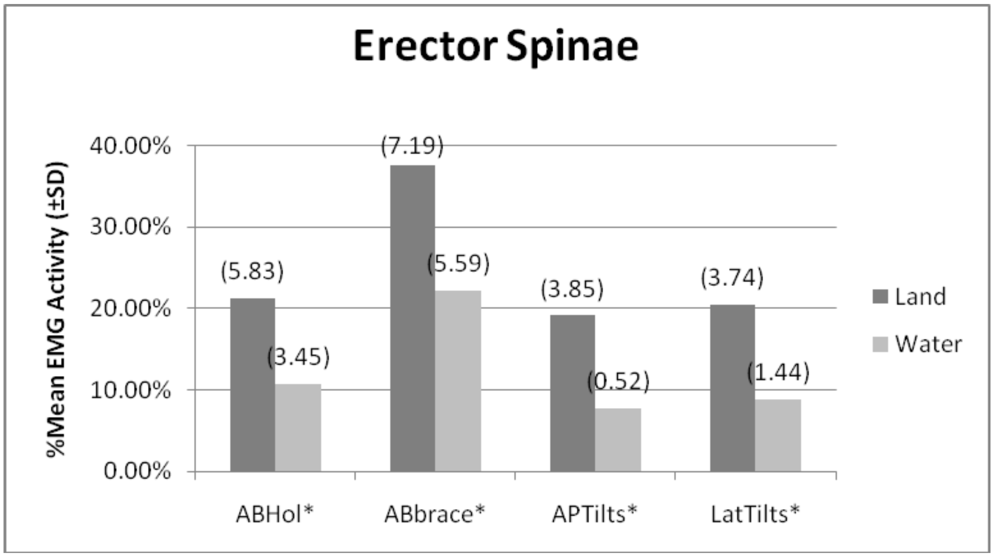

Figure 4. Land vs water comparison of normalized EMG amplitudes (±SD) for erector spinae. *Significant difference between the two conditions ($P < .05$).

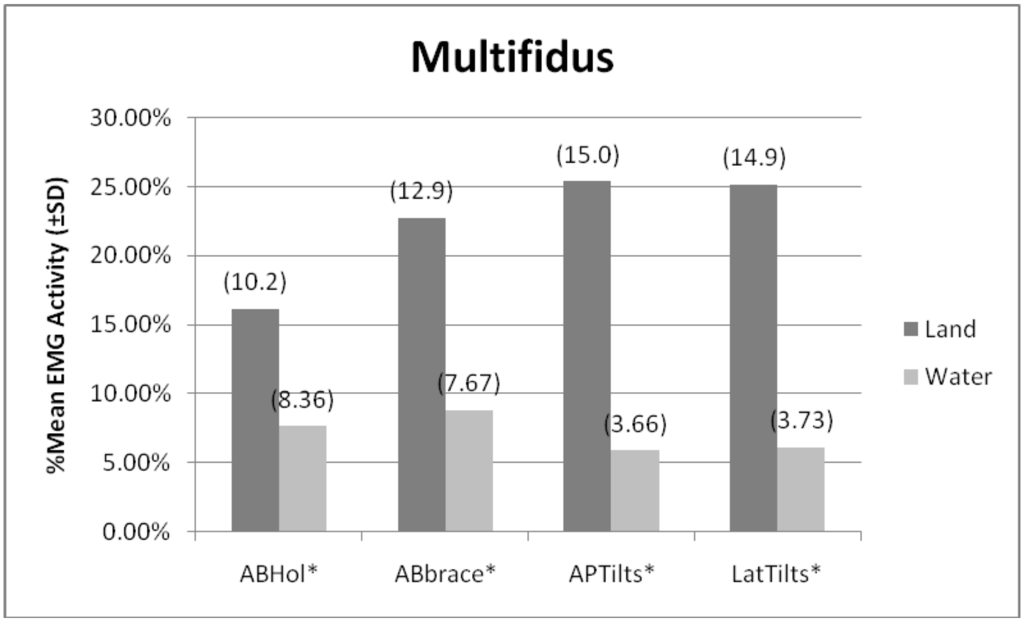

Figure 5. Land vs water comparison of normalized EMG amplitudes (±SD) for multifidus. *Significant difference between the two conditions (*P* < .05).

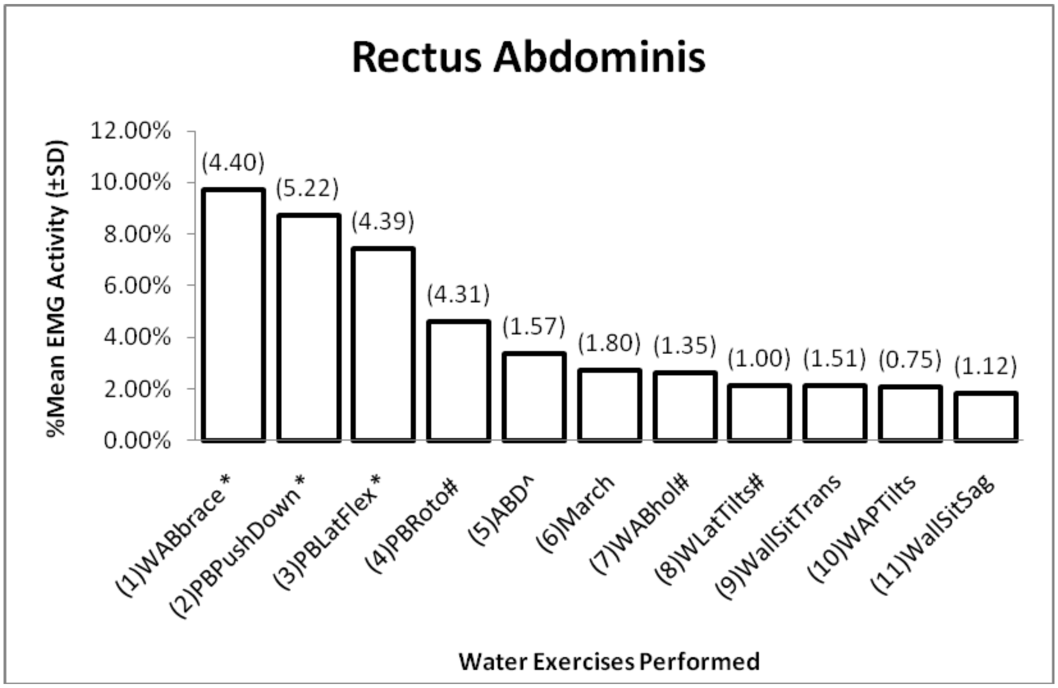

Figure 6. Water exercise comparison of normalized EMG amplitudes (±SD) for rectus abdominis. *Greater activity than exercises 4-11, #greater activity than exercise 11, ^greater activity than exercises 8-11 (*P* < .05).

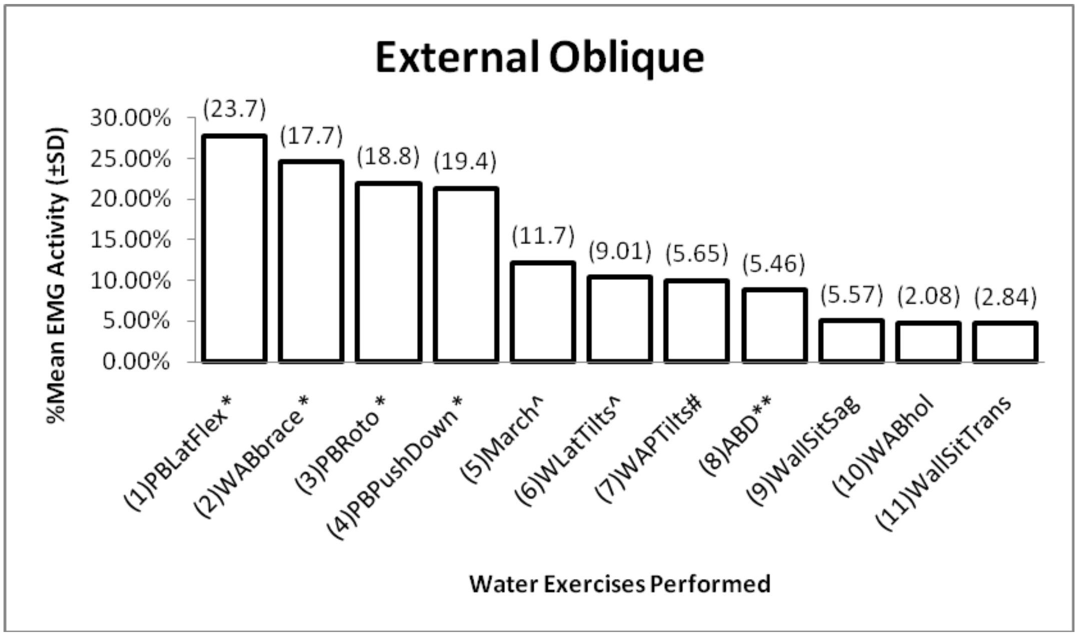

Figure 7. Water exercise comparison of normalized EMG amplitudes (±SD) for external oblique.*Greater activity than exercises 5-11, ^greater activity than exercise 9, #greater activity than exercises 9-11, **greater activity than exercises 9 & 11 (*P* < .05).

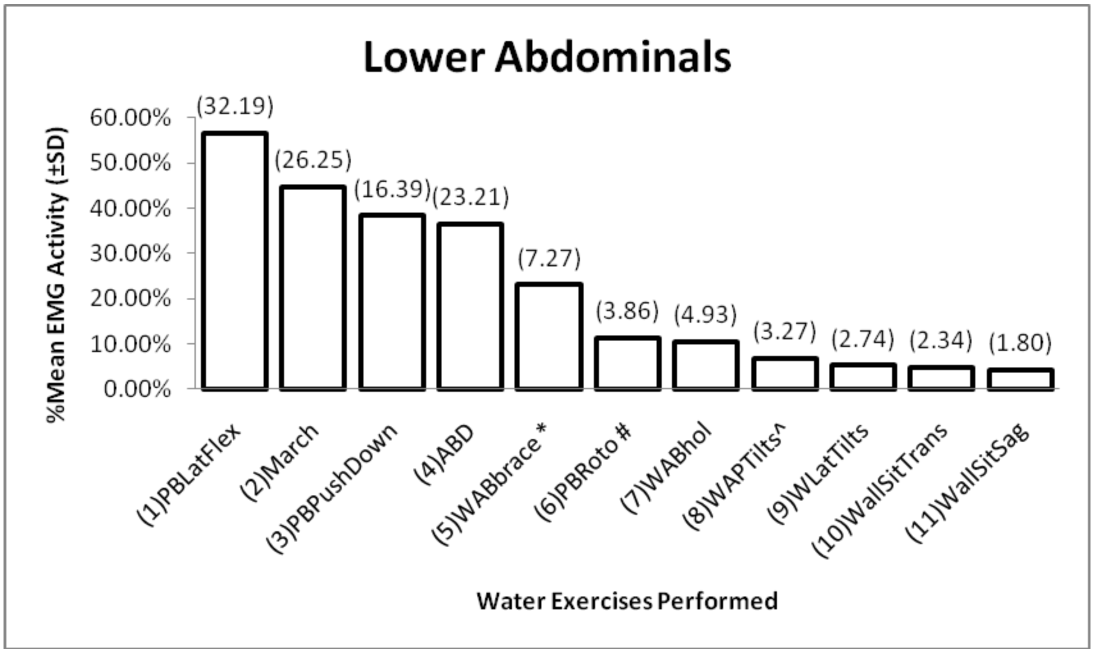

Figure 8. Water exercise comparison of normalized EMG amplitudes (±SD) for lower abdominals. *Greater activity than exercises 6-11, #greater activity than exercises 9-11, ^greater activity than exercise 9 (*P* < .05).

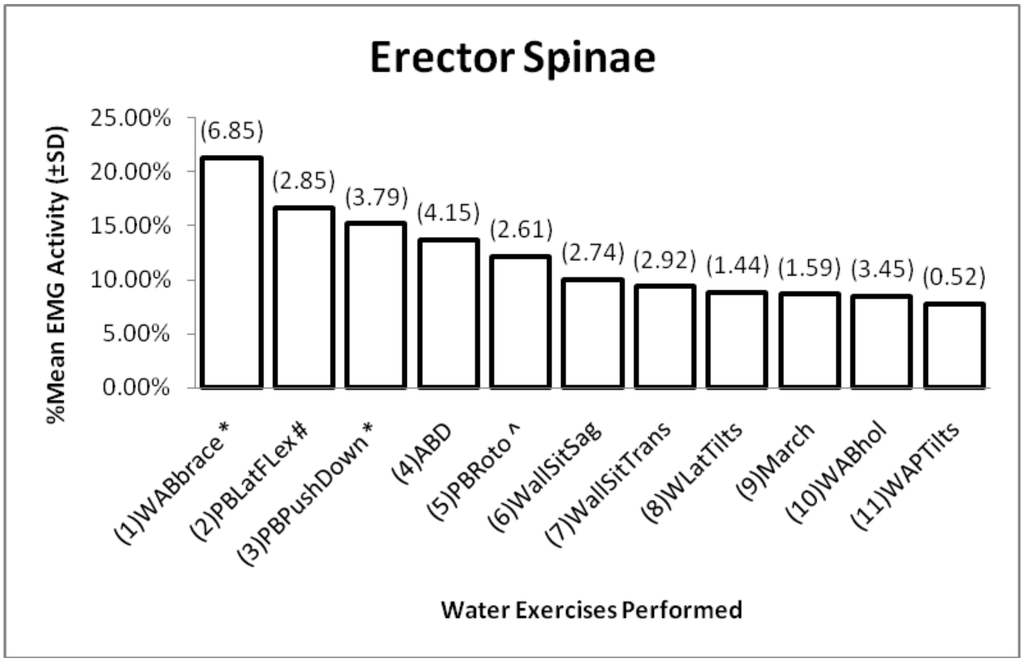

Figure 9. Water exercise comparison of normalized EMG amplitudes (±SD) for erector spinae. *Greater activity than exercise 10, #greater activity than exercises 6-11, ^greater activity than exercise 7 (*P* < .05).

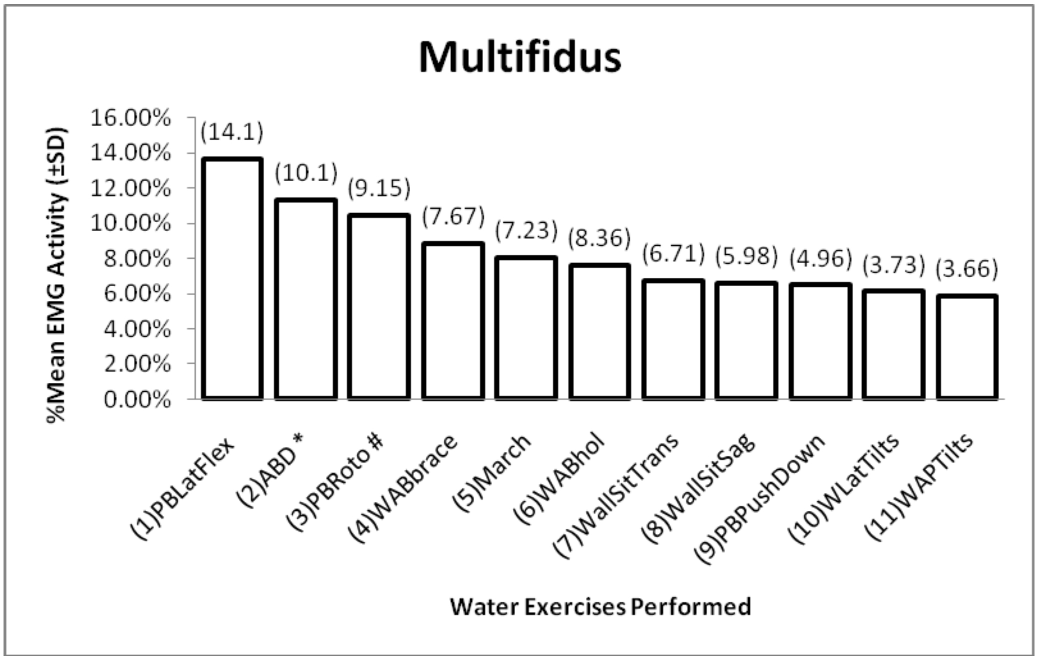

Figure 10. Water exercise comparison of normalized EMG amplitudes (±SD) for multifidus. *Greater activity than exercises 5-8 & 11, #greater activity than exercise 5 (*P* < .05).