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The Evidence of Aquatic Therapy for Painful Shoulder Disability

Academic thesis submitted in partial fulfilment of the requirements for obtaining a doctoral degree in Physiotherapy according to the Decree-Law nº. 74/2006 March 24th.

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Dedications

To my father (José Joaquim Graça in memoriam)
To my mother (Maria Amália Sanina for her support)
To my children (Marco e Margarida Vargas for their emotional care in all learning process)

“Experience is not what happens to us,

it is what we do with what happens to us”

Aldous Huxley

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LIST OF PUBLICATIONS

This Doctoral Thesis is based on the following original studies, which are referred in the text by their Roman numerals, respectively:

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ABSTRACT

The overall goal of this work was to study Aquatic Therapy for Painful Shoulder Disability. Scientific evidence is not strong. The findings are focused on the postoperative rotator cuff lesion, upper limb dysfunction and biomechanical characterization of the shoulder. What happens in silent shoulder injuries? Aging people adapt to their disability and look for an easier way to move. To promote healthy aging, doctors recommend aquatic activities because of the low impact on the skeletal muscle system. The deep-water is one of the techniques used in long-term programs of aquatic therapy or aquatic activities, with excellent adherence among the elderly. We studied the buoyancy influence in shoulder abduction and horizontal extension in deep-water, through the dual-media biomechanical analysis of the movement of upper limbs, we found a significant influence of the devices on the range of motion, but not on speed or smoothness, these findings showed evidence for making a decision. In a sample of older adults with chronical health conditions and painful dysfunction of the upper limb, we studied for their expectations, satisfaction, functional perception and the association between a functional scale based on the International Classification of Functioning, Disability and Health (ICF) and Disability of Arm, Shoulder and Hand (DASH). Deeper, what immediate effects do patients had from an aquatic therapy session? In addition, what was the effect of detraining of aquatic therapy after a summer pause? The findings showed evidence for continuous programs, as detraining is significant for balance and pain. The goals of a training program suggest being quickly achieved on older adults with a complete program. A case report on one female patient, 60 years old, studied kinematic and EGM during the five rotator cuff tests of a patient with grade 9 on the VAS_Pain scale and 57.80 for the disability of arm, shoulder and hand scale (DASH). The findings by ROM and the recruitment order of activation of the four muscles, left and right sides, in all tests. This suggests that pain symptom occurs in the right confirming the positive test. Through our studies, we hope to contribute to a better understanding and planning of treatment painful shoulder injuries older adult participating in a group aquatic therapy program.

KEYWORDS: AQUATIC THERAPY, PAINFUL SHOULDER, IMMEDIATED EFFECTS, BIOMECHANICS, GLOBAL EVALUATION.

RESUMO

O objetivo geral deste trabalho foi estudar a terapia aquática para a incapacidade dolorosa do ombro com fraca evidência científica. Os achados estão focados na lesão pós-operatória dos rotadores da coifa, disfunção do membro superior e caracterização biomecânica do ombro. O que acontece nas lesões silenciosas do ombro? As pessoas idosas adaptam-se à sua disfunção e procuram uma maneira mais fácil de se movimentar. Para promover o envelhecimento saudável, os médicos recomendam atividades aquáticas devido ao baixo impacto no sistema musculosquelético. Utiliza-se a água profunda em programas de longa duração de terapia aquática ou atividades aquáticas. Estudou-se a influência da flutuabilidade na abdução do ombro e na extensão horizontal em águas profundas, através da análise biomecânica do movimento dos membros superiores em duplo meio, encontrou-se influência significativa dos dispositivos na amplitude de movimento, mas não na velocidade ou suavidade. Em adultos mais velhos com condições crónicas de saúde e disfunção dolorosa do membro superior, estudou-se as expectativas, satisfação, perceção funcional e a associação entre a Escala de Perceção Funcional (FPS) e o Questionário de Incapacidade de Braço, Ombro e Mão (DASH). Também investigámos, os efeitos imediatos dos pacientes, numa sessão de terapia aquática, bem como o efeito do destreino da terapia aquática após uma pausa de verão. Os resultados mostraram evidências de programas contínuos, pois o destreino é significativo para o equilíbrio e a dor. Os objetivos de um programa de treino em adultos mais velhos sugerem ser rapidamente alcançados com um programa anual. Num estudo de caso de uma paciente de 60 anos estudou-se através de cinemática e EMG os cinco testes dos rotadores da coifa com valor 9 na escala VAS_Pain e 57,80 para a incapacidade da escala de braço, ombro e mão (DASH). O resultado na ROM e ordem de recrutamento de ativação dos quatro músculos esquerdo e direito, em todos os testes, sugeriu que o sintoma de dor ocorra à direita, confirmando o teste positivo. Espera-se contribuir para uma melhor compreensão e planeamento do tratamento de lesões dolorosas no ombro de adultos seniores em programas de terapia aquática em grupo.

Palavras-chave: TERAPIA AQUÁTICA, OMBRO DOLOROSO, EFEITOS IMEDIATOS, BIOMECÂNICA, AVALIAÇÃO GLOBAL.

LIST OF ABBREVIATIONS, ACRONYMS AND SYMBOLS

BMI	Body Mass Index
BP	Belly Press
DA	Drop arm
DASH	Disability of Arm, Shoulder and Hand
DoF	Degrees of freedom
EC	Empty can
EMG	Electromyography
FPS	Functional Perception Scale
FRT	Functional Reach Test
GBST	Global Balance Standing Test
HBP	Hyper blood pressure
ICF	International Classification of Functioning, Disability and Health
LABIOMEP	Porto Biomechanics Laboratory
MVC	Maximal voluntary contraction
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QTM	Qualisys Track Manager
RC	Rotator cuff
ROM	Range of motion
SPARC	SPectral ARC length
ST	Step Test
TUG	Time up and go test
VAS	Visual analogic scale

CHAPTER I

GENERAL INTRODUCTION

The shoulder is known to be the most important joint for reaching in daily life activities, as well as in repeated activities. In senescent aging, even with healthier behaviours, the biological degeneration of tissues occurs without any assurance of full recovery. Therefore, a painful shoulder is the most common complaint in older adults. In addition, the shoulder is one of the most well studied body structures due to the consequent disability having a significant impact on the life of older adults. The most prevalent cause of painful shoulder is rotator cuff injury, which is one of the most well studied injuries; a lot of interest has been developed to establish scientific evidence in an attempt to decrease its comorbidity (Downie & Miller, 2012; Yamamoto et al., 2010). Especially in the aging population, shoulder injury is one of the most frequent dysfunctions that results in disability in daily activities. Symptoms such as pain, limb elevation limitation, and muscle weakness are consistent with rotator cuff injury. However, due to senescent aging, the degeneration of rotator cuff tendons may be asymptomatic, and a single event may trigger symptomatology and functional disability. Aging individuals adapt to incapacity and look for easier ways of moving. Based on scientific studies and patient expectations, clinicians recommend aquatic activities due to the lower impact on the musculoskeletal system, in order to promote healthy aging (Yamamoto et al., 2010).

Clinicians are going further in the search for strategies to prove the value of phronesis in healthcare. Phronesis, according to Aristotelian thought, is the practical wisdom gained through knowledge of professional health practice in clinical reasoning (Vaughan-Graham & Cott, 2017). It is common for health professionals to make decisions based on their practical based knowledge, analysing the patient's response to different techniques. Studies have provided evidence for the use of aquatic running in a deep pool for populations with low back pain and cancer (Cantarero-Villanueva et al., 2013; Cuesta-Vargas et al., 2012). Aquatic activities may be a useful strategy to promote healthy aging of older adults (Mooventhan & Nivethitha, 2014), due to the benefits for all body systems. The most important outcomes older adults look for, as users of aquatic activities in many musculoskeletal conditions, are pain reduction and reduction of disability (Verhagen et al., 2012). These strategies in deep-water, without joint impact, may be understood as an aerobic aquatic exercise with cardiovascular results, which may positively influence non-communicable diseases that are usually linked to hypertension, diabetes mellitus and high cholesterol (Cuesta-Vargas & Heywood, 2011; Waller et al., 2013a).

There is evidence that biomechanical parameters underwater provide benefits for the recovery of shoulder injury. Floatation promotes less muscle activation in water when compared to the same velocity in land (Castillo-Lozano et al., 2014). We can confirm that, in an early intervention, acute post-surgery or acute events of osteoarthritis, intervention should promote less stress on the structures. However, it is unclear how the upper limb reacts in two media. There is a lack of knowledge about kinesiology in two media for upper limb abduction. Therefore, health professionals need to be better acquainted with evidence of deep-water exercise with regard to movement quality and fluctuation strategies, in order to obtain the expected results in shoulder mobility/stability (Wilder & Brennan, 1994). Clinicians seek to find strategies that promote functional improvement and symptom control. For instance, in the last 30 years, specialized surgery has been supported by the advancement of diagnostic technologies. However, the best results appear at 16 weeks, with accompanying physiotherapy combined with hydrotherapy (Brady et al., 2008; Hultenheim-Klintberg et al., 2009a).

Research into intervention processes frequently present weaknesses in the evaluation and treatment protocols. The lack of evidence on this topic and the degree of residual disability that patients present justify further investigation into this area in order to improve global rehabilitation results, expressed by the reduction of symptomatology, enhancement of functionality and improvement of the emotional state of patients that present this type of dysfunction (Hickey et al., 2007). However, we acknowledge that symptomatology does not always reflect the degree of severity of rotator cuff injury (Phadke et al., 2009). The evaluation protocols are usually based on questionnaires, range of movement measures and ultrasound control (Brady et al., 2008; Burmaster et al., 2016; Hultenheim-Klintberg et al., 2009a). This is due in part to the fact that the fibre injury is painful, compromising the collaboration in specific muscle tests of the rotator cuff. On the one hand, there is controversy regarding the evidence for rotator cuff tests, the literature used healthy samples to collect electromyography (EMG) and found patterns inconsistent with practitioner phronesis (Barratt, 2009).

Recovery interventions had been driven by results in the reduction of pain and in gains in mobility and functionality in daily life activities (Devereux et al., 2005; Thein & Brody, 2000). Treatment protocols have been based on adjusting land exercises to the principles of hydrodynamics, with the perspective of involving patients according to their phase of recovery (Downie & Miller, 2012; Dunn et al., 2008). In the initial phase, it is intended to take advantage of floatation, reducing the activation of antigravity muscles, shoulder elevators and their synergistic rotators. With the progression of the rehabilitation process, the exercises should be promoted to reinforce muscle activity with the aim of facilitating the binomial key of functionality: stability and mobility (Brady et al., 2008; Burmaster et al., 2016; Hultenheim-Klintberg et al., 2009a). All the problems above justify the development of the current thesis.

To search for the best evidence, a systematic review was first carried out (**Chapter 2**) with the application of the Newcastle-Ottawa scales, which were used to evaluate the methodological quality, and the Centre of Evidence-Based Medicine of Oxford to determine the level of scientific evidence on the efficacy of aquatic therapy for rotator cuff recovery.

Second, based on the lack of evidence for shoulder protocols in deep-water, the assumption was made that the most important outcomes looked for by older adults are pain and disability reduction and strategies in deep-water, which have no joint impact. The need for deeper knowledge about buoyancy conditions related to horizontal extension and abduction of the shoulder involved the study of a number of kinematic parameters (maximum and minimum angles, angular velocity, velocity magnitude, and smoothness of movement) in 10 healthy adults in deep-water (**Chapter 3** and **Chapter 4**).

Third, the poor understanding of aquatic therapy programs for older adults with upper limb dysfunction led to a cohort study with a sample of 108 individuals to validate the functional perception scale (FPS) based on the core set for older adults related to the International Classification of Functionality (ICF) (**Chapter 5** and **Appendix A**). Through convenient samples (**Chapter 6, Chapter 7 and Appendix B**) the immediate effects and detraining and training impacts of aquatic therapy for older adults with upper limb dysfunction (pain, balance and functional reach) were studied using a protocol based on evidence for patient problems.

Fourth, a case study (**Chapter 8**) about the approach towards studying EMG using five rotator cuff tests, using one subject, was performed. Finally, the general discussion, conclusions, suggestions for future researches and references are presented in **Chapter 9, Chapter 10** and **Chapter 11,** respectively. A detailed description of the studied performed is provided below.

There is a need for in depth knowledge of buoyancy conditions related to the horizontal extension and abduction of the shoulder based on deep-water practice; these movements are often used in functional reach for gaming or other tasks (Cuesta-Vargas et al., 2014; Killgore, 2012). Therefore, an exploratory study (**Chapter 2**) analysed the motion variability and smoothness during horizontal extension and abduction of the shoulder with different levels of buoyancy in deep-water. Our main question was about the quality of motion in deep-water for horizontal extension and abduction of the shoulders with different buoyancy conditions. Ten healthy, right-handed participants, who were already adapted to the water environment, repeated upper limb abduction movements ten times at maximum speed. The upper limb movement protocol consisted of horizontal extension and abduction of the shoulders (no aided buoyancy, with a pool-noodle and with a buoyancy belt), which gave six movement variations for each participant. The range of movement (ROM), peak angular velocity and smoothness coefficient were highlighted. Consistent with the recommendations of the International Society of Biomechanics describing thoracohumeral motion, joint angle kinematic calculations were made by applying X-Y-Z (corresponding to the elevation plane, elevation and axial rotation), using axes defined from anatomical landmarks (Wu et al., 2005), specific shoulder kinematics were monitored using a Qualisys twin (surface and underwater) Motion Capture system. The QTM calculations were done based on the labelled trajectories.

For further information, how the dual media, velocity, time spent and smoothness coefficient influence the range of motion in shoulder abduction was studied (**Chapter 3**). The same ten participants repeated upper limb abduction movements ten times at maximum speed. The upper limb movement protocol consisted of abduction in three ways in the same three ways as described previously, which gave three movement variations for each participant. The study of the two media characterised the curve of the magnitude of velocity, and found a pattern to kinematically describe the different reference points and the three distinct phases: underwater, above-water and in the transitory phase (based on the velocity curve synchronised with motion frame capture). With regard to outcomes between dominant limbs, ROM results pointed out differences for all buoyancy conditions underwater. The smoothness coefficient between dominant limbs pointed out differences between the above-water phase for sessions with no aided buoyancy devices, the underwater phase for buoyancy belts and the transitory phase for pool noodles.

Moreover, the understanding of aquatic therapy programs for older adults with upper limb dysfunction initiated a cohort study (**Chapter 4** and **Appendix A**) with a sample of 108 individuals to validate the Functional Perception Scale (FPS) based on the core set for older adults related to the International Classification of Functionality. The Spearman correlation pointed out a high association between Disability of Arm, Shoulder and Hand (DASH) and FPS (0.708; significance set at 0.01), reinforcing the finding that the upper limb disability was related to motor control performance. Our sample scores are lower in both scales, showing functional impairment. Health problems like Body Mass Index (BMI), Hyper blood pressure (HBP) and more than four medications showed a high association with DASH and FPS, providing a predictive factor to water adaptation. The fear of falls showed a stronger association with DASH and FPS (0.512 and 0.543, respectively) with a predicted significance for successful water interventions.

Afterwards, a quasi-experimental study (**Chapter 5** and **Appendix B**) included an experimental group (12 subjects) and a control group (10 subjects) and studied the immediate effects of hydrotherapy on pain, steps, functional reach and balance when standing. At baseline, the participants showed no differences; the results found only differences for the Global Balance Standing Test (GBST). An observational study (**Chapter 6**) compared three times of collection, the M1 (at end of year of the aquatic therapy program), the M2 (after two month of summer brake) and the M3 (after six weeks of training) in more depth. The outcomes analysed were Visual analogic scale (VAS) for Pain, Step Test (ST), Functional Reach Test (FRT) and GBST; these were tested for the effects of detraining and training.

Finally, a case report (**Chapter 8**) about the best approach for studying the EMG included five rotator cuff tests from one subject from a sample (18 subjects) in a biomechanical laboratory. The aim of this case study was to develop the protocol for biomechanical analysis of the EMG of the five following rotator cuff tests: belly press, drop arm, empty can, Neer and Hawkins. Rotator cuff pathology has a huge impact in public health politics. Due to this evidence is crucial to a more cost-effective approach. Further research with older adults with upper limb dysfunction related to rotator cuff injury should be projected based on all achieved knowledge. We also suggest a long follow up of these patients using the first data collection.

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CHAPTER II

STUDY I · COMMENTARY ON THE EFFICACY OF AQUATIC THERAPY PROGRAMS FOR ROTATOR CUFF INJURY

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Abstract

Rotator cuff injury is one of the most frequent disabling problems of the shoulder complex in ambulatory rehabilitation, leading to function impairments and activity limitations, especially in the elderly. Over the last three decades, studies concerning rotator cuff injury recovery have only provided weak consensus on the best rehabilitation strategies. Nonetheless, scientific evidence is available showing the benefits of therapeutic aquatic exercise on pain, activity level, joint mobility, strength and balance in individuals with musculoskeletal injuries. A therapeutic aquatic exercise program maybe prescribed comprising different loads, depending on the gravity-buoyancy distribution and hydrodynamic resistance. The use of buoys and other resistance equipment in therapeutic aquatic exercise provides the opportunity to perform open or near to closed kinetic chain exercises with patients. This chapter aims to examine the effectiveness of therapeutic aquatic exercise for recovery from rotator cuff injury. For that purpose, the databases PubMed, Cochrane CENTRAL, SPORTDiscus and PEDro were searched for relevant articles to conduct a literature review. After applying the eligibility criteria, two cohort studies (a pilot and a feasibility study) and a single case study evaluating the efficacy of a program in rotator cuff injury were identified. The Newcastle-Ottawa scale was used to assess the methodological quality and the Oxford Center of Evidence Based Medicine scale to determine the level of evidence. The two cohort studies compared the effectiveness of a traditional physiotherapy program with a combined program that also used therapeutic aquatic exercise, and the case study used combined aquatic and dry land therapy. Despite presenting different protocols, both studies showed that the addition of therapeutic aquatic exercise provided extra benefits in reduction of shoulder pain and gain of range of motion and function. However, due to the lack of available studies on aquatic exercise therapy programs' efficacy in patients with rotator cuff injury no strong conclusion can be made, highlighting the need for further research in this field.

Keywords: rotator cuff injury, aquatic rehabilitation protocols, aquatic therapy, aquatic exercises, effectiveness

Introduction

Rotator cuff injury is one of the most disabling problems of the shoulder complex in ambulatory rehabilitation, causing functional impairments, especially in the elderly (Pegreffi et al., 2011). Over the last 30 years, clinicians have developed rehabilitation strategies for this injury and studied patient outcomes, however without reaching consensus. Unvarying after surgical repair, functional impairment may remain for several months after the rehabilitation process. Nevertheless, clinical practice shows that the pain intensity pattern is not related to the lesion magnitude (Dunn et al., 2014; Simon et al., 2016). Compared to other tendon injuries, the rotator cuff displays a completely different response to pain, which has intrigued researchers worldwide. The reduced capacity to use the upper limb related to the major deficit of this injury keeps the injured shoulder at relative disuse, by avoidance of daily living activities that might otherwise be painful (Conti et al., 2009; Pegreffi et al., 2011; Yamamoto et al., 2010).

Patients often report absence of pain, which is not equivalent to being completely asymptomatic as they still may mention symptoms of weakness, lack of mobility, stiffness and instability (Matsen, 2014). The therapeutic monitoring of this particular population should be based on an appropriate exercise program aimed at the improvement of shoulder function (Hickey et al., 2007). Moreover, understanding the physiological effects in the human body, can aid the clinicians to create an effective treatment plan through appropriate adjustment of aquatic exercises, immersion temperatures and treatment duration (Becker, 2009).

Within this line, Waller et al. (2013) research on aquatic therapy for knee osteochondritis reported benefits in the management of patients with musculoskeletal problems. In addition, there are reports of improvements in pain, function, self-efficacy, joint mobility, strength and balance, particularly amongst the older adults but with very poor level of evidence (Geytenbeek, 2002). Also, Waller et al. (2016) concluded through a meta-analysis that aquatic exercises appear to be effective at maintaining and improving physical function in healthy older adults. If compared to land exercises, aquatic exercises seem to be at least as effective and could be used as an alternative training modality when land exercises are not feasible or desired.

Aquatic therapy combines different strategies to increase, maintain and restore maximum movement and functional ability. This can be helpful at any stage of life and may help in different types of injuries, diseases, disorders, conditions or environmental factors that threaten movement and function. An aquatic exercise program may be designed varying the amount of gravity loading by using buoyancy and hydrodynamic drag as a counterforce, support or resistance. These criteria are accomplished by the use of paddles and other resistive equipment allied to velocity (Thein & Brody, 2000). We searched for rehabilitation for this injury through reviews and studies, expecting to find the answers for some questions concerning what are exactly the best solutions or why we make additional treatment or should we go to aquatic therapy as a standalone, and what is better in water than on dry land. Nevertheless, as the validation of aquatic exercises for rotator cuff injuries has not been accomplished, this chapter intends to systematically review and discuss the different approaches that have been used, combining aquatic and dry land interventions for rotator cuff injury and draw conclusions based on these results.

Methods

According to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement, the conducted systematic review aims to improve the standard of reporting of systematic reviews (Liberati et al., 2009). For this purpose, a comprehensive literature search was performed, using Pubmed, Cochrane CENTRAL, SPORTDiscus and PEDro databases to identify studies in humans that assessed the efficacy of aquatic therapy programs in the rehabilitation of rotator cuff injuries. The search included the following keywords: hydrotherapy, aquatic physiotherapy, aquatic physical therapy, aquatic exercise, aquatic therapy, aquatic rehab, aquatic rehabilitation, aquatherapy and rotator cuff, shoulder or glenohumeral disorder. In the PEDro database, the search was conducted with the filters therapy (hydrotherapy, balneotherapy) and body part (upper arm, shoulder or shoulder girdle). All literature was sought up to and including September, 2017.

All the searches were conducted by two independent researchers, which completed the initial screening of titles and abstracts, followed by the reviewing of the full texts. After the screening and determination of eligibility, the information was selected by one of the researchers (M. G.) and reviewed for accuracy by another (R. A.), always taking into consideration the characteristics of the population, the aquatic therapy protocols and their outcomes. The inclusion and exclusion criteria were predetermined before the search was performed.

Inclusion criteria were: (i) human subjects; only adults (≥18 years old); (ii) presenting diagnosis of rotator cuff injury; and (iii) if the study presented the description of their intervention protocol. Exclusion criteria were 1) neurologic conditions; 2) other concomitant pathologies, such as arthritic conditions, traumatic injuries, female health conditions and participants that were in palliative care; 3) other reviews or meta-analysis; and 4) technical notes and comments to editor. A third author (A. R.) resolved disagreements between the two authors.

The Cochrane Handbook suggests the Newcastle-Ottawa Scale assess the methodological quality of non-randomized and randomized studies of interventions (Higgins, 2011). This specific tool assesses the risk of bias of some non-randomized designs that involve a different inferential logic compared with parallel group trials (Higgins et al., 2013). Therefore, using respectively the Newcastle-Ottawa Scale and the Oxford Center for Evidenced-Based Medicine, we evaluated the methodological quality and the evidence level of each trial. Discrepancies were discussed until consensus.

Results

The database and hand search resulted in 198 records. A total of 151 titles and abstracts were screened after the duplicate results were removed, yielding 13 potential full-text articles that were read to assess their eligibility. From these, 3 studies were eligible for inclusion in this systematic review, two intervention studies (Brady et al., 2008; Hultenheim-Klintberg et al., 2009a) and one case study (Burmaster et al., 2016). Search strategy steps and reasons for exclusion can be found on the PRISMA flow chart (Figure 2.1). The three studies included comprised 33 patients with rotator cuff injury (13 female and 20 male), with an average age of 55 years.

Brady et al. (2008) included 18 volunteers divided into two groups: one treated with traditional physiotherapy program and the other with a combination of traditional physiotherapy and aquatic exercises. Hultenheim-Klintberg et al. (2009b) included 14 participants, which were randomized into two groups: traditional physiotherapy or combined physiotherapy. The case study of Burmaster et al. (2016) examined a 73-year-old woman prescribed for an early intervention with aquatic therapy (Table 2.1).

Brady et al. (2008) used a traditional protocol on dry land which included an initial phase (first to the third week) with passive exercises in forward flexion and external rotation, pendulum and scapular stabilization and a second phase (fourth to the ninth week) with active assisted pulley exercises. The third phase (tenth to twelfth week) was comprised of resisted external rotation, internal rotation and scapular retraction (isometric with Thera-band) and wall push-ups. The combined protocol started with the traditional physiotherapy program.

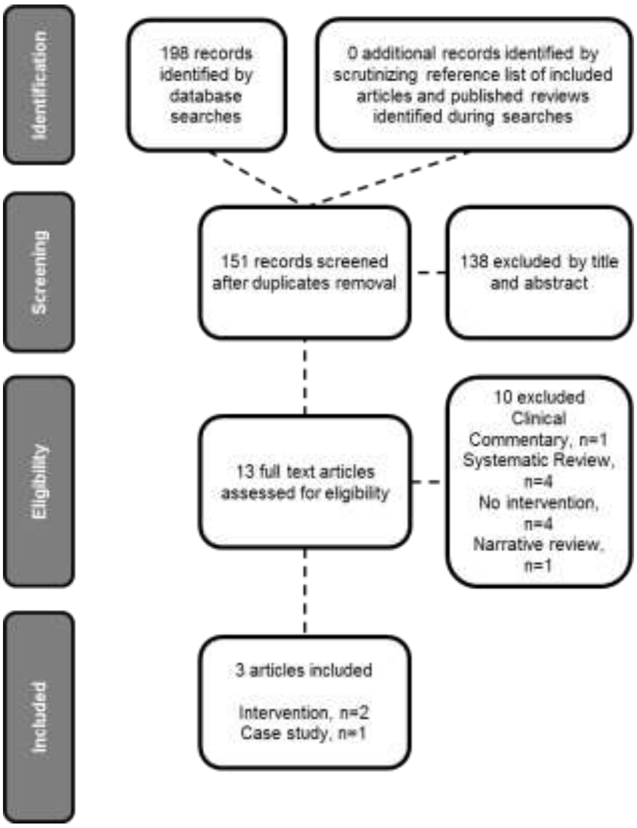


Figure 2.1 – PRISMA flow chart for the database search.

After the stiches were removed, the traditional physiotherapy program was complemented at the 10th day with aquatic therapy exercises that began with buoyancy assisted forward flexion and external rotation, scapular stabilizers and pendulum exercises. At the sixth week, standing breaststroke, hand behind back and kickboard exercises were added to the aquatic program At the eighth week, the program added resisted forward flexion and external rotation using paddles and at the tenth-week ball proprioception and resistance and wall push-up exercises. The standard protocols are described on Table 2.2.

Hultenheim-Klintberg et al. (2009b) included 14 participants, randomized into two groups: traditional physiotherapy or combined physiotherapy. The traditional group started the day after surgery including a first home training program performed (three times per day) and passive range of movement program (two or three times per week) which was performed by a physiotherapist until six weeks post-surgery. The combined group also started the day after surgery with the first home training program, including activation of the rotator cuff (three times per day).

Table 2.1 – Characteristics of the studies included in their goals and follow-up.

Author/Year Sample/Number /Gender	Goals	State of rotator cuff	Duration & follow-up
Brady et al. (2008) 18 patients (55 years) 7 ♀ / 11 ♂	Investigate the feasibility of a combined aquatic and dry land physiotherapy program in post-surgery rehabilitation of rotator cuff tears.	Diagnosis of rotator cuff tear with symptoms present greater than 3 months and less than 12 months.	2x/week during 12 weeks Follow-up not reported
Burmaster et al. (2015) 1 patient (73 years) 1 ♀	Detail and describe the implementation of a unique comprehensive evidence-based, aquatic-assisted rotator cuff repair rehabilitation protocol for a medium-size supraspinatus tendon tear.	Non retracted, medium-size, full-thickness tear (2.5 cm) of the supraspinatus tendon	3x/week during 6 weeks 8 weeks
Hultenheim et al. (2009) 14 patients (55 years) 5 ♀ / 9 ♂	Describe the clinical changes following two different physiotherapy treatment protocols after rotator cuff repair.	Full-thickness rotator cuff tear, who underwent surgery involving subacromial decompression and repair of the torn rotator cuff completed.	2x/week during 24 weeks 2 years of follow-up

Table 2.2 – Comprehensive of the standards protocols of the studies.

Author/Year Sample/Number /Gender	Intervention protocol	Aquatic intervention protocol
Brady et al. (2008) N= 18 (55 years) 7 ♀ / 11 ♂	Group I – Combined aquatic and dry land therapy. Group II – Traditional dry land therapy.	10th day: Buoyancy assisted forward flexion and external rotation; scapular stabilizers; pendulum. 6th week: Standing breaststroke, hand behind back and kickboard. 8th week: Resisted forward flexion and external rotation using paddles. 10th week: Wall push-ups, ball proprioception and resistance.
Burmaster et al. (2015) 1 patient (73 years) 1 ♀	Combined aquatic and dry land therapy.	3rd week: controlled motion/buoyancy-assisted exercises 5th week: increase speed of the exercises 7th week: increase speed of the exercises and use of resistive devices to the patient dry land rehabilitation and complementary home aquatic exercises provided at each phase.
Hultenheim et al. (2009) 14 patients (55 years) 5 ♀ / 9 ♂	Group I – Combined physiotherapy Group II – Traditional physiotherapy	Both group performed the aquatic training but in different timings. Program 1: active assisted exercises performed with both the upper limb in front of the body, 2x/week. Program 2: active, aquatic-resisted exercises performed throughout full ROM, 2x/week.

At the fourth week post-surgery, the combined group removed the immobilizing sling and started a second home training program. This included exercises with increased loading and active/assisted range of movement of the rotator cuff, supervised by an outpatient physiotherapist (two or three times per week) and an aquatic therapy program (once per week) with active/assisted exercises performed with the upper limb in front flexion.

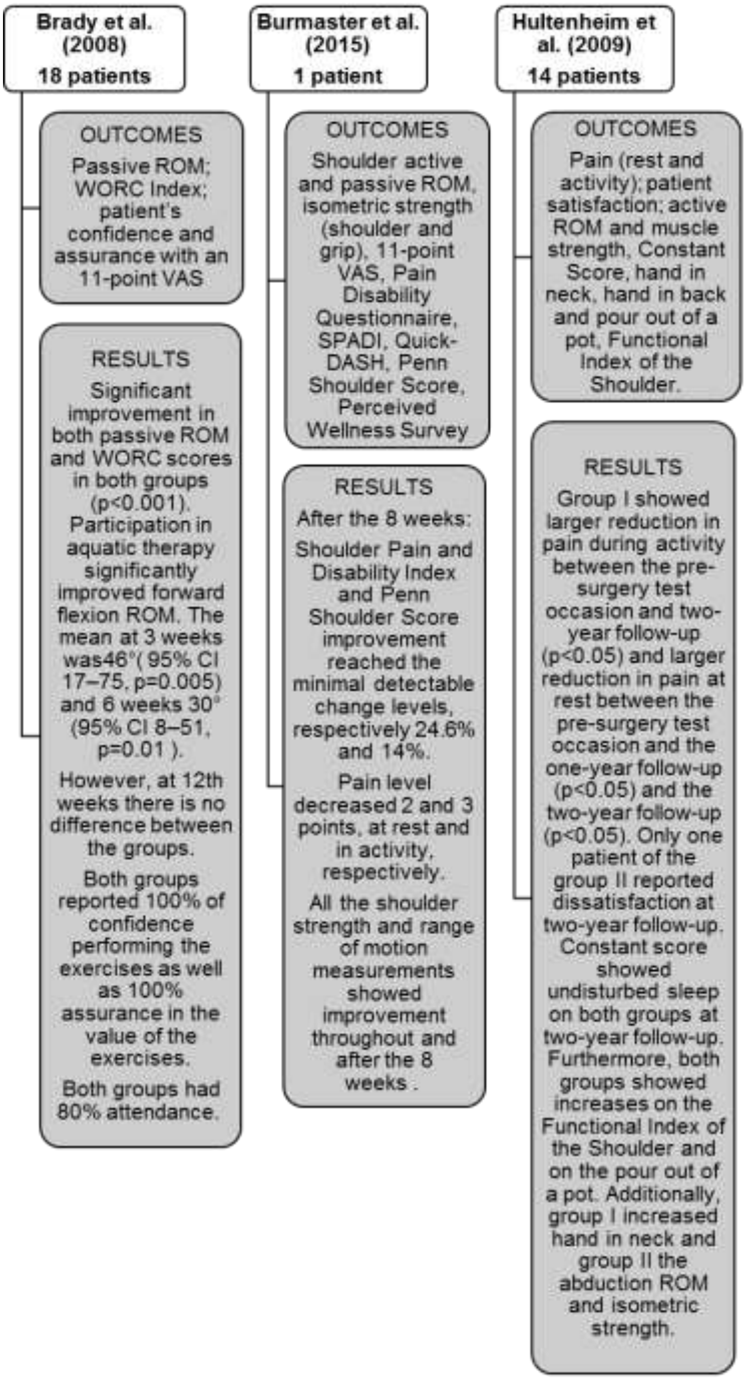
At the sixth week post-surgery, the traditional group removed the immobilizing sling and started the second home training program which included activation of the shoulder’s internal and external rotators and active-assisted range of movement in flexion and elevation in the plane of scapula supervised by an outpatient physiotherapist (two or three times per week). On other hand, the combined group at the sixth week post-surgery, increased loading of the rotator cuff by the home training program with isometrics and active range of movement in flexion and abduction with elbows flexed as well as passive range of movement, emphasizing restoration of the internal rotation, with increasing load during supervised physiotherapy.

At the eighth week post-surgery, the combined group started a third home training program with increased load on the rotator cuff with rubber-elastics (two times per day), dynamic strengthening exercises of the rotator cuff and scapular muscles throughout the full range of movement with the elbow fully extended (long lever upper limb). Then, at the 10th week, the traditional group started the first aquatic training program with active/assisted exercises performed with the upper limb in front of the body. Meantime, the combined group started the second aquatic training program with aquatic-resisted movement throughout full range of motion two times a week.

Finally, at the 12th week, the combined group included eccentric loading of the rotator cuff until the end of the therapy program. In the sixteenth week, the traditional group began the third home training program with dynamic strengthening exercises for the rotator cuff and scapular muscles throughout the full range of movement and the second aquatic training program. Finally, the traditional group at the 20-40th week post-surgery initiated the eccentric load on the rotator cuff during supervised physiotherapy until the end of the therapy program. Study outcomes and results can be seen in Figure 2.2.

Burmaster et al. (2016) presented a case study of rotator cuff tear repair rehabilitation with aquatic therapy aiming at the promotion of healing, protection and repair with gradual restoration of the joint's motion and strength, to allow the patient to return to the normal function. The shoulder program rehabilitation focused on endurance training of the rotator cuff, protection of the rotator cuff musculature from adverse forces, restoration of normal flexibility of the joint capsule, ensuring of correct thoracic posture and scapular positioning for optimal scapula-humeral rhythm. The protocol was based on a literature review, with weekly assessments of the outcomes and the respective minimal detectable change.

The included studies reported different assessment parameters, resulting in heterogeneity regarding the reported results. In the Brady et al. (2008) study quality of life was assessed with the Western Ontario Rotator Cuff Index. Passive range of movement was assessed, as well as, the patient's self-assurance and confidence with the Visual Analogue Scale. Range of movement and scores of the Western Ontario Rotator Cuff improved significantly in all subjects over the 12 weeks of the study (p < 0.001), showing clinical relevance.



Brady et al. (2008)
18 patients

OUTCOMES
Passive ROM; WORC Index; patient's confidence and assurance with an 11-point VAS

RESULTS
Significant improvement in both passive ROM and WORC scores in both groups (p<0.001). Participation in aquatic therapy significantly improved forward flexion ROM. The mean at 3 weeks was46°(95% CI 17–75, p=0.005) and 6 weeks 30° (95% CI 8–51, p=0.01).

However, at 12th weeks there is no difference between the groups.

Both groups reported 100% of confidence performing the exercises as well as 100% assurance in the value of the exercises.

Both groups had 80% attendance.

Burmaster et al. (2015)
1 patient

OUTCOMES
Shoulder active and passive ROM, isometric strength (shoulder and grip), 11-point VAS, Pain Disability Questionnaire, SPADI, Quick-DASH, Penn Shoulder Score, Perceived Wellness Survey

RESULTS
After the 8 weeks:

Shoulder Pain and Disability Index and Penn Shoulder Score improvement reached the minimal detectable change levels, respectively 24.6% and 14%.

Pain level decreased 2 and 3 points, at rest and in activity, respectively.

All the shoulder strength and range of motion measurements showed improvement throughout and after the 8 weeks .

Hultenheim et al. (2009)
14 patients

OUTCOMES
Pain (rest and activity); patient satisfaction; active ROM and muscle strength, Constant Score, hand in neck, hand in back and pour out of a pot, Functional Index of the Shoulder.

RESULTS
Group I showed larger reduction in pain during activity between the pre-surgery test occasion and two-year follow-up (p<0.05) and larger reduction in pain at rest between the pre-surgery test occasion and the one-year follow-up (p<0.05) and the two-year follow-up (p<0.05). Only one patient of the group II reported dissatisfaction at two-year follow-up. Constant score showed undisturbed sleep on both groups at two-year follow-up. Furthermore, both groups showed increases on the Functional Index of the Shoulder and on the pour out of a pot. Additionally, group I increased hand in neck and group II the abduction ROM and isometric strength.

Figure 2.2 – Outcomes and results of the studies included.

However, only the forward flexion range of movement was greater in the patients of the aquatic therapy program followed by the control group, with a 46º difference (95% confidence interval 17–75, p = 0.005) at the third week and 30º difference (95% confidence interval 8–51, p = 0.01) at the sixth week. The active range of movement at the twelfth week and the Western Ontario Rotator Cuff Scores of both groups reported the same rates for confidence and assurance (100%) and both had the same attendance rate (80%).

For Hultenheim-Klintberg et al. (2009b) the assessment of pain scores measured by a Visual Analogue Scale - from 0 to 100 mm - decreased from 27 and 4 mm (almost no pain) at the pre-surgery stage to zero mm (no pain) at second-year follow-up at rest, for both combined and traditional groups. During activity, the pain score also decreased greatly over the second year follow-up, from 73 and 60 mm to two mm and zero mm. Regarding the active range of movement values, abduction improved from 140 and 110º at the pre-surgery stage to 170 and 175º at first-year follow-up.

In the same line, the external rotation in abduction improved from 50 and 70º to 70 and 90º at the first-year follow-up, for combined and traditional groups. The Functional Index of the Shoulder decreased over the second year follow-up from 54 and 44 points to 1 and 18 points. The Constant Score improved from 60 to 82 and 76 to 77 points, for combined and traditional groups, respectively from the 6 to 24th month follow-up. Considering different baseline values, the combined group showed significance in the Constant Score and Functional Index of Shoulder and apparent faster functional improvements and relief of the symptoms.

For the case study, Burmaster et al. (2016) reported improvements within the minimal detectable changes for Shoulder Pain, the Penn Shoulder Score and the Disability Index. Pain decreased at rest and during activity also by between two and three points (30 mm). The shoulder strength and range of movement improved positively over eight weeks. Despite the different approaches, the results reported showed decreased pain intensity and improved range of motion and joint functionality.

Besides the different approach and similar outcomes measures of the randomized controlled trials, the results are clearly significant for pain, improvement of sleep and increase in activity. The range of movement increased in all experimental groups. In addition, the functionality outcomes showed improvement for activities of daily life. Therefore, we may say that the addition of aquatic therapy to traditional rehabilitation can be a strong input to improve the recovery of the patients with rotator cuff injury.

Table 2.3 – Newcastle-Ottawa Scale and Oxford Centre of Evidence-based.

Medicine (CEBM)*.

	Selection				Comparability	Outcome			Total scores	CEBM
Study	1	2	3	4	1	1	2	3		
Hultenheim et al. (2009)	-	-	*	*	**	*	*	*	7/9	2b
Brady et al. (2008)	-	-	*	*	**	*	-	-	5/9	2b
Burmaster et al. (2015)	-	-	*	*	-	-	*	*	4/9	5

*Methodological Quality and Level of Evidence (http://www.cebm.net/blog/2009/06/11/oxford-centre-evidence-based-medicine-levels-evidence-march-2009/)

The average score of methodological quality of the studies was 5.3 ± 1.5 out of nine possible points according to Newcastle-Ottawa scale and the level of evidence was 2b and 5 across all the studies (Table 2.3). The most common methodological limitation according to Newcastle-Ottawa scale was the representativeness of the sample and the selection of the non-exposed cohort, where none of the studies was able to achieve these parameters, as the participants did not truly represent the average of the population and represented a specific cohort. Moreover, Brady et al. (2008) did not report any follow-up; therefore, the parameters two and three from the Outcomes section were not achieved. Regarding the level of evidence, the two studies were rated 2b as they represented cohort studies from a feasibility study (Brady et al., 2008) and a pilot study (Hultenheim-Klintberg et al., 2009b) and the case study (Burmaster et al., 2016) was rated as 5.

Discussion

The main finding of this systematic review is that there is a lack of studies in the scientific literature examining the effectiveness of aquatic therapy programs in patients with rotator cuff injury. Moreover, the few available studies were underpowered and presented many limitations. On one hand, Vierville (2012) stated that the new millennium could bring a stronger understanding about aquatic rehabilitation in the personal and social sense, since the resources for research have been upgraded through technology and new approaches to the “whole person.” Moreover, the authors of this commentary believe, the shoulder is a complex and specific joint in the human body because it is an important tool for work, sports activities or self-care. Aquatic therapy programs improve the shoulder active range of movement, strength and function in patients when the injured or surgically repaired tissues have not been fully compromised (Subaşi, 2012).

At the same time, novel surgical techniques require research on improved or accelerated rehabilitation protocols (Brady et al., 2008; Liotard et al., 2003; Murtaugh & Ihm, 2013; Petersen & Murphy, 2011). In addition, knowledge is growing about the viscosity and the turbulence proprieties of the water which add resistance to the movements performed underwater. It is known that progression of intensity obtained inside water may be enhanced by increasing speed of motion and thus, muscular strengthening could be performed with decreased joint loading (Hultenheim-Klintberg et al., 2009b), reducing the impact often present in dry land exercises.

This fact will allow patients to perform rehabilitation exercises with less load at the joint, decreasing the joint stress. Recently, shoulder joint moment, work and power in a slow underwater scapular plane abduction/adduction have been studied. Results are encouraging for the use of aquatic shoulder exercises with a real benefit from the upward lift of buoyancy. In slower speeds, the buoyancy contribution is sufficiently high to elicit eccentric work during the abduction, which is favourable to regain joint mobility with very little effort and the best effectiveness (J. Lauer et al., 2016). In addition, a significant methodological improvement with the integrated use of computational fluid dynamics and inverse dynamics leads to paramount understandings into aquatic movement biomechanics. The researcher affirms the importance to more applied forms of research on aquatic rehabilitation. It may be used in competition or in clinical settings, for explore the differences between males and females about joint load (Jessy Lauer et al., 2016).

Through the use of computational fluid dynamics and inverse dynamics we know shoulder and elbow muscle groups equally contribute to more than 97% of the total work and power during a stroke when performing sculling motion in a pool. The limiting factors of underwater power production and the human musculoskeletal system adapted to substantial changes in mechanical demands when performing in water, suggest a general motor strategy of power of all joints of upper limp. This insight could be applied to the protocols rehabilitation exercises with the specific shoulder injury for a better understanding (Lauer et al., 2017).

An electromyographic study showed decreased shoulder muscular activity during aquatic exercises if the elevation is performed at slower speeds (30 or 45º/s) within the scapular plane with neutral rotation of the humerus. However, if elevation is fast (90º/s), the load is similar to dry land exercises (Kelly et al., 2000). This suggests that the buoyancy effects of water may be balanced by the water drag and create similar levels of muscular activation, despite the difference in the kind of load. The effect in reducing pain intensity when the exercise is performed underwater is the main goal pursued by all patients. Hence, protocols should use slow motion, supported by buoyancy, to relieve pain symptoms (Liotard et al., 2003).

To reinforce this rational, McCreesh et al. (2017) studied the impact of load and fatigue promoted by the exercise therapy for painful supraspinatus tendinopathy. They had two groups, one with painful rotator cuff tendinopathy and the other pain free controls. Ultrasound examinations evaluated the response of supraspinatus (at 1, 6 and 24 h) to fatigue after concentric and eccentric shoulder exercises. In addition, the acromion humeral distance showed reduction in both groups, but the recovery in the painful group was slower to recover to baseline tendon characteristics. Their findings suggest that physiotherapists should take into account the potential for increased tendon thickness and reduced subacromial space after loading, especially when planning a rehabilitation program in the early management of rotator cuff injury, avoiding the fatigue.

On other hand, rotator cuff injury often leads to disability and severe pain, which promote immobilization of the shoulder (Beaudreuil et al., 2009). Muscular weakness and immobilization lead to more disability and higher pain intensities. On the other hand, clinicians should make the correct clinical reasoning for improving the shoulder movement, as the patient benefits from the biomechanics proprieties of aquatic movement. Therefore, the effectiveness of movement gains after aquatic therapy may be justified by the promotion of core stability, which facilitates the selectivity of the motion (Colado et al., 2008). However, the systematic review of Wagner (2012) concluded that better understanding is needed to adjust intensity, duration, repetitions and progressions of aquatic exercises.

In addition, Thomson et al. (2016) performed a systematic review regarding the rehabilitation of rotator cuff in general. They showed insufficient scientific evidence on aquatic exercise due to the poor methodological quality of the studies and the reporting quality of protocols. When following surgical repair, no single aquatic therapy protocol was superior to another. The researchers highlighted the need for additional studies with a higher number of participants and longer follow-ups to investigate their effects and obtain conclusions that are more reliable. Nevertheless, the results showed pain reduction at four weeks after surgery repair, regain of some range of movement usually within three months, but never complete until the 12 months. After 12 months, there are evidence of aquatic therapy programs on shoulder muscle strengthening. Regarding functional outcomes, the clinical and functional measures report improvements after the 24 months.

The evidence for exercise therapy in the conservative management of full-thickness tears of the rotator cuff also points out the poor consensus of the outcomes of rotator cuff rehabilitation in the elderly population. Usually, the clinicians prescribe exercise, but the evidence is weak and equivocal. In this sense, Ainsworth e Lewis (2007) performed a systematic review concluding that evidence from RCTs is very poor because the outcomes and the time between measurements had no support in literature or in previous studies. Therefore, comparison of these results is needed with the exercises recommendation and the type of injury. Still, it is unclear why exercise has a beneficial effect. The reasons may be pain modulation, training others muscles to activate and co-coordinate in motion. In addition, Ainsworth e Lewis (2007) stated that the type of damaged rotator cuff muscles and tendons might confound the therapeutic effect of aquatic exercise, the reduction of motion, the kinesiophobia or placebo effect.

Others authors, such as Hayes et al. (2004) compared an individualized dry land program supervised by a physiotherapist and an unsupervised home exercise program. Results showed that there were no statistical differences between the two groups. Seida et al. (2010) also studied the evidence on conservative management versus surgical treatments for rotator cuff tears. Their results were inconclusive and limited due to bias and the low quality of the studies. The authors of this commentary recognize how painful recovery of this injury may be, therefore, prevention strategies may be the cornerstone to find the evidence of the specific dry land exercises that protect and prevent rotator cuff injury in young competitive swimmers.

The knowledge on overuse of the upper limbs by the displacement of the total body in front crawl, backstroke and butterfly was the starting point of the randomized controlled trial of Batalha et al. (2015). They studied a dry land exercise program with Thera-Band® for strengthening of the shoulder during 16 weeks. The results showed an increase in absolute strength values and better muscle balance in shoulder muscles of the swimmers (rotator cuff included). This finding suggests that the prescribed shoulder-strengthening exercises could be helpful to reduce the risk of injury (Batalha et al., 2013).

Examining the randomized control study performed by Brady et al. (2008), it was found that a combined aquatic and dry land physiotherapy program improves shoulder passive range of motion and function. However, these results were found in both groups (aquatic with dry land physiotherapy and traditional dry land therapy). Once aquatic physiotherapy was combined with dry land exercises, it is possible to speculate that the addition of aquatic physiotherapy brought greater improvement to dry land exercises, but it is not possible to say that the greater amount of exercise produced these results. On the other hand, the positive passive range of motion in front flexion can be associated with the buoyancy in the water, and improvement in external rotation can refer to a lack of stabilization in these specific aquatic exercises. However, some bias may be found because the combined program had twice the number of participants.

The study of Hultenheim-Klintberg et al. (2009b) indicated that a more proactive and combined rehabilitation program was associated with a faster recovery, reducing additional adverse effects. The protocols based on the biomechanical proprieties of the exercises, looked at all the symptoms of the patients. The combined group showed significant reductions in pain at rest and during the activity and in the Functional Index of the Shoulder. No consistent conclusion can be made about the effect of aquatic physiotherapy, as both groups included the same aquatic protocol, but at different rehabilitation stages. However, it is not possible to be sure if the earlier implementation of aquatic programs in the rehabilitation process has more benefits, as there are no records relating to the starting time of the program in the rehabilitation process of the participants. It is not possible to determine whether there are beneficial results achieved by the early loading through aquatic exercises, in combination with dry land exercises.

But, the Burmaster et al. (2016) case study illustrates the safety of inclusion of an aquatic therapy program as an early strategy to deal with severe pain during activity, immobilization and compromised active range of motion. The measurement of the patient’s self-efficacy showed the positive results of the patient’s wellness. The case had several comorbidities (two-year history of chronic rotator cuff injury) and the expectation was weak for a good recovery. Based on this literature review, the low-stress aquatic exercises performed had a good impact on the recovery of this patient. The reported outcomes based on minimal detectable change were very positive at eight weeks. The authors provided insights into the selection of patients based on the pain pattern and shape of the upper limb (large and heavy).

Patients who experience high pain with heavy or large upper limbs may obtain more benefit from buoyancy and water drag to relieve the symptoms (Murtaugh & Ihm, 2013; Speer et al., 1993). The physiologic changes sustained by the body immersed, offer special impairment-based treatment, as well as suggestions for cardiovascular conditioning, stretching frequency and duration, and concentric and eccentric strength training (Thein & Brody, 2000). It is possible to say that there is a key advantage to the early incorporation of buoyancy-assisted low percent maximal voluntary contractions (Batalha et al., 2013). However, the three studies used different outcome assessment parameters, which made it impossible to compare quantitatively (meta-analysis) the results from the included studies. Beyond that, these studies did not focus primarily an aquatic therapy intervention, but a combination of other interventions, hampering the conclusions taken from their results regarding the benefits of aquatic therapy.

In addition, another common limitation was the selection of no treatment control group. None of the studies had a no treatment control group or blinding of patients or treatment providers or making outcomes measures. Furthermore, Brady et al. (2008) did not include any follow-up in their study, making it impossible to determine if the rehabilitation effects lasted the following months. All these issues presented above can lead to bias within the studies and provide low internal quality. As no dry land program seem to be better than the other, studies with combined aquatic therapy programs should be emphasized that they may relieve symptoms more effectively.

Furthermore, the electromyographic difference between flexion and abduction suggests that protocols should first introduce shoulder flexion exercises at low speeds in water, then at medium speed in water or dry land and finally at high speeds on dry land before performing in water. In addition, due to the needs of higher stabilization, abduction movements should be done after flexion exercises. These facts seem to provide safer rehabilitation than the traditional dry land rehabilitation protocols since aquatic therapy reduces the stress on the repaired tissues and allows an earlier rehabilitation (Castillo-Lozano et al., 2014; Kelly et al., 2000; Villalta & Peiris, 2013).

Therefore, according to the available scientific literature, it is still not clear if the addition of aquatic exercises or if aquatic therapy program provides beneficial effects when compared to the conventional dry-land rehabilitation programs alone. In addition to the studies limitations discussed above, other problems can be identified. No high evidence-level studies were found, providing poor internal validity and low evidence on the conclusions. No homogeneity in the rehabilitation exercises were found. Again, it becomes difficult to make a feasible comparison between these. Furthermore, the small samples used, compromise the external validity of the studies.

Due to the insufficient scientific evidence on aquatic exercise for this injury in elderly and the weak knowledge of underwater shoulder biomechanics for this kind of patients, it is not possible to draw any conclusions about the best intervention. The complexity of this joint has a large impact on a person's life when severe injuries occur resulting in absence from work or sports participation or self-care. This burden should stimulate the investment in research on better rehabilitation and prevention options. In this sense, the authors of this commentary encourage future studies comprising larger samples, randomization of their patients to aquatic or dry land rehabilitation programs, blinding of their assessors and include a follow-up long enough to assess recovery.

Conclusion

No strong conclusion can be made due to the high heterogeneity in rehabilitation protocols, times of assessment, included samples and outcome measurements used within the available studies. Further research on rotator cuff injury rehabilitation is needed combining programs for patients with higher level of pain and restriction of range of motion, supported by the outcomes on patients' beliefs and responses to clinical changes. Additionally, further investigation on aquatic exercises is required to better develop aquatic therapy protocols for implementation in clinical practice.

Conflicts of interest statement

The authors declare no conflict of interest.

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CHAPTER III

STUDY II · THE INFLUENCE OF ADDITIONAL BUOYANCY ON SHOULDER EXERCISE PERFORMED IN DEEP-WATER

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Abstract

Introduction: Health professionals use activities such as running and walking in deep-water. We examined the smoothness coefficient as an important criterion to characterize this movement's performance. **Objective:** Study motion variability and smoothness during horizontal extension and abduction of the shoulder with different buoyancy conditions in deep-water. **Methods:** Ten healthy right-handed subjects, adapted to water environment, repeated upper limb movements 10 times at maximum speed in three buoyancy conditions (no aided buoyancy, with a pool noodle and with a buoyancy belt). **Results:** For horizontal extension, differences were found in the range of movement (ROM) between the upper limbs with a pool noodle (t (9)=-0.22). For abduction, differences were found for ROM and the maximum angle between the upper limbs with the buoyancy belt. Considering buoyancy conditions, the maximum angle was significantly different between the pool noodle and the buoyancy belt (t (9)=-0.76). **Conclusion:** Shoulder ROM during abduction and horizontal extension changes with added buoyancy during deep-water exercise. The pool noodle appears to restrict the movement of the upper limbs. However, for horizontal extension the use of buoyancy belt produces greater symmetry. The pool noodle seemed to give more symmetry for abduction.

Keywords: upper limb; water exercises; type of buoyancy conditions; biomechanical outcomes, motion analysis.

Introduction

It is common that physiotherapists' decisions are based on their practical knowledge through analysing the patients' responses to different activities. Because of its frequent use, it is imperative to know more about the quality of water motion, particularly in joints with multiple degrees of freedom such as the shoulder. This is particularly relevant in deep-water therapeutic exercises, where there is no solid support on the pool floor and a pool noodle or buoyancy belt are used to support the patient. Activities such as running and walking have been previously examined in water to determine the optimal movements in lower and upper limbs and the economy of effort during various situations (Kapandji, 2007; Killgore, 2012).

Deep-water activity is applied in aquatic therapy through a combination of different strategies to increase, maintain and restore maximum movement and functional ability for the shoulder (Geytenbeek, 2002). This can be helpful at any stage of life and may help in different types of injuries, diseases, disorders, particular conditions or environmental factors that threaten movement and function (Thein & Brody, 2000). Deep-water running has gained the interest of therapists as a supplemental training method, since a decrease in the impact forces of land-running is frequently suggested for distance runners (Chu & Rhodes, 2001). Some studies on deep-water running have found that high knee and cross-country running style can result in different efficacy (Mercer & Masumoto, 2009). However, upper limb movements have been deeper studied in swimming styles.

Recommendations for upper limb rehabilitation movement suggest relaxation, starting the movement from the shoulder joint (as stable as possible) with the elbows bent at 90º (Thein & Brody, 2000). To start the movement and to change direction, when in deep-water, the participant needs to be balanced on a buoyancy support and move the upper limbs in horizontal extension or abduction of shoulder. Using electromyography of the upper limb muscles, researchers have studied how the turbulence and the water resistance on upper limbs increases shoulder muscle activity. This resistance increases with velocity of movement, confirming the practical understanding and better management of the load imposed by water (Cantarero-Villanueva et al., 2013).

Physiotherapists usually choose deep-water movements to achieve improvement of trunk activity, resulting in better motor control of the limbs (Kanitz et al., 2015). They also use deep-water to allow special movements to improve the strength of the shoulder muscles and the stability of the shoulder girdle after upper limb injury. Deep-water exercises may stimulate stabilizing activity of the trunk (Cuesta-Vargas et al., 2012). Indeed, the main goal of upper limb movements is to use the stability of the shoulder girdle and trunk to obtain better motor control of the upper limbs (Colado et al., 2013; McCreesh, Purtill, Donnelly, & Lewis, 2017; Reeser et al., 2010).

Kinematic variables have been studied to achieve a better understanding of the impact of movement smoothness on the evaluation of the rehabilitation process. Smoothness is a quality of movement that is related to its continuality or non-intermittency and independent of its amplitude and duration (Sivakumar Balasubramanian, Melendez-Calderon, Roby-Brami, & Burdet, 2015). Intermittency of movement provides an understanding of coordination during a task. Smoothness is measured through the amount of movement intermittency, which is directly related to the movement’s temporal organization or coordination. The development of a sensitive smoothness measure, which can change proportionally to the changes in movement intermittency, can add to the knowledge of aquatic movements (S. Balasubramanian, Melendez-Calderon, & Burdet, 2012).

This study proposes to compare the performance of shoulder movements supported by different buoyancy devices usually used for deep-water activities. Given the growing popularity of deep-water activity in aquatic therapy and the paucity of evidence for shoulder motion quality in this dual-media, two movements were studied: horizontal extension in the transverse plane and abduction in the frontal plane. We expected that the buoyancy conditions had different impacts on movement performance related with symmetry. The hypothesis of the study was that the best buoyancy device should result in ROM symmetry and motion measured by velocity, time and smoothness coefficient.

Methods

Participants

Ten participants volunteered to take part in this study. Five females (mean ± SD: age 32.60 ± 13.45 years old; 20.72 ± 1.63 kg/m2 BMI) and five males (mean ± SD: age 27.60 ± 1.52 years old; 22.92 ± 3.49 kg/m2 BMI) who were all right-handed, already adapted to a water environment and with no previous history of shoulder injury. All participants provided written informed consent in accordance with the Declaration of Helsinki and the Oviedo Convention. A local ethics committee approved the research (code 28.2018).

Procedures

Participant's upper limb dominance and anthropometric measures (height and weight) were registered. Data collection was performed at the middle of a 25 m long and 2 m deep indoor swimming pool, and recording started only after a researcher verified that the subject was performing the movement correctly and at the maximum speed. The shoulder movement protocol studied the horizontal extension (with upper limb elevation in 90° of flexion in the sagittal plane), the upper limb moves to extension in a transverse plane that has less than 180° of ROM. And, the abduction (with upper limb elevation in the frontal plane moving away from the trunk to a position more vertical) the upper limb moves to abduction up to 180° of ROM (Kapandji, 2007). Those movements done in three buoyancy conditions (no aided buoyancy, with a pool noodle and with a buoyancy belt) with the dominant and non-dominant arm, resulting in six different movements/conditions for each subject.

During the first condition, the no aided buoyancy condition was used, and the subject had to use lower limb movements to stay at the water's surface. In the second buoyancy condition, the subject sat on a pool noodle while performing the upper limb movements. The third buoyancy condition was performed wearing a buoyancy belt. Ten repetitions of each movement were collected at maximum speed for each condition. Then, the best repetition considering the dual-media reconstruction and motion capture quality was chosen for subsequent kinematic analysis. Three-dimensional kinematical data were registered by tracking 48 reflective markers positioned in a full-body configuration (Figure 3.1).

Figure 3.1 – Reflective body marker setup model with 48 body markers.

A dual-media motion capture system (Qualisys, Gothenburg, Sweden) comprised of eight underwater cameras and 12 below water cameras operating at a sampling frequency of 100 Hz was used. Cameras were positioned around the activity zone. Calibration was performed using a fix referential (L-shape reference frame) and a wand with two markers—the first for the below water cameras, followed by the underwater cameras. Finally, a dual-media calibration was performed, with a marker reconstruction accuracy of 99.8% (Figure 3.2).

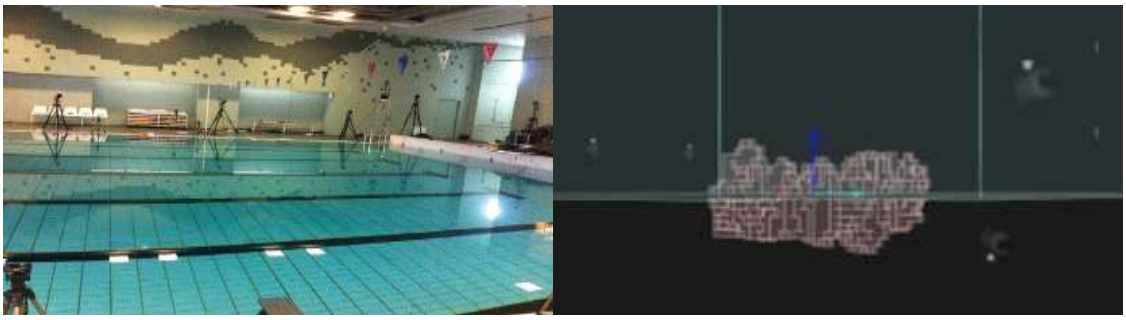
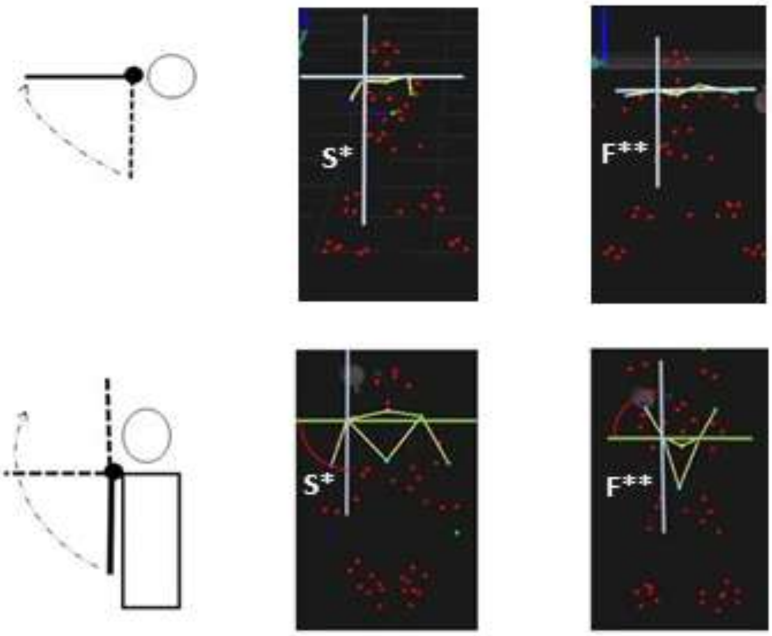


Figure 3.2 – Cameras setup for dual-media motion capture and space calibration

Data Collection

The collected data were first pre-processed through the Qualisys Track Manager 2.9 software (Qualisys AB, Sweden), in terms of marker labelling and trajectory gap filling. Afterwards, the best performance of each condition was chosen to guarantee the quality of trajectory and least error in calculation. The variables studied for horizontal extension and abduction were range of motion (ROM), maximum angle, angular velocity and linear velocity, which were used to calculate the coefficient of smoothness (Equation 3.1) for both the dominant and non-dominant upper limb in the three buoyancy conditions.

Consistent with the recommendations of the International Society of Biomechanics, Wu et al. (2005) described thoracohumeral motion, joint angle kinematic calculations were made by applying X–Y–Z (corresponding to elevation plane, elevation and axial rotation), using axes defined from anatomical landmarks (Wu et al., 2005). To control the accuracy of data treatment, visual inspection was used to check if the L-shaped reference frame was aligned with the subject. The Qualisys Track Manager calculations were done based on the labelled trajectories. Finally, the maximum and minimum angles were calculated for each of the six DoF and the ROM by subtracting the minimum angle from the maximum angle (Figure 3.3).



*Start angle (S); **Final angle (F); ROM=F-S

Figure 3.3 - Calculation of the range of motion in shoulder horizontal extension in a plane with 90º of flexion (motion in the transverse plane) and abduction (motion in the frontal plane).

The angular velocity was calculated through the first derivative of angular position. Using the endpoint of the upper limb, the linear velocity (magnitude) was calculated by the same method. All data were exported to a TSV file. Using the magnitude of velocity (ω), threshold ($\hat{V}$) and upper bound of magnitude of velocity (ω_c^{max}), the coefficient of smoothness (ω_c) was calculated by the SPARC algorithm (Equation 3.1).

$$\omega_c \triangleq \min\left\{\omega_c^{max}, \min\left\{\omega, \hat{V}(r) < \bar{V} \, \forall \, r > \omega\right\}\right\}$$

Equation 3.1 – Equation of spectral arc length metric coefficient (SPARC) (Balasubramanian et al., 2015).

Statistical Analysis

Data distribution was screened in scatter plots and formal test (Shapiro-Wilk test). The comparison of means for variables normally distributed T-test for repeated measures was used. Alternatively, Wilcoxon Test was performed for analysed variables non-normally distributed. SPSS version 24.0 (SPSS Inc., Chicago, IL, USA) was used and statistical significance was defined as α = 0.05.

Results

The table 1 present the distribution of variables, which showed for horizontal abduction non-normal distribution for the maximum angle in all conditions, except the non-dominant upper limb with no aided buoyancy, and for angular velocity only for non-dominant upper limb with no aided buoyancy. Looking for results in abduction, a non-normal distribution was seen for ROM and angular velocity in the non-dominant upper limb with the buoyancy belt (Table 3.1).

The table 2 show the comparison in the same buoyancy condition between dominant and non-dominant upper limb for each produced differences for ROM horizontal extension only for the pool noodle (-0.65 ± 9.51 with t [9] = -0.22; $p<0.05$). For abduction, results for the maximum angle showed differences for the no aided buoyancy (1.87 ± 12.25 with t [9] = 0.48; $p<0.05$), for the buoyancy belt (1.84 ± 8.51 with t [9] = 0.68; $p<0.05$). Continuing, for the ROM pointed out differences between no aided buoyancy (-1.70 ± 12.95 with t [9] = -0.42; $p<0.05$) and with the buoyancy belt (2.24 ± 13.87 with t [9] = 0.51; $p<0.05$). In the comparison between the three buoyancy conditions for the dominant upper limb and non-dominant upper limb, abduction of the shoulder results only pointed out differences for maximum angle between the pool noodle and the buoyancy belt (-2.41 ± 10.02 with t [9] = -0.76).

Discussion and implications

When the upper limbs move in the transverse plane from the front to the side, it is designated as horizontal extension. For a reaching action, it is assumed that the shoulder girdle has an important stabilizing role (Cantarero-Villanueva et al., 2013; Castillo-Lozano et al., 2014; Cuesta-Vargas et al., 2014). When a rotator cuff injury occurs, scapular stability (without pain) is an important goal to achieve, performing those special reaching movements in a special task.

The reaching task in persons with shoulder impingement syndrome has been studied. Furthermore, through the research on shoulder muscle activity levels in water compared with dry land, it was found that water motion could be significantly shorter at low speed, similar at medium speed, and significantly longer at high speed. The scapular plane elevation is defined as lifting the arms from the sides in a slightly forward alignment. Castillo-Lozano et al. (2014) study on water, showed higher activity on the *pectoralis* and *latissimus dorsalis* muscles during abduction and scapular plane elevation (Scaption), indicating a greater stabilization function in this environment.

Mercer and Masumoto (2009) study used the EMG, ROM and Borg Scale to compare the magnitude of contractions for movement performed during deep-water running (DWR) with treadmill running (TMR), the findings were less co-contraction for flexor/extensor pairs of muscles during DWR than TMR at lower intensities. It suggested that higher intensity DWR was to achieve co-contraction magnitudes similar to that of lower intensity TMR (Mercer & Masumoto, 2009).

Therefore, the maximum speed demand in the current study was to study the strength exercise for the upper limbs. There is a lack of literature on the use of aided buoyancy conditions to support particular body movements, for example, to achieve more activity of the trunk or upper limbs. Our results showed no differences for angular velocity and smoothness coefficient, which suggested a good motor control for the task, as participants were healthy. The differences found in the ROM and maximum angle suggested a relation between the kinds of aided buoyancy.

Through the comparison of dominant with non-dominant upper limbs, we can suggest the symmetry was related to aided buoyancy. This symmetry could be related to stability, as pointed out in the differences between the pool noodle and the buoyancy belt. In horizontal extension of the shoulder (performed on the transverse plane), the means of the maximum angles were lower for both upper limbs with the pool noodle, which suggests instability. Further, the angular velocity was higher for the buoyancy belt than the pool noodle or no aided buoyancy, suggesting the greater angular velocity with the higher maximum angle gave more stability. When we compared the floating conditions for dominant and non-dominant upper limb, the results pointed out differences for ROM with the pool noodle, which can reinforce our suggestion of instability for this task.

On the other hand, shoulder abduction (performed in the frontal plane) had differences for ROM and angular velocity for the non-dominant upper limb with the buoyancy belt, suggesting instability for the task. Further, the comparison between dominant and non-dominant upper limb gave differences for no aided buoyancy and the buoyancy belt. It suggests the pool noodle is more stable for this specific task. In addition, the comparison of for each type of aided buoyancy had differences for the non-dominant upper limb. This result cannot be compared to previous knowledge due to the lack of research for these specific movements in dual-media.

Table 3.1 – Distribution of variables (Mean/SD).

		NaB_D	F1_D	F2_D	NaB_ND	F1_ND	F2_ND
Horizontal Extension	Max Ang	**177.98 ± 2.00***	**170.29 ± 18.09***	**176.35 ± 5.82***	178.29 ± 1.02	**174.58 ± 6.42***	**175.54 ± 5.73***
	ROM	78.93 ± 7.08	67.70 ± 17.37	80.57 ± 10.73	83.99 ± 7.84	68.35 ± 16.11	77.01 ± 8.70
	ω	120.13 ± 22.86	108.46 ± 19.54	97.87 ± 29.58	**123.53 ± 43.94***	103.99 ± 19.92	**136.24 ± 58.6***
	C Sm	-1.95 ± 0.23	-2.00 ± 0.11	-1.98 ± 0.11	-1.96 ± 0.28	-1.96 ± 0.15	-1,99 ± 0,34
Abduction	Max Ang	144.58 ± 19.14	152.30 ± 16.27	159.25 ± 15.86	142.71 ± 13.50	155.00 ± 11.96	157.41 ± 12.15
	ROM	119.03 ± 25.70	136.44 ± 14.50	140.41 ± 22.61	120.73 ± 19.69	142.89 ± 14.54	**138.18 ± 12.80***
	ω	122.65 ± 26.57	136.9 ± 26.06	134.29 ± 21.62	153.79 ± 48.47	135.52 ± 26.8	**144.04 ± 35.04***
	C Sm	-1.83 ± 0.08	-1.77 ± 0.20	-1.81 ± 0.24	-1.88 ± 0.16	-1.80 ± 0.13	-1.86 ± 0.21

NaB, no aided buoyancy; F1, pool noodle; F2, buoyancy belt; D, dominant; ND, non-dominant;Max Ang, maximum angle; ROM, range of motion; ω, velocity; C Sm, coefficient of smoothness; *Significance $p<0.05$

Table 3.2 – Comparisons between dominant and non-dominant upper limb considering buoyancy conditions.

		NaB_D/NaB_ND	F1_D/F1_ND	F2_D/F2_ND	NaB_D/F1_D	NaB_D/F2_D	F1_D/F2_D	NaB_ND/F1_ND	NaB_ND/F2_ND	F1_ND/F2_ND
Horizontal Extension	Max Ang	-0.31 ± 2.21	-4.29 ± 13.89	0.81 ± 9.32	7.70 ± 18.04	1.62 ± 6.37	-6.06 ± 20.14	3.71 ± 6.40	2.75 ± 5.13	-0.96 ± 6.20
	ROM	-5.06 ± 9.18	**-0.65 ± 9.51 ***	3.56 ± 12.59	11.23 ± 16.42	-1.64 ± 12.95	12.87 ± 16.33	15.64 ± 16.15	6.98 ± 11.67	-8.66 ± 14.27
	ω	-3.40 ± 24.66	4.48 ± 14.68	-38.37 ± 52.55	11.67 ± 25.25	22.27 ± 32.39	10.60 ± 27.10	19.55 ± 40.74	-12.70 ± 34.28	-32,25 ± 60,17
	C Sm	0.02 ± 0.16	-0.05 ± 0.15	0.09 ± 0.35	0.05 ± 0.25	0.02 ± 0.31	-0.03 ± 0.17	0.00 ± 0.16	0.03 ± 0.52	0.03 ± 0.42
Abduction	Max Ang	**1.87 ± 12.25***	-2.70 ± 11.55	**1.84 ± 8.51***	-7.72 ± 17.23	-14.67 ± 19.23	-6.95 ± 14.86	-12.30 ± 13.63	-14.71 ± 19.50	**-2.41 ± 10.02***
	ROM	**-1.70 ±12.95***	-6.44 ± 14.65	**2.24 ± 13.87***	-17.42 ± 26.06	-21.39 ± 25.57	-3.97 ± 18.31	22.16 ± 21.37	-17. 45 ± 22.38	4.71 ± 14.78
	ω	-31.14 ± 55.32	1.38 ± 18.21	-9.75 ± 20.12	18.27 ± 53.28	9.75 ± 28.24	-8.52 ± 29.59	-14.25 ± 39.86	-11.64 ± 32.83	2.61 ± 24.25
	C Sm	0.16 ± 0.15	-0.02 ± 0.14	0.02 ± 0.13	-0.05 ± 0.14	-0.02 ± 0.26	0.03 ± 0.24	-0.08 ± 0.20	-0.02 ± 0.19	0.06 ± 0.20

NaB, no aided buoyancy; F1, pool noodle; F2, buoyancy belt; D, dominant; ND, non-dominant;Max Ang, maximum angle; ROM, range of motion; ω, velocity; C Sm, coefficient of smoothness; *Significance $p<0.05$

Smoothness coefficient normative scores depended on the performed task. The point-to-point reaching tasks are the only well-studied tasks in the literature; scores are around –1.6 in dryland tasks. There are no references available for the smoothness coefficient using the spectral arc length metric (SPARC) in water movements. This study obtained a lower mean value for this variable during shoulder abduction in the frontal plane for the dominant upper limb with the pool noodle (-1.77±0.20) and a minimum mean value for shoulder abduction in the transverse plane for the dominant upper limb with the pool noodle (-2.00±0.11).

Those values are indeed lower but close to those found in dryland tasks (Balasubramanian et al., 2015). Therefore, if we intend to characterize the smoothness of movement in our sample, we can carefully state that our healthy participants had performed below normative scores, meaning that findings may express a specificity of movement smoothness on underwater conditions, with and without aided buoyancy solutions. This might be explained by compromised overall balance conditions and the presence and variability of hydrodynamic drag force.

For shoulder horizontal extension (performed on the transversal plane), the comparison between buoyancy conditions shows that buoyancy belts are more stable to perform movements in the transverse and sagittal planes. On the other hand, the opposite occurs with the pool noodle (less stability for sagittal plane movements). It suggests that to perform shoulder horizontal extension deep-water exercises with the pool noodle, the performer needs more work to achieve stabilization, consequently decreasing the maximum angle.

For shoulder abduction (done in the frontal plane), compared outcomes between the buoyancy conditions showed differences for ROM with no aided buoyancy and with the buoyancy belt, suggesting better stabilization with the pool noodle. This finding supports wide practical knowledge suggesting that no aided buoyancy equipment instability imposes a higher ROM to maintain the head out of water. However, more specific studies must be conducted to allow understanding this “interface interference phenomena”, and its implications on rehabilitation of shoulder injuries.

The findings of this study confirms hypothesis of the importance of the type of aided buoyancy in deep-water exercises, particularly for the symmetry of ROM. We can state that the more unstable the buoyancy condition, the higher and asymmetrical the ROM. Our hypothesis were validated for shoulder horizontal extension, the buoyancy belt as the device promoting better alignment and movement contralateral symmetry, for shoulder abduction, the pool noodle was the more stable solution. These findings should be understood as an important contribution to decision making on clinical intervention in dual-media. The choice of the buoyancy condition and the kind of device are determinant steps for achievement of the main goal for aquatic therapy interventions.

Limitations of the study

The study was limited by the few literature about the subject.

Conclusions

This study found differences in kinematic parameters associated with different buoyancy conditions. Through the maximum angles and ROM of upper limbs, we can suggest, for shoulder horizontal extension, the buoyancy belt as the device promoting better alignment and movement contralateral symmetry. Additionally, the smoothness coefficient and the angular velocity outputs reinforce that shoulder horizontal extension was done with the best quality of motion when using the buoyancy belt. For shoulder abduction, the pool noodle was the more stable solution. More studies are needed with evaluation of muscle activation to acutely study the relationship between all shoulder components (scapular, glenohumeral and acromial joints) in dual media.

Conflicts of interest statement

The authors declare no conflict of interest.

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CHAPTER IV

STUDY III · SHOULDER'S ABDUCTION MOVEMENT IN DEEP-WATER - DUAL-MEDIA BIOMECHANICAL ANALYSIS

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Abstract

Introduction: Using the smoothness coefficient is possible to develop clinical reasoning for sensorimotor control; it can determine an elderly person's overall sensorimotor capability, providing a quantitative basis for tracking patient recovery in water exercises. **Objectives:** This study was to examine dual-media shoulder abduction performed in deep water with different float equipment and the differences between dominant and non-dominant upper limb movement. **Methods:** Ten healthy right-handed participants already adapted to the water environment, repeated upper limb abduction movements 10x at maximum speed. The upper limb movement protocol consisted of abduction in three conditions (no aided buoyancy, pool noodle, and buoyancy belt), which produced three movement variations for each participant. ROM, the smoothness coefficient, phases time and velocity magnitude at the endpoint of the upper limb (third finger). **Results:** For the dominance and buoyancy conditions, peak velocity showed differences. The time phases had differences for dominance and equipment in the transitory phase. **Conclusions:** There was asymmetry for underwater ROM in all buoyancy conditions. Differences for dominant limbs suggest different strength between upper limbs. The underbody support (pool noodle) offers better motor control, because the placement of the noodle in the direction of the movement promotes better stability.

Keywords: aquatic exercises; upper limb abduction; under water; below water.

Introduction

Physiotherapists and other health professionals often use hydrotherapy exercises, particularly deep-water exercises, in which the feet do not touch the pool floor. The participant is normally supported by a pool noodle or buoyancy belt as aided buoyancy solutions, with different goals. Most of the time, the goal is to allow upper limb movements with strong stability of the shoulder girdle linked to a stabilised trunk (McCreesh et al., 2017). Nevertheless, more information is important to validate treatment strategies for better rehabilitation and health promotion in prevention programs. When it comes to upper limb impairment, like rotator cuff injuries, kinematic analyses can offer a better understanding for patterns of daily life activities and functional recovery (Dunn et al., 2008; Vidt et al., 2016).

Smoothness is an important variable in understanding the quality of movement and developing clinical reasoning for sensorimotor control, providing an idea of a patient’s overall capability with a quantitative basis for tracking recovery (Balasubramanian et al., 2015). The movement smoothness coefficient usually increase with motor control improvement, so the motion smoothness is normally considered an important recovery marker (Hogan & Sternad, 2009).

The spectral arc-length (SPARC) metric (smoothness coefficient) seems to be a very suitable measure for assessing motor recovery in neurological diseases and motor learning in unhealthy people (Balasubramanian et al., 2012). This measure, shown in Equation 1, is independent of temporal scaling and retains a good sensitivity and reliability. To study upper limb smoothness, researchers analyse the hands’ third fingertip kinematics (Balasubramanian et al., 2015; Hogan & Sternad, 2009) in global indicators of integer sensorimotor capacity, similar to a wide range of real-world dry land activities, e.g. point-to-point reaching tasks.

A person with a density of 0.97 reaches floating equilibrium when 97% of their volume is submerged. To maintain balance in water, we must use our motor control through our muscle activity to vertically align the centre of body mass with the centre of body volume. An asymmetrical distribution of shape and density will influence hydrostatic torque and equilibrium (Becker, 2010). A human body in water has to make the necessary adjustments to equal gravity and buoyancy forces directly in line with each other to obtain equilibrium.

Aquatic therapy uses this concept to recover trunk strength, head control or other body functions (Lambeck & Gamper, 2010). However, with buoyancy devices, the symmetry could be disturbed. This is the case for a shoulder abduction movement initially performed underwater and, subsequently, above the water. Underwater movements are constrained by hydrodynamic drag resistive force, and movements above water are not (aerodynamic drag is negligible due to the relatively low movement speed above water). This movement is characterised by changes in velocity and smoothness because of dual-media changes, with intermittencies and instability occurring during the transition phase.

The smoothness coefficient can be used for dry land as well as for underwater or dual-media movements, to understand the quality of deep-water exercise. We proposed a study of upper limb abduction in dual media through range of motion (ROM), peak angular velocity, smoothness coefficient and time spent in different movement under or above water in different floating conditions. Further, we intend to examine the left and right arm symmetry with the different float equipment. Distinctions will be made between under and above water phases as well as the interface between under and above water.

Our first hypothesis is that if there are similar outcomes between the left and right upper limbs, it could be related to the more stable float equipment in dual media. The second hypothesis is that if there are distinctions between under and above water as well as the interface phases, it can suggest a better choice of buoyancy equipment for minimal impact on shoulder abduction.

Methods

Participants

Ten subjects volunteered to participate in this study: five women (mean ± SD: age 32.60 ± 13.45 years old; 1.68 m ± 0.04 m height; 58.20 ± 2.28 kg body mass; 20.72 ± 1.63 K/m2 BMI) and five men (mean ± SD: age 27.60 ± 1.52 years old; 1.82 m ± 0.04 m height; 76.66 ± 14.40 kg body mass; 22.92 ± 3.49 kg/m2 BMI). All participants were right-handed, already adapted to the water environment and had no previous history of shoulder injury. A Shapiro-Wilk test showed no differences between genders for height, weight and BMI, therefore, male and female data were pooled and analysed as a single group. All participants provided written informed consent, in accordance with the Helsinki Declaration and the Oviedo Convention. A local ethics committee approved the study (code 28.2018).

Procedures

Participants completed an upper limb dominance questionnaire, and anthropometric measures (height and weight) were registered. Data collection was performed in the middle of a 25 m long, 2 m deep indoor swimming pool. The studied movements included abduction of both shoulders in three buoyancy conditions (no aided buoyancy, seated in a pool noodle and wearing a buoyancy belt), in neck-deep water. Acquisitions started only after a researcher verified that the subject was performing the movement correctly, at the maximum speed. Three-dimensional kinematical data were registered by tracking 48 reflective markers positioned in a full-body configuration (Figure 4.1).

During the first condition, no floating devices were used, and the subject had to use lower limb movements to maintain the water level at neck position. In the second buoyancy condition, the subject sat on a pool noodle while performing the upper limb movements. The third buoyancy condition involved wearing a buoyancy belt attached to the waist. Ten repetitions of each movement were collected at the maximum speed for each condition and subject, and then the best repetition per condition, in terms of movement kinematical reconstruction, was chosen for subsequent kinematic analysis.

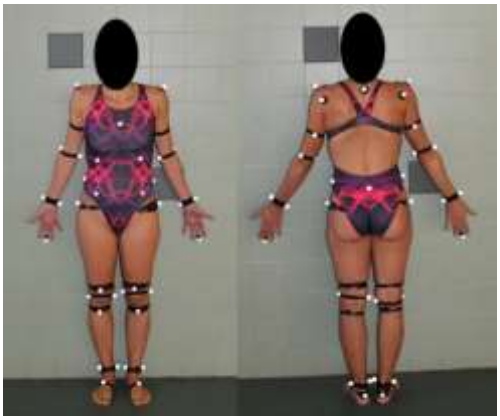


Figure 4.1 – Reflective body markers setup, model with 48 body markers.

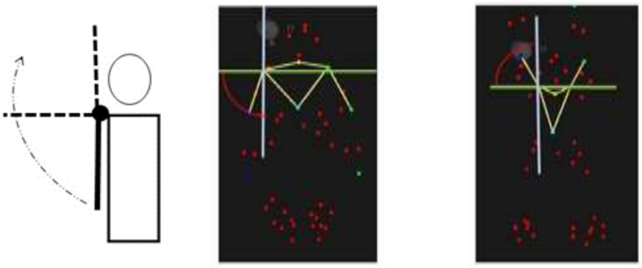
A dual-media motion capture system (Qualisys, Gothenburg, Sweden), comprised of eight underwater cameras (Oqus) and 12 land cameras (MRI) operating at a sampling frequency of 100 Hz, was used. Cameras were positioned around the subject’s performing zone, and the calibration was performed both with an L-shaped reference frame and a wand, first for the land cameras, followed by the under-water cameras, and finally a dual-media calibration was performed, with a marker reconstruction accuracy of 99.8% (Figure 4.2).

Figure 4.2 – Cameras setup for dual-media motion capture and space calibration.

Data collection

The collected data was first pre-processed through the Qualisys Track Manager 2.9 (Qualisys AB, Sweden) software, in terms of marker labelling and trajectory gap filling. Afterwards, the best performance of each condition was chosen as described above in order to guarantee the quality of trajectory and less error in calculation. The studied variables for the shoulder abduction were linear velocity (magnitude) to calculate peak velocity and smoothness coefficient for dominant and non-dominant upper limbs in the three buoyancy conditions (without aided buoyancy, pool noodle and buoyancy belt). The shoulder abduction was studied based on the Kapandji (2007) concepts (Figure 4.3), on the frontal plane, with upper limbs moving away from the trunk in vertical elevation. This lateral flexion can have a ROM of 180 degrees (Kapandji, 2007). Consistent with the International Society of Biomechanics recommendations describing thoracohumeral motion, joint angle kinematic calculations were decomposed with X–Y–Z on the six degrees of freedom (DoF), corresponding to elevation plane, elevation, and axial rotation, using the axis defined from anatomical landmarks (Wu et al., 2005). Maximum and minimum angles were calculated for each of the three conditions, total ROM, and under- and above water phases. ROM was calculated by subtracting the minimum angle from the maximum one (Figure 4.4).

To calculate the magnitude of linear velocity, the upper limb endpoint (fingertip) was used as a referential component of motion analysis by the same method. All data were exported to a TSV file.



*Start angle (S); **Final angle (F); ROM = F-S

Figure 4.3 – Shoulder abduction based on Kapandji concepts.

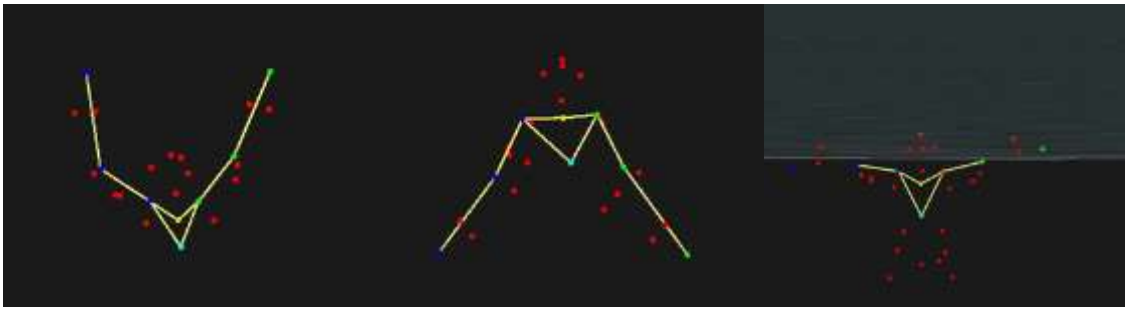


Figure 4.4 – Motion analysis in dual-media through the QTM.

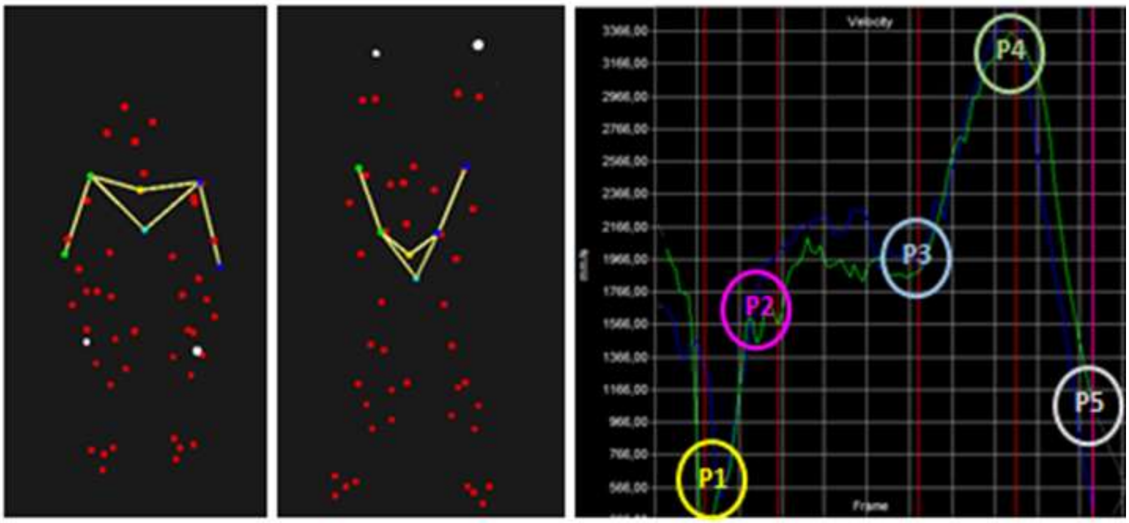
The values of magnitude of linear velocity were used to calculate the smoothness coefficient of SPARC (Equation 4.1) and to characterise the velocity pattern in all ROM, specifically comparing the phases performed above, under water and transitory dual media. Using the magnitude of velocity (ω), threshold ($\bar{V}$) and upper bound of magnitude of velocity (ω_c^{max}), the coefficient of smoothness (ω_c) was calculated by the SPARC algorithm (Equation 4.1).

$$\omega_c \triangleq \min\left\{\omega_c^{max}, \min\left\{\omega, \hat{V}(r) < \bar{V}\,\forall\, r > \omega\right\}\right\}$$

Equation 4.1 – SPARC smoothness coefficient equation (Balasubramanian et al., 2015).

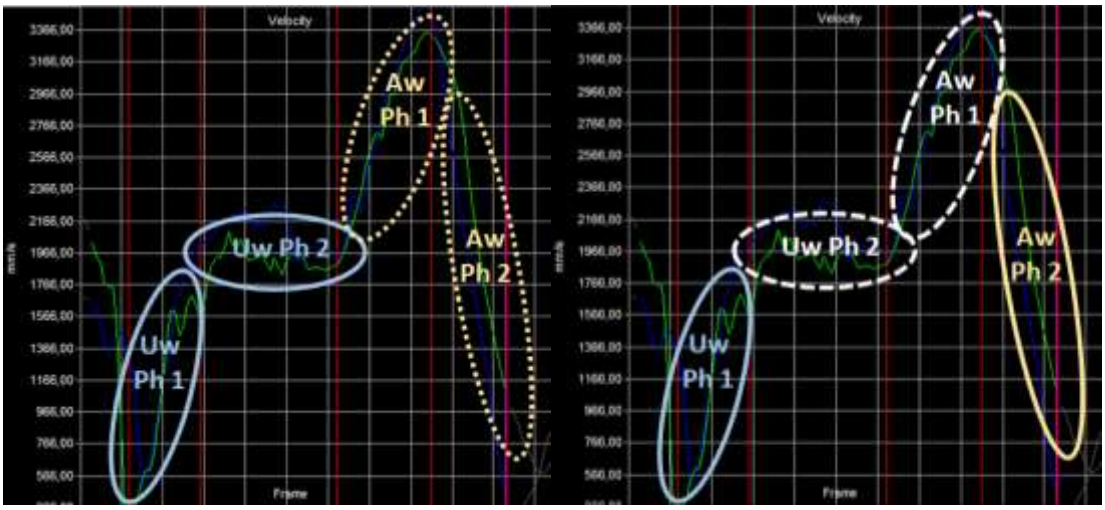
This study used, as independent variable, the magnitude of linear velocity, through the graph of linear velocity magnitude values over time, were determined five points, to define the dual-media phases. The P1 is the starting point, P2 the point where the trajectory becomes instable, P3 the point of changing – water surface –, P4 is the point of highest velocity and finally the P5 the end of the movement (Figure 4.5). Then we characterized the dual-media movement, through the velocity information, through four distinct phases: i) first under-water phase (Uw Ph 1) between P1 and P2; ii) second under-water phase (Uw Ph 2) between P2 and P3; iii) first above-water phase (Aw Ph 1) between P3 and P4 and iv) second above-water phase (Aw Ph 2) between P4 and P5.

Finally, we got the transitory phase based on the transition point (P3), including the Uw Ph 2 and Aw Ph 1 (between P2 and P4), where the shoulder abduction were performed between the two medium (Figure 4.6).



P1 –start movement under-water in phase 1; P2 – change to under-water in phase 2; P3 – interface point change to above-water phase 1; P4 – change to above-water phase 2; P5 – finish movement above-water in phase 2.

Figure 4.5 – Reference points of the shoulder abduction at dual-media based on the velocity information.



Uw Ph 1 - under-water in phase 1; Uw Ph 2 - under-water in phase 2;
AW Ph 1 - above-water in phase 1; AW Ph 2 - above-water in phase 2
Int Ph – Transitory phase for smoothness

Figure 4.6 – Reference under, above and transitory water phases of the shoulder abduction at dual-media based on the velocity information.

Statistical analysis

Data analysis was conducted with the statistic software SPSS version 24.0 (SPSS Inc., Chicago, IL, USA). The normality of data distribution was screened in scatter plots and formal test (Shapiro-Wilk test) separately for male and female participants and with merged groups. Calculation had one missing case for the pool noodle condition. The comparison of means for variables normally distributed T-test for repeated measures was used. Alternatively, Wilcoxon Test was performed for analysed variables non-normally distributed. Data were reported as mean ± SD, differences of means ± SD and statistical significance level was set at $p<0.05$.

Results

On Table 4.1 mean and SD values are shown or all outcome measures. Looking at the ROM, there are higher means for above-water phase (84.41 degrees) for the buoyancy belt for the dominant upper limb, with no normal distribution for the buoyancy belt condition. The peak angular velocity values were between 186.05 m/s (under-water) and 311.71 m/s (above-water) for all conditions, with no normal distribution for pool noodle condition. The smoothness coefficient values for shoulder abduction ranged between -1.6 and -1.8 for above-water and between -1.8 and -2.0 for under-water. Time spend per phase showed larger values in under-water phase (0.6 s) and were equal for dominant and non-dominant upper limb. For the transitory phase results pointed out mean values of -1.6, and the time spent also similar to under-water (Table 4.1).

T-test repeating measures for comparing upper limbs results showed differences for all ROM in floating conditions in the underwater phase for no aided buoyancy (, t[9] = -0.60; pool noodle, t[9] = 0.10; buoyancy belt, t[8] = -2.18) and above of water in no aided buoyancy, t[9] = 0.34. For the peak velocity, results showed differences between upper limbs for underwater (t[9] = -1.00) and above-water (t[8] = -1.00) with the buoyancy belt. For the smoothness coefficient, results showed differences between upper limbs, with no aided buoyancy in the underwater phase (t[8] = 1.89), for pool noodle differences in in the interface phase (t[9] = 1.61) and for the buoyancy belt in the above-water phase (t[8] = 1.39). For time of phase, results showed differences between dominant and non-dominant upper limbs in all floating conditions in all phases Regarding differences between floating conditions, for peak velocity, results showed differences in the underwater phase between no aided buoyancy and pool noodle for dominant (t[9] = -0.11) and non-dominant (t[8] = 0.79) upper limbs. For time spent, the transition phase showed differences between pool noodle and buoyancy belt (t[9] = 0.04) (Table 4.2).

Table 4.1 – Distribution of study variables (Mean ± SD).

	NaB_D	F1_D**	F2_D	NaB_ND	F1_ND**	F2_ND
ROM_UwPh (°)	49.02 ± 20.7	61.14 ± 18.0	50.80 ± 11.4	51.35 ± 21.7	65.98 ± 19.9	49.16.38± 16.4
ROM_TrPh (°)	75.76 ± 29.91	**79.15 ± 29.87***	83.42 ± 20.69	90.72 ± 21.59	72.76 ± 17.71	79.94 ± 15.90
ROM_AwPh (°)	71.73 ± 20.6	76.16 ± 15.7	84.41 ±13.8	71.25 ± 18.6	76.95 ± 12.6	83.46 ± 15.0
PeakV_UwPh (m/s)	186.05 ± 38.5	220.34 ± 58.9	194.12 ± 34.1	**202.24 ± 50.9***	219.32 ± 50.3	202.84 ± 78.0
PeakV_TrPh (m/s)	228.54 ± 50.46	247.20 ± 39.23	255.25 ± 46.56	258.80 ± 29.72	263.80 ± 48.45	280.52 ± 50.05
PeakV_AwPh (m/s)	205.99 ± 86.4	224.34 ± 78.01	277.42 ± 51.4	271.64 ± 80.3	251.57 ± 57.5	311.71 ± 53.4
Sm_Cf_UwPh (λ/s)	-1.9 ± 0.2	-1.9 ± 0.2	-1.8 ±0.3	-1.9 ± 0.2	-1.9 ± 0.2	-2.0 ± 0.2
Sm_Cf_TrPh (λ/s)	-2.1 ± 0.2	-1.7 ± 0.7	**-2.0 ± 0.1***	-2.0 ± 0.4	**-1.9 ± 0.7***	-2.1± 0.1
Sm_Cf_AWPh (λ/s)	-1.7 ± 0.3	**-1.7 ± 0.3***	**-1.7 ± 0.2***	**-1.6 ± 0.4***	-1.7 ± 0.1	**-1.8 ± 0.2***
Time_UwPh (s)	0.6 ± 0.1	0.6 ± 0.1	0.5 ± 0.1	0.6 ± 0.1	0.6 ± 0.1	0.5 ± 0.1
Time_TrPh (s)	0.5 ± 0.2	0.6 ± 0.3	0.6 ± 0.3	0.5 ± 0.3	0.5 ± 0.2	0.5 ± 0.2
Time_AwPh (s)	0.5 ± 0.1	0.4 ± 0.1	0.4 ± 0.1	0.5 ± 0.1	0.4 ± 0.1	0.4 ± 0.1

NaB - No aided buoyancy; F1- pool noodle; F2- buoyancy belt; D- dominant; ND- non-dominant; ROM- range of motion; PeakV_Total - peak velocity; Sm_Cf_Total -Smoothness coefficient; Time - spent time in the phase;UwPh - under-water phase; TrPh- transitory phase; AwPH - above-water phase; *Shapiro-Wilk with $p < 0.05$; ** 1 missing

Discussion

The current study examined upper limb abduction in dual media through the water surface in three phases: above water, underwater and transitory. ROM, peak angular velocity, phase duration and smoothness coefficient were examined in different movement phases. The ROM results suggests the smaller ROM underwater phase relates to the drag water action. However, comparing the dominant and non-dominant upper limb results shows differences in all conditions in the underwater and transitory phases. The comparison between floating conditions shows differences in the transitory phase for the dominant upper limb between pool noodle and belt buoyancy and for the non-dominant upper limb in all conditions.

The peak velocity showed values between 186.05 m/s (underwater) and 311.71 m/s (above-water). These results showed differences between dominant and non-dominant upper limbs with a buoyancy belt at all water phases, suggesting more asymmetry and difficulty when using this floating equipment. Comparing floating conditions, the peak velocity showed differences in the underwater phase between the pool noodle and no aided buoyancy in both upper limbs, suggesting more stability when using the pool noodle. High peak velocity values in the above-water phase suggest a strategy for maintaining balance in floating conditions. The higher values in the transitory phase can be related with the entrance to the air media.

The time of phase results showed differences between dominant and non-dominant upper limb in all phases. For comparison of floating conditions on the time phases, results pointed out differences on non-dominant upper limb between pool noodle and buoyancy belt The smoothness coefficient results are compatible with the SPARC scores previously obtained on dryland for point-to-point reaching tasks: around -1.6 (Balasubramanian et al., 2015). This is particularly true for the above-water phase (ranging between -1.6 and -1.8). Lower smoothness values (ranging between -1.8 and -2.0) were observed for the underwater phase, which might be explained by the disturbing effect of the aided resistance imposed by hydrodynamic drag force.

Table 4.2 – Comparison of measures by upper limb dominance and buoyancy conditions (Means difference ± SD)

	NaB_D/NaB_ND	F1_D/F1_ND	F2_D/F2_ND	NaB_D/F1_D	NaB_D/F2_D	F1_D/F2_D	NaB_ND/F1_ND	NaB_ND/F2_ND	F1_ND/F2_ND
ROM_UwPh (°)	**-2.12 ± 12.36***	**-5.38 ± 7.39***	**1.21 ± 11.19***	-12.12 ± 31.72	-1.78 ± 27.99	10.34 ± 17.14	-14.63 ± 34.15	1.76 ± 23.62	16.39 ± 22.72
ROM_TrPh (°)	**-3.39 ± 11.33***	**-7.30 ± 15.41***	**-7.18 ± 12.81***	-7.66 ± 24.27	-1.80 ± 26.08	**10.65 ± 15.41***	**-11.57 ± 17.13***	**-3.40 ± 20.09***	**10.78 ± 13.48***
ROM_AwPh (°)	**0.48 ± 15.93***	0.88 ± 12.58	0.60 ± 16.28	-4.43 ± 24.34	-12.33 ± 25.71	-7.90 ± 12.96	5.70 ± 23.46	-12.21 ± 27.88	-6.51 ± 17.66
PeakV_UwPh (m/s)	-27.00 ± 74.80	-25.81 ± 49.38	**-18.80 ± 54.00***	**-3.66 ± 101.69***	-28.87 ± 75.51	-53.54 ± 63.05	-**1.66 ± 89.18***	-3.19 ± 87.33	-23.11 ± 73.53
PeakV_TrPh (m/s)	-18.66 ± 43.69	-3.55 ± 40.51	**-16.72 ± 34.41***	-26.71 ± 74.53	-39.26 ± 58.27	-8.55 ± 58.96	-11.59 ± 31.36	-33.31 ± 39.88	-21.71 ± 53.36
PeakV_AwPh (m/s)	-51.43 ± 123.19	-12.29 ± 94.05	**-18.95 ± 56.83***	-13.06 ± 47.82	-3.85 ± 91.47	-4.30 ± 110.73	-4.85 ± 63.08	-13.19 ± 50.32	-15.76 ± 105.43
Sm_Cf_UwPh (λ/s	0.05 ± 0.08 *	0.06 ± 0.20	0.22 ± 0.37	0.02 ± 0.23	-0.09 ± 0.45	-0.11 ± 0.33	0.02 ± 0.25	0.08 ± 0.21	0.06 ± 0.28
Sm_Cf_TrtPh (λ/s)	-0.08± 0.39	0.17± 0.33*	0.04± 0.13	-0.37± 0.73	-0.05± 0.15	0.32 ± 0.78	-0.12 ± 0.77	0.07± 0.47	0.19 ± 0.66
Sm_Cf_AWPh (λ/s)	-0.06± 0.48	0.09 ± 0.33	0.04 ± 0.09 *	-0.01 ± 0.25	0.05 ± 0.33	0.07 ± 0.28	0.14± 0.38	0.16 ± 0.36	0.02 ± 0.20
Time_UwPh (s)	**0.01 ± 0.06***	**-0.01 ± 0.03***	**0.04 ± 0.14***	-0.03 ± 0.19	0.04 ± 0.16	0.08 ± 0.15	-0.05 ± 0.22	0.03 ± 0.17	0.09 ± 0.15
Time_TrPh (s)	**0.04 ± 0.11***	**0.11± 0.09***	**-0.03 ± 0.08***	-0.04 ± 0.29	0.09 ± 0.19	0.14 ± 0.27	0.11 ± 0.29	0.11 ± 0.23	**0.00 ± 0.18***
Time_AwPh (s)	**-0.03 ± 0.05***	**0.01 ± 0.03***	**0.02 ± 0.14***	0.05 ± 0.17	-0.02 ± 0.15	-0.08 ± 0.15	0.08 ± 0.17	0.00 ± 0.13	-0.09 ± 0.15

NaB - No aided buoyancy; F1- pool noodle; F2- buoyancy belt; D- dominant; ND- non-dominant;
ROM- range of motion; PeakV_Total - peak velocity; Sm_Cf -smoothness coefficient; Time - time in the phase; UwPh - under-water phase; TrPh- transitory phase; AwPH - above-water phase; * significance p <0.05.; ** 1 missing for pool noodle values

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Smoothness coefficient showed no differences between dominant and non-dominant upper limbs or floating conditions in all phases, suggesting a good motor control during the exercises. The higher instability suggests a higher peak of velocity to compensate imbalance, considering the differences between ROM, peak velocity and smoothness coefficient underwater. This finding suggests that the approach used may discriminate between compromised and healthy limbs or subjects (Balasubramanian et al., 2015; Hogan & Sternad, 2009).

The smoothness coefficient is an important marker of movement analysis for clinician/therapist planning and evaluation of the recovery on land (Hogan & Sternad, 2009). Besides the ROM asymmetry in the underwater phase, the peak velocity, with the better smoothness coefficient in the transition phase, suggests that the buoyancy belt is the best floating equipment for improving performance of this movement in dual media. The study was limited by the small amount of literature on the subject. More studies should be done for the improvement of knowledge for aquatic therapy strategies for shoulder pain.

Summarily, through ROM, peak velocity, phase duration and smoothness coefficient, we could examine symmetry between upper limbs regarding different floating conditions. Based on the present results, we suggest the use of the buoyancy belt when performing shoulder abduction in dual-media, as it seemed to give more symmetry. This suggests that the buoyancy belt is the best equipment to perform movements with minimal impact on shoulder abduction. Further studies should be done for the improvement of knowledge of aquatic therapy strategies for patients with shoulder pain involving shoulder abduction exercises in deep water.

Limitations of study

The study was limited by the few literature about the subject.

Conclusion

Through the ROM, the peak velocity, the phase duration and the smoothness coefficient, we could examine symmetry between upper limbs regarding the different floating condition. Based on the present results, we suggest the use of the pool noodle when performing shoulder abduction in dual-media, as it gave more symmetry. This suggests that the pool noodle is the best equipment to performance the movement with minimum impact on shoulder abduction. Further studies should be done for the improvement of knowledge on the aquatic therapy strategies for painful shoulder patients with shoulder abduction exercises in deep-water.

Conflicts of interest statement

The authors declare no conflict of interest.

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CHAPTER V

STUDY IV · OUTCOMES OF OLDER ADULTS WITH UPPER LIMB DYSFUNCTION INDUCED BY AN AQUATIC THERAPY PROGRAM

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Abstract

Introduction: Aquatic therapy (AT) appears to be an effective way to develop strength, balance and pain relief in individuals with various health conditions. For degenerative joint diseases, AT provides symptom relief and advances dry-land functionality. This functional empowerment is based on performing movements and tasks in water, which it is not possible for the same subjects to achieve on dry-land. **Objective:** The objective of this study was to determine the risk factors that could be used to screen for to predict the water adaptation and motor performance of AT program users with upper limb dysfunction. **Methods:** A cohort study was performed with users of AT in a sports pool; participants completed written questionnaires (sociodemographic data, clinical data, the shoulder and hand disability scale (DASH) and the functional perception scale (FPS) based on International Classification Functionality (ICF)). Statistical analysis of the distribution of normality means comparison, correlations between variables and linear regression was performed. **Results:** Spearman Correlation pointed out results with strong correlation between the DASH and the FPS (708**). Important correlations between these scales and HBP, DM2, HC, the use of more than four medications, falls last year and “fear of falls” were noted. **Conclusion:** The correlation between DASH or FPS and BMI, HPB, the use of more than four medications and a fear of falls can be a predictive factor of increased difficulties with water adaptation and successful interventions. We suggest that a long-term AT program should validate their self-efficacy and assess other effects on successful aging.

Keywords: motor control, predictive factors, aquatic therapy

Introduction

Patients aged fifty five years old or above with osteoarthritis (OA) symptoms, such as pain, upper limb dysfunction and general weakness, show decreased activities of daily life, disturbed balance when walking and dual task limitations (Coelho et al., 2016; Rhudy et al., 2007; Soto-Varela et al., 2016). The common pain cycle shows that people who become less active demonstrate more pain, thus continuing the cycle. Indeed, inactive subjects need a higher stimulus to become active. Fortunately, effective health promotion leads to increased exercise in healthy aging persons (Alikhajeh et al., 2012; Avelar et al., 2018). Aquatic therapy (AT) exercise is an increasingly popular option, enabling inactive subjects to return to an active lifestyle (Kang et al., 2007). However, despite being progressively prescribed, therapists have a limited knowledge about this therapeutic solution and patient responsiveness (Bartels et al., 2016). Load characterisation and dose response for each patient category is still a problem that needs to be addressed for most of the AT conditions and exercises (Adsett et al., 2017; Adsett et al., 2015). More information is needed before better promotional programs and activity sessions can be developed. This seems to be particularly relevant for elderly people, due to their frailty and limited plasticity (Kunduracilar et al., 2018). These subjects have chronic diseases, use daily medication, and show a fear of falling; therefore, they can no longer move safely (Cadore et al., 2013; Moreland et al., 2004; Stalenhoef et al., 2002). Deeper knowledge of the functional perception profile of these patients will help clinicians to make a stronger prognosis for better therapy results (Brauer et al., 2000; Loeser et al., 2012). Although several studies have shown the efficacy of AT on balance gain and pain reduction in older adults, there is little information on the relationship between function in water and on dry-land conditions, particularly in the case of degenerative joint diseases (Crenshaw et al., 2018; Devereux et al., 2005; Munukka et al., 2016).

To evaluate practice and collect clinical evidence, researchers developed a functional perception scale (FPS) based on the ICF for an initial assessment in adult users (55 years and older) of group AT programs. The ICF is a worldwide tool for functional assessment and characterisation (Dibble et al., 2009).

Clinicians have used this tool since 2002 to better understand chronic disability, evaluate improvements and the impact on patients' lives and make functional diagnoses (WHO, 2002). Studies focused on older adults with deficits in activities of daily living and with upper limb disability, who participated in long-term AT programs with physiotherapist supervision, showed significant improvements in quality of life (Kang et al., 2007; Kars Fertelli et al., 2018). Therefore, we also studied the health problems, expectations of patients, and the disability of arm, shoulder and hand scale (DASH) to related disability with the perception of functionality (Beaton et al., 2001). Those dimensions seem to have an impact on adaptation to and performance with AT. The current study used a convenience sample of older adult users of AT, aged 55 years or more. This study aimed to determine which risk factors of the available scales and questionnaires could be used to screen users of AT programs to predict water adaptation and performance.

Methodology

This cohort study was performed in accordance with the Declaration of Helsinki and the Oviedo Convention. All participants provided written informed consent and completed questionnaires for the collection of sociodemographic data, clinical data, main health problems, expectations and three self-reported scales: i) disability of arm, shoulder and hand scale (DASH); ii) satisfaction questions; and iii) functional perception scale based on the International Classification of Functionality (ICF).

Settings

In two public swimming pools, researchers invited all users of any formal AT program aged 55 years and older to voluntarily participate.

Participants

To participate in this study, subjects had to meet the following inclusion criteria: i) regular attendance at a formal AT program for six months or more, ii) not suffering from severe mobility deficits, and iii) not presenting with mental disorders or deficits in communication and understanding the instructions for questionnaires. One hundred and eight subjects were recruited, 78 females and 30 males, with a mean (SD) age of 66.30 (6.67) and 67.43 (7.15) years, respectively, a body mass of 69.78 (12.20) and 79.13 (9.88) kg, respectively, a height of 1.58 (0.07) and 1.69 (0.05) m, respectively, and a BMI of 28 (5) and 28 (4) kg/m^2, respectively (Figure 5.1).

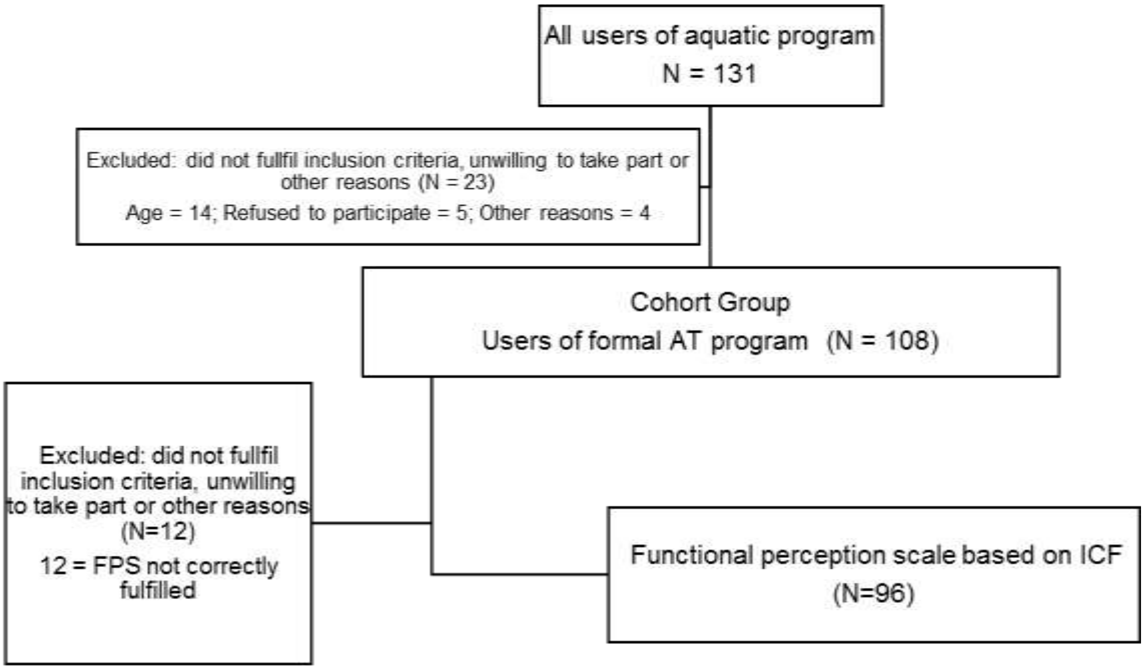

Figure 5.1 – Study participant flow chart.

Evaluation Tools

All included participants completed three scales: i) disability of arm, shoulder and hand scale (DASH); ii) satisfaction question; and iii) functional perception scale based on ICF. DASH is a self-reported scale used to evaluate the perception of upper limb function. It consists of two parts: the first with 30 questions related to pain, other symptoms or activities of daily living, and the second with 8 questions related to leisure and professional activities. The items are answered from 1 to 5 (1 – no difficulty, 2 – slight difficulty, 3 – moderate difficulty, 4 – great difficulty, 5 – cannot execute). For our score, we only used the first part. The participants had to answer a minimum of 28 questions to allow DASH score calculation, shown in Equation 5.1. DASH was designed to be a disability questionnaire. As such, scaling was ranked from zero, indicating the lowest level of disability, to 100, indicating the greatest disability. The normative DASH values were published by Hunsaker (2002); no cut-off points were proposed by the authors (Hunsaker et al., 2002). The calculation of DASH disabilities/symptoms was conducted using the equation 5.1:

$$\text{DASH Score}^* = [\left(\frac{sum\ of\ answers'values}{number\ of\ valid\ answers}\right) - 1] \times 25$$

Equation 5.1 – For the calculation of DASH disabilities/symptoms (* if more than three answers are not valid, the calculation is not possible) (Atroshi et al., 2000).

The satisfaction question evaluated the level of perception of the treatment program by the simple question: would you recommend this program to others? It was scored from zero to four (0 – No, 1 – Maybe not, 2 – Maybe, 3 – Maybe yes, 4 – Certainly yes). Through this global dimension, patient feedback is important for the community program. The functional perception scale, based on ICF, is an instrument composed of the domains of function taken from the geriatric core set related to the perception of essential functions for dynamic balance, upper limb function and fall prevention. It consists of 19 items, which are answered from zero to four (0 – no difficulty, 1 – slight difficulty, 2 – moderate difficulty, 3 – big difficulty, 4 – cannot execute). Scale development work was carried out in the context of functional healthcare in persons with chronic spine pathology. This instrument covers two domains: basic motor control (nine items), and advanced motor control (10 items). The participants completed the scale related to their perception of function in dry-land and scaling was ranked from zero indicating less motor control to 76 indicating the best motor performance.

Statistical analyses

Data distribution was screened (Shapiro-Wilk test, $p<0.05$), and non-normal distribution was observed only for height, weight and BMI for females. As all variables had non-normal distribution by gender or together, data were pooled and analysed as a single group. Tests for means, standard deviation, and percentage were screened. Spearman correlation was calculated between the risks factors, expectations and scales scores. SPSS version 24.0 (SPSS Inc., Chicago, IL, USA) was used, and statistical significance was defined as $\alpha = 0.05$.

Ethical procedures

Researchers obtained approval from the local hospital Ethics Committee (07/12/2017-CE) and National Data Protection Commission (nº. 7103/ 2017) to collect and treat the data and publish the obtained results.

Results

The main characteristics of the sample reported were number of years using AT, the satisfaction question, the DASH score and the FPS score; the results are showed in Table 5.1 and Figure 5.2.

Table 5.1 – Participants characteristics.

	N (missing*)	Mean ± SD	Median	Minimal value	Maximal value
Years of AT (female)	78 (1)	7 ± 5	5	1	20
Years of AT (male)	30 (0)	5 ± 4	4		
Satisfaction Question Score (female)	78 (1)	3.8 ±0.4	4	3	4
Satisfaction Question Score (male)	30 (0)	3.6 ± 0.5	4		
DASH Score (female)	78 (1)	34.57 ± 20.43	28	1	85
DASH Score (male)	30 (0)	17.53 ± 15.28	13.5		
FPS Score (female)	67 (0)	28.82 ± 14.41	28	1	73
FPS Score (male)	29 (0)	20.18 ± 10.19	19.5		

*Listwise method

The following common health problems were present in the sample: type 2 diabetes mellitus (DM2) - 19.40%, high blood pressure (HBP) - 46.30%, osteoarthritis (OA) - 57.40% and high cholesterol (HC) - 6.20%. Only 13.9% had previous experience in a designated therapy pool and only 32.4% knew how to swim. Nearly 50% of participants took more than four medications daily, 50% had fallen during the previous year and 62% were afraid of falling. There were high expectations that participation in AT programs would increase their performance of activities of daily living (ADL) (81.5%), well-being (8.6%) and relaxation (72.2%) and decrease pain (88.0%). Only 39.8% took part expecting to decrease their fall risk and 44.0% expected to become stronger. These were individuals taking part in a group program in public pools led by physiotherapists rather than in sessions in a therapy pool. Nevertheless, they were positive about the program recommendations (Probably/Certainly 76.15%/23.85%) (Figure 5.2).

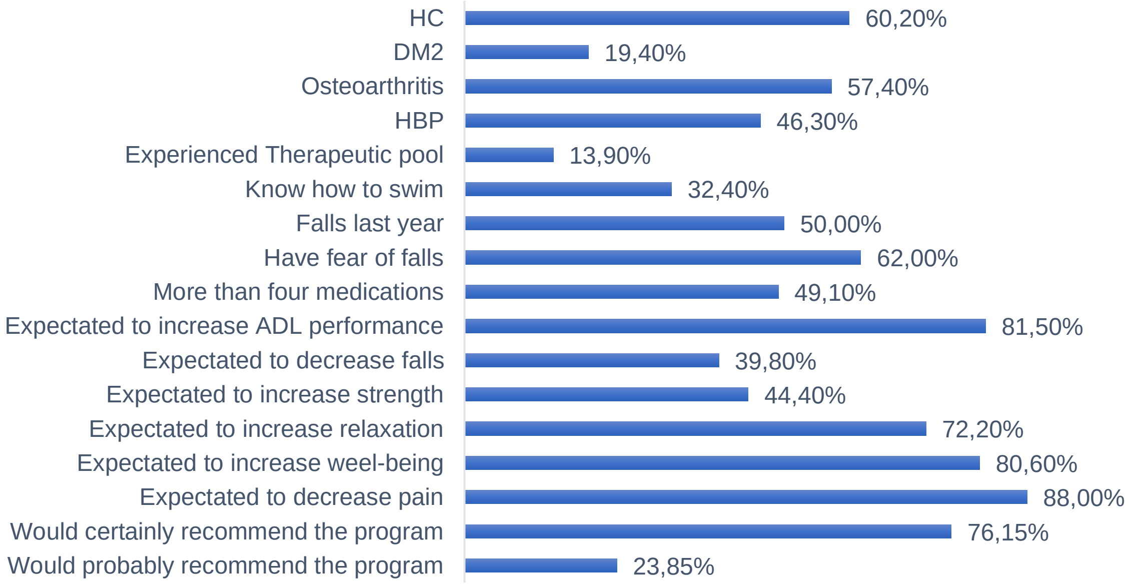

Figure 5.2 – Percentage expression of health problems, experiences, expectations and satisfaction among the 108 participants.

The Spearman results pointed out a strong correlation between DASH and FPS (708**). Important correlations between these scales and HBP, DM2, HC, the use of more than four medications, falls last year and “fear of falls”. Other significant correlations are reported in Table 5.2.

Table 5.2 – Correlation between DASH, FPS, Health Problems and Expectations.

Spearman	**DASH score**	**FPS score**	HBP	DM2	HC	Osteoarthritis	medication	Falls last year	Fear of falls	Decrease pain	Improve well-being	Get relaxed	Improve balance	Improve strength	Decrease falls	ADL
DASH score	1.000															
FPS score	**0.708****	1.000														
HBP	**0.267****	**0.298****	1.000													
DM2		**0.280****	**0.264****	1.000												
HC	0.249*				1.000											
Osteoarthritis						1.000										
Medication	**0.269****	**0.285****	**0.368****	0.212*	0.206*		1.000									
Falls last year	**0.371****	**0.317****		**0.266****			**0.291****	1.000								
Fear of falls	**0.512****	**0.543****	**0.269****	0.221*	**0.367****		**0.355****	**0.489****	1.000							
Decrease pain									0.233*	1.000						
Improve well-being	**-0.495****	**-0.335****				0.235*		-0.256*	**-0.303****		1.000					
Get relaxed	**-0.526****	**-0.343****				**0.391****			-0.255*		**0.583****	1.000				
Improve balance													1.000			
Improve strength						**0.270****			0.217*	**0.270****		0.260*	**0.536****	1.000		
Decrease falls						0.213*			**0.295****		0.261*	0.226*	**0.571****	**0.725****	1.000	
ADL			**0.292****			0.258*				**0.280****						1,000

*** The correlation is significant at the 0.01 level (bilateral).*
** The correlation is significant at the 0.05 level (bilateral).*
Listwise N=96

Discussion

The objective of this study was to determine the risk factors that could be used to predict water adaptation and motor performance of AT program users with upper limb dysfunction. Our results over a number of years in AT programs have provided no evidence; however, it was important to relate AT program results with satisfaction and well-being. We suggest this as a strong reason for older adults to continue the program. Moreover, this social community program in public pools was cheaper and was prescribed by doctors to help with aging.

This sample had common health problems like high blood pressure, high cholesterol, type 2 diabetes mellitus and OA, and participants had a preference for AT based on their expectations and satisfaction with the program. Expectations were centred on decreased pain and falls, and increased wellbeing, strength, relaxation and activities of daily life. These are the variables used in studies of the effectiveness of AT for fall prevention, decreasing pain, and increasing functionality. Like other studies with OA patients, the patient goals are focused on pain, fall prevention, quality of life and well-being (Kanitz et al., 2015; Munukka et al., 2016).

Physiotherapists have studied the efficacy and self-efficacy of AT in the daily life of older adults with OA. Researchers have concluded that the aquatic exercise program decreased pain, stiffness, and difficulties with physical function, while increasing self-efficacy in individuals with knee or hip OA (Kars Fertelli et al., 2018). This reinforces the usual prescription of AT by doctors to manage OA problems.

Regarding recommendations, patients mostly answered (76.15%) “certainly yes” when asked if they would recommend the program, with 23.85% stating “probably yes”. This is a very good result, and is comparable with other studies in older adults (Monnin & Perneger, 2002; Vanti et al., 2013). Older adults usually accept their therapies and activities for the management of health care better, with few misunderstandings, and provide a more peaceful feedback

(Monnin & Perneger, 2002). Our sample also showed that the majority would recommend the program, as they were satisfied with the results.

For the DASH results, Gummerson et al. (2003) analysed 109 patients undergoing surgery and performed a longitudinal study of the construct validity of disabilities of the arm, shoulder and hand scale (DASH). This is a self-administered questionnaire and region-specific outcome instrument developed as a measure of self-rated upper extremity disability and symptoms. The results showed the mean (SD) DASH score preoperatively to be 35 (22) and postoperatively to be 24 (23); the mean score change was 15 (13) (Gummesson et al., 2003). Another DASH study using a general healthy population by Atroshi et al. (2000) found results with a mean score (SD) of 35 (20) and median of 34 (Atroshi et al., 2000). Comparing the current study results was the score mean (SD) for females of 35 (20) and male of 18 (15), it is possible to suggest that our sample is characterised by a disability condition which influences the patients' functionality and expectations.

The FPS results gave a mean score (SD) for females of 29 (14) and for males of 20 (10); it is therefore possible to suggest that our sample involved better motor control for women than men. This motor control group were globally weak; the median of ST was down than half of the maximum score. Stalenhoef et al. (2002) studied a questionnaire with the predictors postural sway, fall history and depression; their results provide added value in the identification of community-dwelling elderly at risk of recurrent falls (Stalenhoef et al., 2002).

Finally, the Spearman correlation used to understand the association between variables, pointed out a high association between DASH and FPS (0.708; significant at the 0.01 level). This reinforces the fact that upper limb disability was related to motor control performance; our sample scores were lower in both scales, showing functional impairment. Health problems like BMI, HBP and the use of more than four medications showed a strong association with DASH and FPS, indicating that this is a predictive factor for water adaptation. The fear of falls showed a stronger association with DASH and FPS (0.512 and 0.543, respectively; significant at the 0.01 level), with a significant effect predicted for successful water intervention.

This suggests the importance of using DASH and FPS to evaluate patients, as well health problems and the expectations questionnaire to point out the problems in community-dwelling older adults and provide adequate water adaptation to obtain real benefits and successful AT intervention.

Limitations and future research

Researchers focused on understanding the expectations and health problems of a long-term AT intervention sample. In the future, adults aged over 54 years, with upper limb dysfunction and associated health problems, should be studied in a long-term follow-up to understand the cost-benefits on the health services.

Conclusion

The correlation between DASH and FPS with DM2, HPB, the use of more than four medications and a fear of falls can all be predictive factors for greater difficulties with water adaptation and successful interventions. The greatest expectations for older adults with upper limb dysfunction are promoting wellbeing and becoming relaxed. We suggest that a long-term AT program should validate their ability and enable the assessment of other effects when studying the impact on successful aging.

Conflicts of interest statement

The authors declare no conflict of interest.

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CHAPTER VI

STUDY V · IMMEDIATE EFFECTS OF AQUATIC THERAPY FOR OLDER ADULTS WITH UPPER LIMB DYSFUNCTION: AN EXPLORATORY STUDY

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Abstract

Aging is a natural phenomenon that affects all and is characterized by biological changes such as decreased muscle strength, balance and motor coordination. Decreased joint mobility also occurs, leading people to look for the best environment for exercise and relaxation. Aquatic therapy appears to be effective in developing balance, strength and functional reach. The objective of this exploratory study was to evaluate the immediate effects of aquatic therapy on standing balance, strength and its relationship with functional reach in individuals over 55 years of age who attend to aquatic therapy classes for pain reduction, general strengthening, global mobility development, coordination and promotion of well-being. Participants underwent an aquatic therapy session in a sports pool or at a tracking of falls risk in the hospital gym. All participants were assessed before and immediately after the aquatic therapy intervention or a 45 minutes' passive period sitting in a chair (control group) by the step test, functional reach test, and global balance-standing test on the force platform. Results showed no significant differences in either group between the two measurement moments. However, the comparison between groups with the factor BMI, showed differences in the Standing Test and Global Balance Standing Test. Further studies should measure physiologic and kinematic parameters, related with the clinically relevant expectations. Is important to understand deeply why repeaters patients look for the aquatic therapy in long-term programs and establish the minimal important clinical changes to give an important goal for physiotherapist.

Keywords: single aquatic intervention; outcomes; functional performance

Introduction

Recent research has studied the benefits of exercise on the enhancement of functional capacity and reduction in risk and rate of falling in older adults. Exercise interventions should focus on increasing the muscle strength, muscle mass, improving balance and increase gait ability (Cadore et al., 2013; Sherrington et al., 2011). The Portuguese Plan for Patient Safety 2015-2020 targets the prevention and reduction of falls in healthcare institutions (Ministério da Saúde, 2015).

Exercise programs that stimulate several physical capacities, such as muscle strength and endurance, cardiorespiratory fitness, balance and coordination, appear to result in greater improvements in aging adults' ability to perform activities of daily living (Cadore et al., 2013; Freiberger et al., 2012; Hagedorn & Holm, 2010). Aquatic therapy has been proposed as an effective therapeutic approach to improve balance and reduce the risk of falls in older adults. It has several advantages compared to non-aquatic exercise, due to the physical properties of water (Alikhajeh et al., 2012; Avelar et al., 2010; Kaneda et al., 2008).

Buoyancy acts on the body to reduce the vertical load on the joints (Miyoshi et al., 2004) and this antigravity effect may reduce perception of fatigue and aide energy conservation (Wilcock et al., 2006). Furthermore, the viscosity of water and the associated drag resistive hydrodynamic force requires the individual to exert more force when performing immersed movements (Miyoshi et al., 2004), meaning that aquatic therapy allows high-intensity exercise while ensuring both low joint impact and greater comfort for the individual.

The thermal properties of water impose higher capacity to dissipate heat, compromising the capacity to maintain constant body temperature. This is mainly used as a mean to control oedema and inflammation, diminishing fatigue and pain and promoting recovery. Another important property of water is hydrostatic pressure. This, besides determining buoyancy, also leads to a favoured conduction of fluids from the extremities towards the central cavity structures of the human body (Torres-Ronda & Del Alcazar, 2014). The decrease in perception of fatigue may also be due to reduced neuromuscular responses during water immersion (Wilcock et al., 2006). Other advantages include low risk of injury from falling and the consequent lack of fear of falling during water exercise (Simmons & Hansen, 1996).

Although several studies show the efficacy of aquatic therapy on balance gain in older adults, immediate effects remain unclear. For example, are their precautions needed for first time users, or can we expect quick results which stimulate to continue? Therefore, the aim of this exploratory study was to measure the immediate effects of a single session of aquatic therapy on balance, strength and functional reach in persons with chronic osteoarthritis, older than 55 years of age.

Methodology

Study design and Setting

A quasi-experimental trial was carried out. Participants were recruited from the Hospital after ethical approval. An expert physiotherapist performed the aquatic therapeutic session. Another physiotherapist performed the lower limb strength measurements, dynamic balance and static balance tests, before and immediately after intervention (not more than 2 min from completion). The control group without aquatic therapy intervention agreed to take part in the functional tests before and after 45 minutes of a rest period in a chair. The hypothesis was that there was a significant positive effect of the intervention program at the functional tests.

Subjects

From the hospital falls risk assessment program, all subjects with 55 years and older were invited to participate. A sample of 22 participants was assessed for eligibility, met the inclusion criteria and agreed to participate in the study. All participants were given an informed consent according to the Helsinki Declaration and Oviedo Convention. The Intervention Group (n = 12) included those previously involved in an aquatic therapy program and the remaining were included in the Control Group (n = 10) – Figure 6.1. Inclusion criteria were: a) not having severe mobility deficits, b) be able to walk and stand independently and c) do not present mental disorders or deficits in communication and understanding instructions. Individuals with severe mobility deficits, inability to walk or stand independently, and individuals unable to communicate or understand commands to perform proposed activities were excluded.

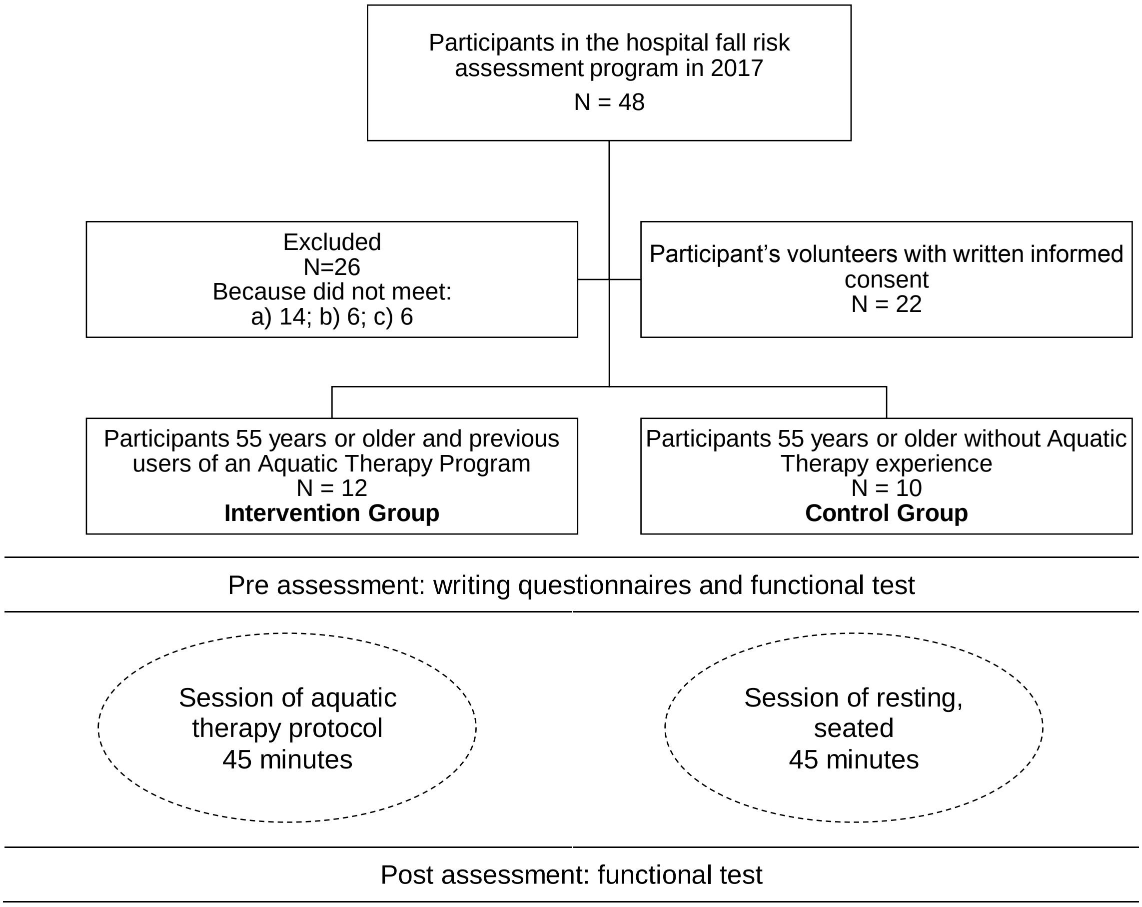


Figure 6.1 – Study flow chart.

Procedures

All data for the intervention group were collected in the pool building in a quiet room, temperature 25 C, with the participants wearing comfortable clothes (t-shirt and swim suit). The measurements were made immediately before and following a 45min aquatic therapy program. Height and body mass measurements were attained using a stadiometer and balance weighing scales.

The control group took part in data collection in the hospital gym. Participants were measured and then waited and then asked to sit quietly for 45 minutes before the second measurement. Initially, all participants completed a written questionnaire for sociodemographic data and health conditions. Outcome measures were Visual Analogic Scale for Pain (VAS_Pain), Step test (ST), Functional Reach Test (FRT) and the Global Balance Standing Test (GBST).

The DASH is a scale that assesses the perception of upper limb functionality. It consists of 21 questions related to pain or other symptoms, activities of daily living, leisure activities and professional activities (Atroshi et al., 2000).

The VAS_Pain is a 10 cm scale where the users quantified their pain from 0 to 10 in real time. It is considered that 0 represents no pain and 10 is considered the worst pain imaginable. The score is categorized as follows: less than 3cm - little pain, between 3 and 6cm - moderate pain, more than 7cm severe pain (Hawker et al., 2011).

The ST is a test that evaluate dynamic balance. The users were instructed to stand in front of a step 7.5 cm high without any type of support alternately on right and left foot while simulating the movement of ascent and descent stairs (Figure 6.2). Complete repetitions were counted during the 15 seconds of test duration (Devereux et al., 2005). The number of steps counted can be predictive of fall risk for some age groups (Brauer et al., 2000).

The mean values of each one of the three scores was recorded.

Figure 6.2 – Step test example (Brauer et al., 2000).

The FRT is a test that evaluates the frontal dynamic balance. The patient must be able to stand independently for at least 30 seconds without support and be also able to flex the shoulder to at least 90 degrees (Figure 6.3). The participant was instructed to stand next to a wall so that he can reach forward along the length of the metric stick as far as possible. they repeat the movement 3 times and the evaluator measures the best distance achieved in centimetres (Duncan et al., 1990). The mean of the second and third attempt is recorded.

Figure 6.3 – Functional reach test example (Duncan et al., 1990).

The GBST on the force platform (Hercules model from Sensing Future, 60 cm x 48 cm x 45 cm, used Wi-Fi to monitor communication, acquisition frequency until 100 Hz and software from Sensing Future) to evaluates the static balance with biofeedback in the computer monitor, using a red and green cross as indicator of bad or good equilibrium, respectively. The equation for calculating the percentage in equilibrium is as follows (Equation 6.1):

$$\%balance = (\frac{equilibrium\ time(in\ seconds)}{total\ time\ (in\ seconds)}) \times 100$$

Equation 6.1 – The equation for the calculation of time percentage values on equilibrium at the force platform**.**

The equilibrium time is the permanence time in the green indicator, is when the weight difference between left and right side and the difference of weight between front and back are within the defined tolerance. Tolerance (5%) is the allowable weight margin for the indicator to remain green (Figure 6.4).

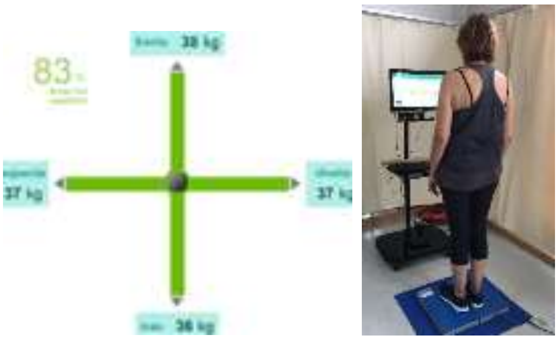


Figure 6.4 - Monitor picture of physio sensing platform for good feedback as be in balance and a subject collect moment.

Each user was asked to stand up straight and completely still, with eyes open, during one minute and repeated three times. The best score is recorded (Martins et al., 2015; Martins et al., 2016; Whyatt et al., 2015).

Intervention

The intervention sessions in the pool lasted 45 minutes and included a warm-up, conditioning and cooling down period. The warm-up included gait exercises in all directions, with change of pace, gait with dissociation of waist, and walking on toes and on heels (Adsett et al., 2017). The main objective of conditioning was to improve balance. Exercises such as bicycling with legs, upper limb reach, pushing the water and slips with noodle float support were included. Balancing exercises were also performed in the sitting and standing positions with floating plates (Alikhajeh et al., 2012; Lord et al., 1993; Methajarunon et al., 2016) and Ai-chi movements with exercises in unipodal or bipodal support according to participant tolerance (Pérez-de la Cruz et al., 2016; So et al., 2017). Cooling down included gait exercises with waist dissociation, standing-balancing with Ai-chi upper limb movements (first five movements), followed by relaxing cervical movements, shoulder rotations and slow stretches (Assis et al., 2006;

Bidonde et al., 2014; Brady et al., 2008; Burmaster et al., 2016; Candeloro & Caromano, 2007; Rewald et al., 2016).

Ethical procedures

Researchers got permission from the local hospital Ethics Committee (07/12/2017-CE) and National Data Protection Commission (n. º 7103/ 2017) to treat the data and publish the results.

Statistical analysis

Analysis was conducted with the statistic software SPSS version 24.0 (SPSS Inc., Chicago, IL, USA). Normality of data distribution was tested with the Shapiro-Wilk Test. Normality pointed out no differences. Chi-square test and Univariate GLM had been screened for differences between group and gender. T-Test pairs were screened and the repeated-measures ANOVA was used to compare mean values of functional tests before and after intervention (effect time of 45 minutes) for intervention group and before and after a rest for the control group.

Results

After the baseline assessments, all participants were included in the data analysis. Subsequently, 22 participants, 12 in Interventional Group and 10 Controls were tested. No differences were found regarding age, gender, weight, but on contrary, between groups there are differences for health conditions, medication and osteoarthritis status. The proportion of subjects with health conditions, medication and osteoarthritis is higher in intervention group (Table 6.1).

Table 6.1 – Baseline characteristics of the participants.

	Intervention		Control	
	Female	Male	Female	Male
Gender	11	1	7	3
Age (years)	62.9 (5.9)	58	61.9 (5.6)	75 (8.7)
Height (m)	1.6 (0.1)	1.7	1.7 (0.8)	1.7 (0.7)
Weight (Kg)	70.6 (12.4)	100	65.9 (11.2)	72 (11.8)
BMI (kg/m$^{2)}$	27.8 (4.1)	35	27 (4)	25 (2)
Health condition* (yes/no)	11/0	1/0	4/3	1/2
Medication (yes/no)	7/4	0/1	1/6	0/3
Osteoarthritis (yes/no)	10/1	1/0	1/6	0/3
DASH Score	54 (13.8)	67	28.7 (21.8)	6.11 (5.9)

*(High Blood Pressure or High Cholesterol or Diabetes Mellitus 2);

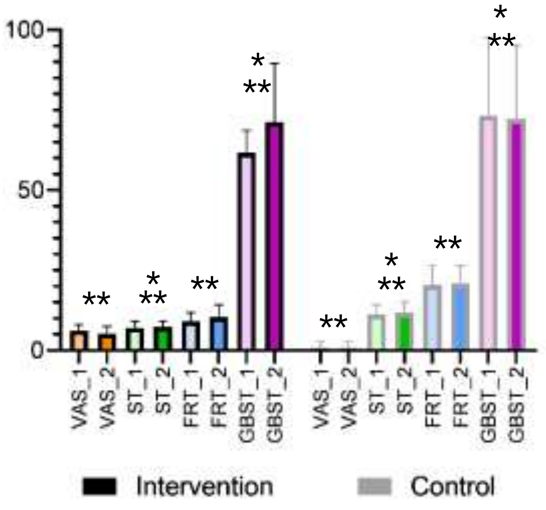
The result for changes with a time effect based on repeated measures, before and after AT intervention, pointed out differences for ST on Intervention Group (t(11) = 1.02) and Control Group (t(9) = -1.48). The same effect for GBST on Intervention Group (t (11) = -1.99) and Control Group (t(9) = 0.38). In addition, the effects between subjects had differences for ST in the Control Group. The repeated measures were screened with BMI pointed out for VAS, ST and FRT similar results, but for GBST results pointed differences in time effect F (1.19) = 5.06, $p < 0.05$, ETA=0.21, Time*BMI F (1.19) =6.32, $P < 0.05$, ETA=0.03 and Group F(1.19) = 9.18, $p < 0.05$, ETA=0.33.

Immediately after the intervention, the scores of all tests grew in the Intervention Group and remained almost unchanged in the control group. Results pointed out differences in first assessments in the groups for the ST and GBST (Figure 6.5).

Table 6.2 – Changes to announce the immediate effects of aquatic therapy. Values are mean (standard deviation) and ANOVA one-factor sig. p<0.05.

		MbI	MaI		
VAS (cm)	Intervention (n=12)	6.2 (1.9)	5.2 (2.3)	Time: F (1.20) = 0.86	$p > 0.05$
				Time*group: F (1.20) = 0,86	$p > 0.05$
	Control (n=10)	0.9 (1.9)	0.9 (1.9)	Group*inter subjects: F (1.20) = 95.22	$p < 0.01$
ST (n)	Intervention (n=12)	7.0 (2.0)	7.4 (1.8)	Time: F (1.20) = 11.20	$p < 0.01$
				Time*group: F (1.20) = 0.39	$p > 0.05$
	Control (n=10)	11.23 (3.1)	11.80 (3.3)	Group*inter subjects: F (1.20) = 297.04	$p < 0.01$
FRT (cm)	Intervention (n=12)	9.1 (2.8)	10.4 (3.8)	Time: F (1.20) = 2.84	$p > 0.05$
				Time*group: F (1.20) = 0,63	$p > 0.05$
	Control (n=10)	20.41 (5.9)	20.91 (5.5)	Group*inter subjects: F (1.20) = 265.72	$p < 0.01$
GBST (% T in balance)	Intervention (n=12)	61.7 (5.9)	71.3 (18.2)	Time: F (1.20) = 2.24	$p < 0.01$
				Time*group: F (1.20) = 3,34	$p > 0.05$
	Control (n=10)	73.24 (24.3)	72.24 (22.9)	Group*inter subjects: F (1.20) = 237.80	$p < 0.01$

VAS – Visual Analogic Scale ST – Step test; FRT – Functional Reach Test; GBST – Global Balance Stand Test; MbI – Measures before intervention; MaI – Measures after intervention.



Legend:
VAS_1 – MbI
VAS_2 – MaI
ST_1 – MbI
ST_2 – MaI
FRT_1 – MbI
FRT_2 – MaI
GBST_1 – MbI
GBST_2 – MaI

*Differences between assessments
** Differences between first assessments in the groups

Figure 6.5 – Clinical improvements in the outcomes for both groups.

Discussion

The purpose of this exploratory study was to evaluate the immediate effects of one aquatic therapy session in a patient's group with 55 years or older, following a wash out period (summer vacation). Many studies look for long term improvements (Adsett et al., 2017; Alikhajeh et al., 2012; Assis et al., 2006; Avelar et al., 2010; Ayán & Cancela, 2012; Burmaster et al., 2016; Kanitz et al., 2015), but in this study, the key point was to find what changes occur immediately after a single training session.

The evidence showed significant benefits after 6 or 12 sessions, but the outcome measures used in those studies were not consistent. In this study and due to the limited period for assessment, we chose measures with strong scientific evidence (Alikhajeh et al., 2012; Bongue et al., 2011; Duncan et al., 1990; Kurz et al., 2016; Pasma et al., 2016).

The speed of performance in the step movement provided significant prediction of non-fallers with a success rate of 70%. Seven or less steps in 15 seconds suggests high instability (Blennerhassett et al., 2012; Brauer et al., 2000; Hong et al., 2012).

The current study for Interventional Group pointed out the scores for the step test, around seven steps before vs. after (7.0 ±2.0 vs. 7.4 ±1.8), these results showed a poor balance standing one foot on the intervention group. The control group had better baseline results around 11 steps, before vs. after, 11.2 (3.1) vs.11.8 (3.3), almost no changes between measurements. For the functional reach test, literature evidence pointed values between 25.5 and 28.9 cm to provide a reasonable standard for interpreting FRT performance in community-dwelling older adults (Bohannon et al., 2017; Duncan et al., 1990). We observed that the Interventional Group results, before vs. after, 9.1 (2.8) vs.10.4 (3.8), were under the stable level related with stability and capacity to protect from a lack of balance, as different from the control group, which had better score, suggesting better balance control.

Finally, for the global balance standing test (Bongue et al., 2011; Hagedorn & Holm, 2010; Martins et al., 2015) based on the predictive study of Martins et al. (2015) the results should be higher than 60% of time in balance to predict a good balance performance to prevent falls. The results appeared to reinforce the good performance of the Interventional Group before vs. after, 62.62 (22.36) vs. 70.28 (17.60), suggesting the good influence of AT in standing balance for older adults with upper limb disability. The protocols of other studies do not allow the comparison.

Pain evaluated with VAS pointed no differences for both groups and no minimal clinically differences which is not in accordance with Salaffi et al. (2004) that demonstrated that it should point more 3 mm difference to be minimal clinically important change effect.

The control group baseline showed better results at the four variables measured when compared to the intervention group. However, the intervention group also had similar values on BMI, with lower height, higher weight and more additional health problems. In general, they were not obese but it is easier to deal with over-weight in water. At the end, the intervention group pointed out a tendency to get higher improvements, however, better for the global balance test than the control group, although no differences were found.

The current results suggest that this population with fragile health condition (11 vs. 1) and osteoarthritis (10 vs. 2) needs to be active in aquatic therapy where the performance shows a decrease of pain and satisfaction with the developed program. It suggests, aquatic therapy appears to help more when the activity is more dynamic and perhaps when the starting point is lower. Importantly there were no adverse effects of an aquatic therapy session. No negative effects on balance were found. Further, it might be important that aquatic therapy aids in maintenance of balance so people do not regress and persons with generally poorer function can easily take part. Patients can experience immediate progress so that motivation to continue is obtained from success.

Limitations and future research

Small sample size compromised the evidence of the results. The establishment of the minimal observable difference should be an important goal in future studies.

Conclusion

The immediate changes of aquatic therapy observed in this sample, reinforces the importance of patients with upper limb dysfunction repeating aquatic therapy annually; the immediate improvement was effective although not evidence. As function decreases with age, we suggest the AT program as promoter of functional maintenance or improvements in a well-succeeded aging. Further studies should measure physiologic and kinematic parameters, related with the clinically relevant expectations, to understand deeply why repeaters patients look for the aquatic therapy in long-term programs and establish the minimal important clinical changes to give an important goal for physiotherapist.

Conflicts of interest statement

The authors declare no conflict of interest.

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CHAPTER VII

STUDY VI · EFFECTS OF DETRAINING AND TRAINING ON BALANCE PERFORMANCE, STRENGTH AND PAIN IN OLDER ADULT WITH UPPER LIMB DYSFUNCTION USERS OF AQUATIC THERAPY

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Abstract

Introduction: Aquatic therapy research needs to provide deeper knowledge about the effects of detraining and training on balance, strength and functional reach related to upper limb disability. The evidence shows significant improvements on balance through aquatic therapy in several patients. Some recent evidence for continuous aquatic therapy programs found advantages for the support of psychological factors influencing quality of life. **Objective:** The aim of this study was to analyse the effects of detraining (two months) and training (six weeks) in aquatic therapy programs on the functional outcomes of older adults with upper limb disability. **Methods:** Participants underwent an aquatic therapy program in a sports pool. All participants with self-reported shoulder and hand disability with positive scores were assessed for functional and perceptual (with biofeedback) test outcomes after the intervention. The researchers divided the participants into two groups: complete follow-up and partial follow-up. Measured time-points were: M1 (at the end of the year-long aquatic therapy program), M2 (after a two month summer break) and M3 (after six weeks of training). The variables used were the results of the visual analog scale (VAS), step test (ST), functional reach test (FRT) and global balance standing test (GBST). Normal distribution of the variables was shown by repeated measures ANOVA. **Results:** The baselines of the complete follow-up and partial follow-up groups showed no significant differences ($p>0.05$). The complete follow-up group showed differences in the detraining effects for correlation measures in the ST with IC(95) and t(11) = 1.11. **Conclusion:** The current study suggests that AT has an important impact on the balance and pain symptoms of older adults with upper limb disability. The response to the program varies with the time spent in the AT program; the group previously engaged in aquatic therapy included fast-responders to training. Through the detraining effects, we suggest that community programs have an important impact on activities of daily living and safety in older adults with upper limb disability.

Keywords: efficacy; long-term aquatic therapy intervention; outcomes.

Introduction

It is already known that aquatic therapy (AT) has positive impacts on knee cartilage in women with mild knee osteoarthritis, shown by progressively increased resistance in a 4-month AT program; the randomised study showed positive impacts on the biochemical properties of knee cartilage and a strong cardiorespiratory effect for this kind of patient (Munukka et al., 2016).

We provide clinical evidence for improvements in functional tests, studied using different strategies (on dry land, underwater and combined) in patients suffering from chronic pathologies (Adsett et al., 2017; Bidonde et al., 2014). The AT was studied using protocols related to quality of life, fall prevention and pain, and showed significant improvements (Bayraktar et al., 2016; Clemson et al., 2012; Waller et al., 2013).

The study by Avelar et al. (2018) reported significant effects on balance stability and in hyper-cholesterol and obesity after two years of AT in obese people. Bocalini et al. (2010) studied the repercussions 12 weeks of training, and six weeks of detraining in healthy women. They measured the quality of life and fitness tests, proving a decrease with 4 or 6 weeks of detraining. However, after a short period of training, all neuromuscular parameters and quality-of-life scores returned to baseline. Also, a study of detraining in fibromyalgia patients gave evidence for the continuity of aquatic therapy programs. It seems that psychological factors may determine a higher quality of life (Tomas-Carus et al., 2007).

Biomechanical studies of patients submitted to AT programs provided evidence of the effects on recovering from surgery or neurological diseases (Brady et al., 2008; Castillo-Lozano et al., 2014; Rodrigues de Paula et al., 2006). It is also possible to find references to increased fall prevention through aquatic therapy, empowering balance, strength and mobility in elderly people (Cadore et al., 2013; Clemson et al., 2012).

The aim of this study was to analyse the effects of an AT program for older adults with upper limb disability on balance, strength and functional reach. It was measured at three time points: first, at the end of a therapy season (ten months of continuous AT), second, after two months of detraining, to study effect of detraining during a summer break, and third, after six weeks of training.

Methodology

Setting and participants

Researchers recruited all patients from the hospital AT program, which was performed in a public swimming pool. Volunteers met the following inclusion criteria: 1) older than 55, 2) not severe mobility deficits, 3) able to walk and stand independently, and 4) no mental disorders or deficits in communication and understanding preventing the ability to carry out the proposed activities. All volunteers admitted were assessed for eligibility, met the inclusion criteria, and signed an informed consent form according to the Declaration of Helsinki and the Oviedo Convention.

Methodological design

After procedures for admission, all volunteers accepted to repeat the measurements after three or two AT interventions in a follow-up period. The flow chart of the sample selection and design of the study are presented in Figure 1. The complete follow-up group was evaluated at three different time points: M1 – at the end of the therapeutic season (July); M2 – at the beginning of the next season (October); and M3 – 6 weeks after the second collection (November). The partial follow-up group was evaluated at phases M2 and M3. Three blind evaluators, who were not aware of the AT session structure, conducted the evaluation procedures. The AT session was performed by the same physiotherapist with expertise in AT.

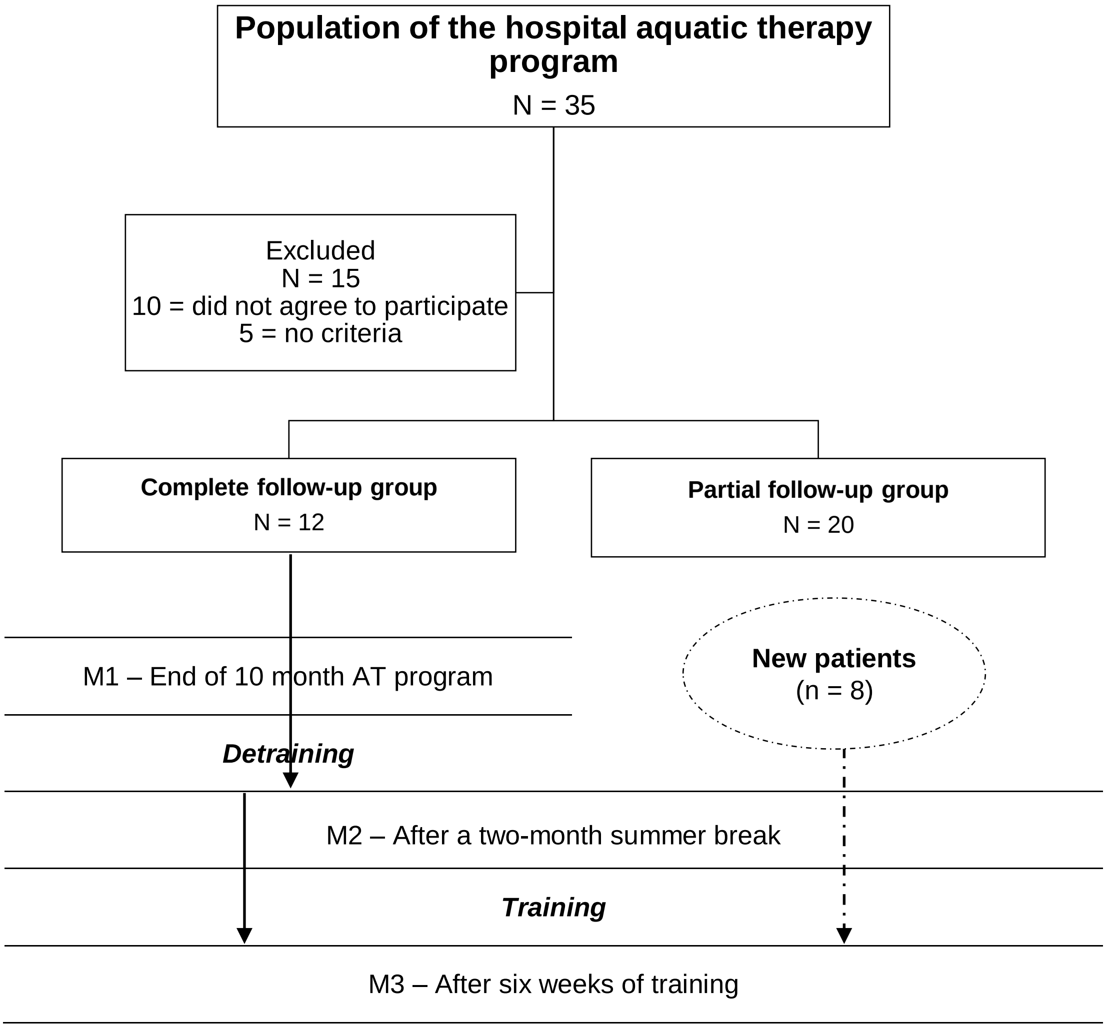

Figure 7.1 – Study design.

Intervention

The sessions occurred twice a week and lasted for 45 minutes. They included a warm-up, a development phase and a cool-down period, which are described in detail in Appendix II. The warm-up included gait exercises in all directions, with the change of pace, gait with dissociation, and different types of walking (Adsett et al., 2015). The development goal was facilitating global balance, with exercises such as bicycling with the arms and legs, floating with jumping and gliding, supported on a pool noodle. Balancing exercises were performed in the sitting and standing positions with pool noodles (Alikhajeh et al., 2012; Jigami et al., 2012; Lord et al., 1993). The cool-down included gait exercises with the dissociation of four limbs, Tai-chi movements for relaxation, exercises on one foot or two feet, according to participant tolerance, cervical movements and stretches, shoulder rotations and stretching movements (Alikhajeh et al., 2012; Jigami et al., 2012; Lord et al., 1993).

Evaluation Tools

Initially, all participants were submitted to a questionnaire for the collection of i) sociodemographic data, ii) health problems, iii) expectations on a self-report scale, and iv) disability of the arm, shoulder and hand scale (DASH). The remaining assessment instruments were applied to all participants immediately after the intervention; these included visual analogue pain scale (VAS), step test (ST), functional reach test (FRT) and the global balance standing test (GBST) on the force platform.

All data were collected in the pool building in a quiet room, at a temperature of 25°C, with the participants wearing comfortable clothes (t-shirt and swim suit). The measurements were made immediately before and following a 45 min aquatic therapy program. Height and body mass measurements were obtained using a stadiometer and balance weighing scales.

DASH is a scale that assesses the perception of upper limb functionality. It consists of 21 questions related to pain or other symptoms, activities of daily living, leisure activities and professional activities (Atroshi et al., 2000).

The VAS is a 10 cm scale where the users quantify their pain from 0 to 10 in real-time. In this scale, 0 represents no pain and 10 is considered the worst pain imaginable. The score is categorised as follows: less than 3 cm - little pain, between 3 and 6 cm - moderate pain, and more than 7 cm - severe pain (Hawker et al., 2011).

The ST evaluates dynamic balance. The users are instructed to stand in front of a 7.5 cm high step without any type of support, alternately on the right and left foot, while simulating the movement used when ascending and descending stairs (Figure 7.3). Complete repetitions were counted during the 15 seconds of the test (Devereux et al., 2005). The number of steps counted may be predictive of fall risk for some age groups (Brauer et al., 2000). The mean values of each of the three scores were recorded.

Figure 7.2 – Step test example (Brauer et al., 2000).

The FRT is a test that evaluates frontal dynamic balance. The patient must be able to stand independently for at least 30 seconds without support and also be able to flex their shoulder to at least 90 degrees (Figure 3). The participant is instructed to stand next to a wall so that they can reach forward along the length of the metric stick as far as possible. The movement is repeated 3 times and the evaluator measures the best distance achieved in centimetres (Duncan et al., 1990). The mean of the second and third attempt is recorded.

Figure 7.3 – Functional reach test example (Duncan et al., 1990).

The GBST on the force platform (Hercules model from Sensing Future, 60 cm x 48 cm x 45 cm, used Wi-Fi to monitor communication, acquisition frequency until 100 Hz and software from Sensing Future) evaluates static balance with biofeedback in the computer monitor, using a red and green cross as an indicator of bad or good equilibrium, respectively.

The equation for calculating the percentage in equilibrium is as follows (Equation 7.1):

$$\%balance = (\frac{equilibrium\ time(in\ seconds)}{total\ time\ (in\ seconds)}) \times 100$$

Equation 7.1 – The equation for calculating percentage values of equilibrium time at the force platform.

The equilibrium time is the time in the green indicator, which is when the weight difference between left and right side and the difference in weight between the front and back are within the defined tolerance. Tolerance (5%) is the allowable weight margin for the indicator to remain green (Figure 7.4).

Figure 7.4 – The green cross picture of physio-sensing platform is a feedback for good balance standing

Each user was asked to stand up straight and completely still, with their eyes open, for one minute; this was repeated three times and the best score was recorded (Martins et al., 2015; Martins et al., 2016; Whyatt et al., 2015).

Ethical procedures

Researchers obtained authorisation from the local hospital Ethics Committee (07/12/2017-CE) and from the National Data Protection Commission (n. º 7103/ 2017) to analyse the data and publish the results.

Statistical analysis

Data analysis was conducted using the statistics software SPSS version 24.0 (SPSS Inc., Chicago, IL, USA). Normality of data distribution was tested with the Shapiro-Wilk Test; no differences were reported. The paired T-test was performed and the repeated-measures ANOVA was used to compare scores of the functional tests between each stage and groups of follow-up.

Results

After the baseline assessments, all participants were included in the data analysis. Subsequently, 20 participants, 12 in the complete follow-up group and 8 in the partial follow-up group were tested. The groups showed no differences (*p*> 0.05) regarding age, gender, weight, height, health conditions and osteoarthritis status (Table 7.1). Distributions of all variables for both groups were normally distributed. In the complete follow-up group, the analysis of detraining effects between M1 (end of annual intervention) and M2 (starting of annual intervention) showed differences for the ST, t(11) = 1.11 (Table 7.2).

Table 7.1 – Baseline characteristics of participants.

	Complete follow-up (n=12)		Partial follow-up (n=8)	
	female	male	female	male
Gender	11	1	7	1
Age (years)	62.9 (5.9)	58	6 (8.1)	66
Height (m)	1.6 (0.1)	1.7	1.6 (0.1)	1.72
Weight (Kg)	70.6 (12.4)	100	67.4 (9.6)	90
BMI (kg/m$^{2)}$	27.8 (4.1)	35	28.0 (5.2)	30
Health condition* (yes/no)	11	1	7	0
Osteoarthritis (yes/no)	10	2	3	0
DASH Score	54 (13.8)	67	62.5 (9.5)	40

*High blood pressure or high cholesterol or diabetes mellitus type 2.

Table 7.2 – Detraining effects: means (SD) after aquatic therapy intervention and comparison of variables (M1 & M2), n=12.

	M1 *means (SD)*	M2 *means (SD)*	M1&M2 T-test (*p*)
VAS_Pain (cm)	4.25 (1.94)	5.23 (2.28)	t(11) = -0.59 ($p > 0.05$)
ST (n)	7.92 (1.98)	7.37 (1.84)	**t(11) = 1.11 ($p < 0.05$)**
FRT (cm)	16.03 (6.01)	10.79 (3.74)	t(11) = 0.75 ($p > 0.05$)
GBST (% T in balance)	55.73 (25.67)	71.38 (18.24)	t(11) = -0.41 ($p > 0.05$)

VAS-visual analogic scale; ST-Step test; FRT-functional reach test; GBST-global balance standing test; M1-end of season on AT annual program; M2-starting AT program after summer break (two months); SD-standard deviation; *T-test repeated measures, sig. p<0.05.

The training effects between M2 (starting of annual intervention) and M3 (after six weeks of training) were studied separately for the complete follow-up group and the partial follow-up group. Presented differences for the complete follow-up group in ST with t(11) = 2.02 and GBST with t(11) = -3.32 (Table 7.3). Looking deeper, we studied the time effect in both groups (Table 7.4), results showed differences between groups with time factor for all functional tests, and for GBST presented differences for time, in the group and between groups. For the changings measures of AT, in both groups, regarding clinical differences (CD) findings, negative and positive values were reported, related to gains and losses, e.g. the negative for VAS Pain should be understood as a positive clinical difference (Table 7.4).

Table 7.3 – Training effects.

	Complete Follow Up (n=12)			Partial Follow Up (n= 8)		
	M2 *means (SD)*	M3 *means (SD)*	M2 & M3 T-test (*p*)	M2	M3	M2 & M3 T-test (*p*)
VAS_Pain (cm)	5.23 (2.28)	4.04 (2.31)	t(11) = 1.33 ($p > 0.05$)	3.98 (1.92)	2.58 (2.24)	t(7) = 1.88 ($p > 0.05$)
ST (n)	7.37 (1.84)	6.69 (2.14)	**t(11) = 2.02 ($p < 0.05$)**	5.88 (163)	6.28 (1.37)	t(7) = -0.66 ($p > 0.05$)
FRT (cm)	10.43 (3.77)	14.43 (4.77)	t(11) = -2.65 ($p > 0.05$)	13.79 (3.90)	14.61 (5.18)	t(7) = -0.38 ($p > 0.05$)
GBST (% T in balance)	71.38 (18.24	82.93 (13.58)	**t(11) = -3.32 ($p < 0.05$)**	68.60 (17.64)	83.84 (8.51)	t(7) = -2.81 ($p > 0.05$)

VAS-visual analogic scale; ST-Step test; FRT-functional reach test; GBST-global balance standing test;
M1-end of season on AT annual program; M2-starting AT program after summer break (two months); MD-means difference; SD-standard deviation;
* T-Test - repeated measures, sig. $p<0.05$; MD-means difference.

Table 7.4 – Comparison of training on time effect.

		Time effect between M2 & M3*	
VAS (cm)	Complete Follow up (n=12)	Time: F (1.18) = 3.14	$p > 0.05$
		Time*group: F (1.18) = 3.14	$p > 0.05$
	Partial Follow up (n=8)	Group*inter subjects: F (1.18) = 128.85	$p < 0.01$
ST (n)	Complete Follow up (n=12)	Time: F (1.18) = 0.18	$p > 0.05$
		Time*group: F (1.18) = 0.18	$p > 0.05$
	Partial Follow up (n=8)	Group*inter subjects: F (1.18) = 292.25	$p < 0.01$
FRT (cm)	Complete Follow up (n=12)	Time: F (1.18) = 3.53	$p > 0.05$
		Time*group: F (1.18) = 3.53	$p > 0.05$
	Partial Follow up (n=8)	Group*inter subjects: F (1.18) = 295.13	$p < 0.01$
GBST (% T in balance)	Complete Follow up (n=12)	Time: F (1.18) = 19.06	$p < 0.01$
		Time*group: F (1.18) = 19.06	$p < 0.01$
	Partial Follow up (n=8)	Group*inter subjects: F (1.18) = 602.15	$p < 0.01$

VAS-visual analogic scale; ST-Step test; FRT-functional reach test; GBST-global balance standing test;
M1-end of season on AT annual program; M2-starting AT program after summer break (two months); MD-means difference; SD-standard deviation;
* ANOVA one factor, time effect, sig. $p<0.05$;

Table 7.5 – The clinically changing effects or Clinically Differences in the follow up of aquatic therapy program.

		M1_2* *MEANS (SD)*	M2_3* *MEANS (SD)*
VAS_PAIN (cm)	Complete Follow Up (n=12)	0.98 (3.19)	-1.19 (3.09)
	Partial Follow Up (n=8)		0.71(3.09)
ST (n)	Complete Follow Up (n=12)	-0.55 (3.09)	-0.68 (1.19)
	Partial Follow Up (n=8)		-0.71 (3.09)
FRT (cm)	Complete Follow Up (n=12)	-5.23 (5.40)	3.79 (5.28)
	Partial Follow Up (n=8)		-4.47 (6.09)
GBST (% T in balance)	Complete Follow Up (n=12)	-2.28 (9.46)	11.51 (12.07)
	Partial Follow Up (n=8)		15.21 (15.95)

VAS-visual analogic scale; ST-step test; FRT-functional reach test; GBST-global balance standing test;
M1_2-Difference between measures at end of annual Intervention and the start of annual Intervention;
M2_3-Difference between the start of annual Intervention and after six week of intervention,
*swags are positive and losses are negative results.

Discussion

The aim of this study was to analyse the effect of detraining and training in older adults with upper limb disability. Two groups were studied to enable two questions to be answered simultaneously: i) are the deleterious effects of detraining perceptible and relevant, and ii) is the training effective?

We observed that the detraining period imposed a serious decline on most of the variables studied (VAS Pain; FRT and GBST). Only GBST showed no significant loss. Moreover, when a return to AT was studied, it was possible to see that the group previously engaged in AT (complete follow-up group) were fast-responders to training in most of the variables (ST and FRT) compared with the newly engaged group (partial follow-up group).

The current study of detraining effects pointed out the negative impact of the lack of balance strategies and an increase in pain, like the results of Bocalini et al. (2010) and Tomas-Carus et al. (2007). These studies confirmed a negative impact of the lack of training in fitness and quality of life. We understand the impact of detraining, even during the summer break to have family time, which suggests that the detraining always has a negative impact on pain, muscle response and sensorial adaptation for older adults.

The study by Tomas-Carus et al. (2007) involved a controlled detraining AT program (three times per week) for women with fibromyalgia, and comparison with a control group. The intervention group underwent 12 weeks of training, and both groups planned a break of 24 weeks, continuing their habitual leisure activities. The outcomes used were SF-36, Canadian Aerobic Fitness, handgrip dynamometry, 10-m walking, 10-step stair climbing, and blind one-leg stance.

Bocalini et al. (2010) studied training and detraining in healthier women using a control group of aged-matched women without any exercise training. The intervention protocol involved 12 weeks of training, with a detraining period of six weeks. Effects measured were BMI, VO_2, neuromuscular fitness and quality of life. VO_2 max used the Bruce treadmill protocol, which consisted of maximal running or walking during 800 meters after a 1 min warm-up without treadmill inclination at 1.0 mph. The Borg scale, with scores of between 6 and 20, was used for the determination of subjective exertion level. The test was considered a success if participants reached their age-predicted maximum heart rate of 220, with the result being measured in beats per minute. Their results highlight no changes for the control group during the follow-up study. However, in the experimental group, there were significant improvements in aerobic power, neuromuscular fitness and quality of life scores. After 6 weeks of detraining, the intervention group was no longer different compared with the control group (p>0.05), indicating an important detraining effect.

Bergamin et al. (2012) performed a systematic review into the potential of water exercise improving physical fitness in the elderly; they found nine studies, which reinforced that water-based exercise, could produce many beneficial effects on physical fitness when properly prescribed in healthy older individuals. There is strong evidence to support the use of water-based exercise for the improvement of aerobic capacity and strength, moderate evidence to support the use of water-based exercises for improvements in flexibility, and inconclusive evidence regarding its effects on body composition.

Munukka et al. (2016) performed an RCT on the efficacy of progressive aquatic resistance training for women with knee osteoarthritis, and highlighted that the outcomes of KOOS (knee injury and osteoarthritis outcome score) showed no between-group changes in any of the domains of the KOOS. Its lack of significance was not a surprise given the high values reported at baseline; however, the strength of this study was high adherence to a highly intensive AT program.

Deeper analysis of the clinically different outcomes answered the question around the effectiveness of training. Lee et al. performed a study of the minimal clinically important difference (MCID) for pain, and pointed out that 30 mm represents a clinically important difference in pain severity that corresponds to patients' perceptions of adequate pain control (Lee et al., 2003). The current study had no MCID for VAS Pain.

Limitations and future research

The small sample size compromised the results. Future studies are needed to provide better evidence of the effect of AT in older adults with upper limb disability.

Conclusion

The aim of this study was to compare the effects of detraining and training with an AT program for older adults with upper limb disability. The results confirm that AT intervention had a positive effect in older adults with upper limb disability, indicating that they need to maintain their AT program for self-regulation and self-efficacy. The response to the program varies with the time spent in the AT program; the group previously engaged in AT were fast-responders to the training. The partial follow-up group had a lower response to the program with lower clinical differences. Through the detraining effects, we suggest that community programs have an important impact on daily life functionality and safety in older adults with upper limb disability.

Conflicts of interest statement

The authors declare no conflict of interest.

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CHAPTER VIII

STUDY VII · MUSCLE ACTIVATION PATTERNS DURING THE ROTATOR CUFF TESTS – A CASE REPORT

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Abstract

Introduction: The application of shoulder tests is frequently used in anatomy and physiology clinical reasoning. Investigations of upper limb muscle activation during reach are rare in the literature for rotator cuff (RC) injury. For decision-making in clinical diagnosis these tests have lack uniformity, validity and reliability. Therefore, the aim of this case study was to develop a protocol for biomechanical analysis and EMG assessment of five well-known RC tests: Belly Press (BP), Drop arm (DA), Empty can (EC), Neer and Hawkins.

Methods: Randomly we chose one female subject from a set of 18 volunteers with rotator cuff injury to apply the procedures of EMG data processing and kinematic parameters to biomechanically analyse Belly press (BP), Drop arm (DA), Empty can (EC), Neer and Hawkins tests. This followed a clinical assessment using visual analogue pain scale (VAS_Pain), disability of arm, shoulder and hand scale (DASH) and ultrasound examinations. Surface electrodes (Delsys Inc. Signal Conditioning Electrodes v2.3, USA) were used according to the SENIAM recommendations (www.seniam.org) for an electromyography recording of the *biceps brachial*, *infraspinatus*, *upper trapezius*, and *lower trapezius*. A twelve-camera 3D motion capture system (Qualisys AB, Sweden) was used to record upper limb movements with a sampling frequency of 200 Hz. Qualisys Track Manager (Qualisys AB Gothenburg, Sweden) and Visual 3D (Standard v5.01.18, C-Motion, Inc) software were used in the motion analysis data. During the experiment, the subjects were sitting on a chair and were asked to perform five clinical tests for the muscles of the shoulder RC as described in the protocol of Scott Sevinsky.(Sevinsky, s. d.) The study got one woman, 60 years old, 61.80 kg body mass, 1.52 m height, 26.75 kg/m^2 BMI, right handed, with physiotherapy experience, with pain for more than 24 months due to rotator cuff injury on the right shoulder

Results: The subject mentioned grade 9 concerning pain on VAS_Pain and 57.80 for the disability of arm, shoulder and hand scale (DASH). Ultrasound assessment on two tendons, showed partial 19 mm rupture at the *supraspinatus* tendon, tendinosis at the *supraspinatus* and *infraspinatus* with calcification on *supraspinatus*. The studied variables were: Time spent in the test collection, Sequence of muscle activation, Time of EMG Peak and EMG Peak value, the angle on the maximal muscle activation and the velocity on the maximal muscle activation.

Discussion and Conclusion: Our results pointed out that *infraspinatus* was always less active than the *biceps brachial*. Especially interesting was the finding related to the moderate activity of the contralateral *upper trapezius* when the injured (right) were tested, suggesting a muscle irradiation neuro proprioceptive activity. This could be a compensation for the weakness or painful symptoms in the injured upper limb. About the recruitment order, if we compare right with left upper limb, it seems that the end muscle on the injured upper limb is related with the pain and the main problem of the patient. These findings could lead for further studies for deeper understanding of motor control in RC injury patients with a larger sample.

Keywords: rotator cuff tests, biomechanics, EMG

Introduction

The most disabling issue that causes functional impairment of the shoulder complex during ambulatory rehabilitation, especially in aging people, is the rotator cuff (RC) injury (Murrell & Walton, 2001). Over the last 30 years, scientific evidence is not strong enough to support the clinician’s decision about patients with shoulder injury. Conservative treatments are not well supported (Vecchio et al., 1995) for elderly people, with pain and immobility impairing daily life activities.

When combined with shoulder injury, other dysfunctions can compromise balance and increase the risk of falling in the elderly (Acree et al., 2006). The application of shoulder tests has been frequently used based on a clinical reasoning of anatomy and physiology, but their poor reliability and accuracy prompted the clinicians to turn to ultrasound examination (Barratt, 2009; Castoldi et al., 2009; Dunn et al., 2014).

On the other hand, some authors believe that, with the combination of 3 or more types of clinical tests it is possible to provide some evidence of shoulder dysfunction related with pain and incapacity (Michener et al., 2009). As literature is not conclusive about test reliability, even when using a controlled protocol, the clinical decision making based on this clinical tests produces a very weak diagnosis due to the lack of uniformity, validity and reliability (May et al., 2010).

RC tests are usually related with pain and ultrasound findings of RC injury (Boettcher et al., 2009; Cadogan et al., 2011; Castagna et al., 2008). Moreover, authors acknowledge that, so far, there are a few kinematic studies related with rehabilitation exercises, de Toledo et al. (2012) focused on the evaluation of post-surgery of shoulder patients, with total and reverse shoulder arthroplasty, related with different loads. Terrier et al. (2013) developed a numerical 3-dimensional model to reproduce the movement of the *scapula* and *humerus*, during 4 activities of daily living measured experimentally. Robert-Lachaine et al. (2015) concluded that *scapulothoracic* lateral rotation progressed more during arm elevation in static condition compared to dynamic ones and in passive compared to active movement, while *glenohumeral* elevation progressed more during arm elevation in active than passive movement. All these ideas concerning assessment are often based on a series of static positions, while clinicians perform either passive or active tests and exercises mostly in dynamic situations.

The current case study proposed to analyse the kinematic response of a single patient to the five RC tests. The aim of this study was to establish the pattern of muscle activation for the disability of the patient’s shoulder and understand the relationship between kinematic findings with pain and injury’s severity.

Methods

Study design and participant

One subject with RC injury was randomly selected from a set of 18 participants to evaluate muscle activation (EMG data) and kinematic parameters to biomechanically analyse Belly Press (BP), Drop arm (DA), Empty can (EC), Neer and Hawkins tests. This followed a previous clinical assessment using visual analogue pain scale (VAS_Pain), disability of arm, shoulder and hand scale (DASH) and ultrasound examinations to make the diagnosis.

The subject is a female patient, 60 years old, 61.80 kg body mass, 1.52 m height, 26.75 kg/m^2 BMI, right handed, with physiotherapy historic, pain for at least 24 months due to right rotator cuff injury. The right shoulder ultrasound exam showed a partial rupture of the *supraspinatus*, with 19 mm of extension, and tendinosis on the *supraspinatus* and *infraspinatus*. Calcification on the *supraspinatus* was also observed. The subject was assessed biomechanically during the muscular tests in both shoulders. The purpose of the study and the examination techniques were explained to the participant, who agreed to participate in the study by signing an informed consent form according to the Helsinki Declaration, Oviedo Convention and Portuguese data protection laws. This study was approved by the Ethics Committee of the Community Hospital.

For electromyographic measurements surface electrodes (Delsys Inc. Signal Conditioning Electrodes v2.3, USA) were used according to the SENIAM recommendations (www.seniam.org) for electromyography recording of the *biceps brachii, infraspinatus, upper trapezius*, and *lower trapezius*. The EMG sites were prepared with a razor to remove hair, an alcohol pad to clean the skin, and an abrasive pad to remove dead skin. The EMG signals were band pass filtered from 10 to 500 Hz and sampled at 2000 Hz, with a common-mode rejection ratio of >80 db. The simple voluntary isometric contraction (SVIC) for each muscle could not been performed for normalizing muscle activity during the Codman exercises, as Ellsworth et al. (2006) study showed that the constant pain produced a higher activation. The EMG data was collected in synchronization with the kinematic data collection.

Kinematic data collection and pre-processing

A twelve-camera 3D motion capture system (Qualisys AB, Sweden) was used to record upper limb movements with a sampling frequency of 200 Hz. An upper limb marker configuration was used, with a total of 14 markers, placed at the midpoint of the sternum (trunk); at the midpoint of the right shoulder (*acromion*); at the midpoint of the left shoulder (*acromion*); in right elbow (*medial epicondyle* and *lateral epicondyle*); on the left elbow (*medial epicondyle* and *lateral epicondyle*); on the right wrist (styloid process styloid process of the *ulna* and the *radius*); on the left wrist (styloid process styloid process of the ulna and the *radius*); on the NAT2 (spinal apophasis of the second thoracic) and on the EISD (right superior iliac spine) and one in EISE (left iliac spine top). The placement of the markers on subject is depicted by Figure 8.1.

Figure 8.1 – Reflective body marker setup

The digitized anatomical landmarks were then used to create 6 degrees-of-freedom segments on the *thorax*, *scapula* and *humerus* segments, with local coordinate systems (LCS) following the recommendations of the International Society of Biomechanics (ISB) (Wu et al., 2005). Qualisys Track Manager (Qualisys AB Gotenburg, Sweden) and Visual 3D (Standard v5.01.18, C-Motion, Inc) software was used in the analysis of motion data.

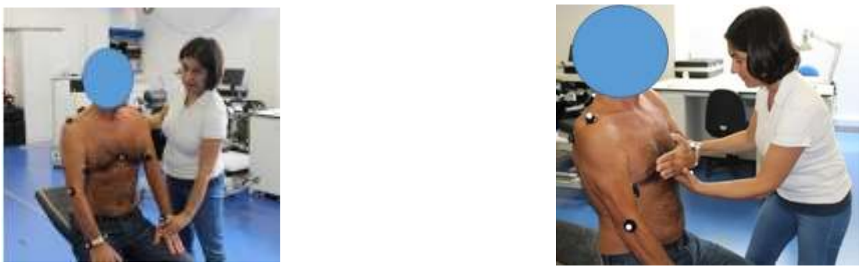
Testing protocols

During the experiment, as the example, the subject was sitting on a chair and was asked to perform five clinical tests for the muscles of the shoulder RC as described in the protocol of Sevinsky (s. d.) (Figure 8.2).

Belly press test: detects the rupture of the sub-scapular. The patient is sitting with his arm tested ahead of the abdomen. The examiner stabilizes the scapula while the patient holds the arm adducted next to the trunk. Apprehension, muscular blockage or pain localized to the anterior shoulder may indicate breakage and positive test. Drop-arm test (Codman's): diagnoses the rupture of the RC. With the patient sitting, the examiner fixes the patient's shoulder at 90° of abduction, asks the patient to slowly adduce. The test is positive if the patient is unable to lower the arm slowly performing the same range of motion or severe pain when start the test. Empty-can test (Jobe): designed to identify a tear in the supraspinatus tendon. The patient is either seated or standing. The patient's upper limbs are positioned horizontally at 30° anterior to the frontal plane, abducted to 90° and internally rotated (static position). The examiner applies a downward force on the patient's limbs. The test is positive if pain and weakness are present. Neer test (Full-can): identifies impingement of the supraspinatus tendon or long head of the biceps in the *coracoacromial* arch. While stabilizing the scapula, the examiner internally rotates the shoulder and brings the shoulder into flexion. Pain reproduced over the *coracoacromial* arch indicates a positive test. Hawkins test: diagnoses the impingement of the supraspinatus when the pain in the *coracoacromial* arch indicates positive impingement the examiner behind the patient's arm at 90° of flexion with the elbow flexed at 90°, then the arm is forced to internal rotation. Pain on the *coracoacromial* arch indicate a positive test.

Results

The subject had grade 9 on the VAS_Pain scale and 57.80 for the disability of arm, shoulder and hand scale (DASH). The studied variables were: Time spent in the test, Sequence of muscle activation, Time of EMG Peak and EMG Peak value. Time until peak EMG occurs per muscle (*biceps brachii, infraspinatus, upper trapezius,* and *lower trapezius*) between the starting movement and the EMG peak. This was normalized by the total time spent on each test execution and consequent sequence of activation during the tests execution. (see table 1). The EMG was simultaneously recorded on right and left muscles (*biceps brachii, infraspinatus, upper trapezius,* and *lower trapezius*). The sequence of activation was determined using the outputs of EMG and visual inspection of synchronised motion capture frames (Figure 8.3, Figure 8.4, Figure 8.5, Figure 8.6, Figure 8.7).



(1) Initial position (2) Belly press test

(3) Drop arm test (4) Empty can test

(5) Neer test (6) Hawkins test

Figure 8.2 – Tests data collection example, Initial position (1), Belly Press (2), Drop arm (3), Empty can (4), Neer (5) and Hawkins (6).

The table 2 showed the shoulder angles at the maximal activation moment and the angular velocity of the *humerus* motion at the maximal activation moment. Comparing angles, the right shoulder (the injured one) with de left shoulder presented important different values were found for the DA test at the internal rotation, with the right values between 00.0º and 4.4º and left values between 33.2º and 32.8º. Continuing the results analysis concerning Hawkins test for the right shoulder was higher values for abduction (right vs left: 5.3º vs 0.8º) and lower values for internal rotation (right vs left: 71.4º vs 82.1º) were found.

Finally, the Neer test showed special differences between flexion and abduction, the right shoulder presented higher values for flexion (104.0º) while comparing with left shoulder (93.6º), also, the right shoulder presented higher values for abduction (33.4º) comparing with left (7.2º). In addition, the different angle values between the activation moment of muscles (*biceps brachii, infraspinatus, upper trapezius,* and *lower trapezius*) showed an order pattern associated with the test movement. The velocity at the maximal activation moment showed negative values (degrees/seconds) for the maximal activation moments were no movement happened as the contraction was isometric. For the positive velocity values, the movement had isotonic or eccentric contraction, so the displacement happened. The values negative were between -34.8 º/s and 0.0 º/s and the values positive were between 0.0 º/s and 18.6 º/s.

Discussion

The aim of this study was to analyse the pattern of muscle activation at a patient's shoulder on the disability and to understand the relationship between kinematic findings with pain and injury's severity. The outcomes of the present study used *biceps brachii, infraspinatus, upper trapezius,* and *lower trapezius* to measure the EMG. Jensen e Westgaard (1995) studied during maximal isometric contractions, the EMG activity pattern of the *upper trapezius* of 18 healthy subjects.

Eight bipolar surface electrodes with 10 mm distance between adjacent electrode pairs were placed on a line from the clavicle to the scapula. At the region near the clavicle, the highest EMG amplitudes were recorded during 90° arm abduction. At the posterior parts, the highest amplitudes were found during both arm abduction and shoulder elevation. Through a double differential recording technique, which reduced the EMG cross-talk contribution supported the finding that the upper trapezius had different activations when the arm posture was changing. In this study, upper trapezius activation was always equal on the injured upper limb, even when the test was in opposite upper limb, suggesting a permanent activation.

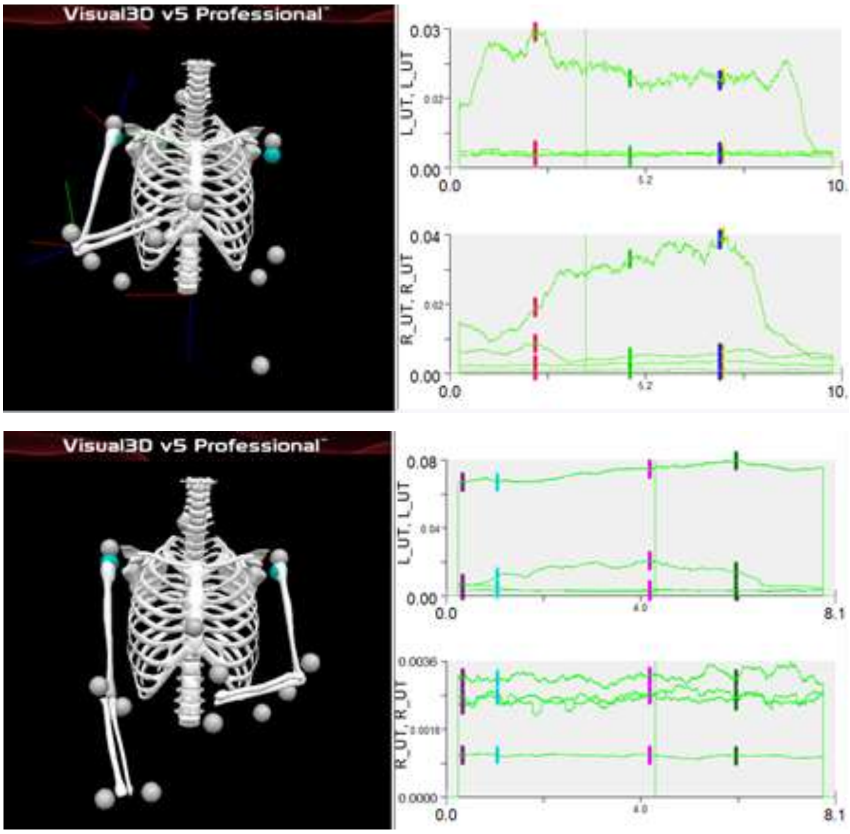


Figure 8.3 – EMG outputs of Belly Press test right and left upper limb on Visual3D.

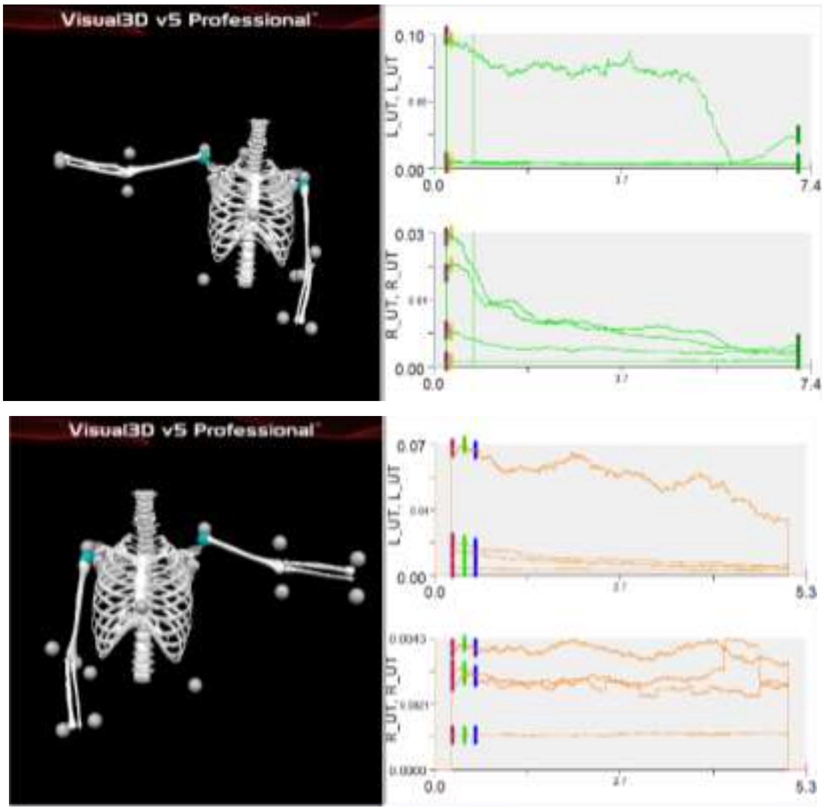


Figure 8.4 – EMG outputs of Drop Arm test right and left upper limb on Visual3D.

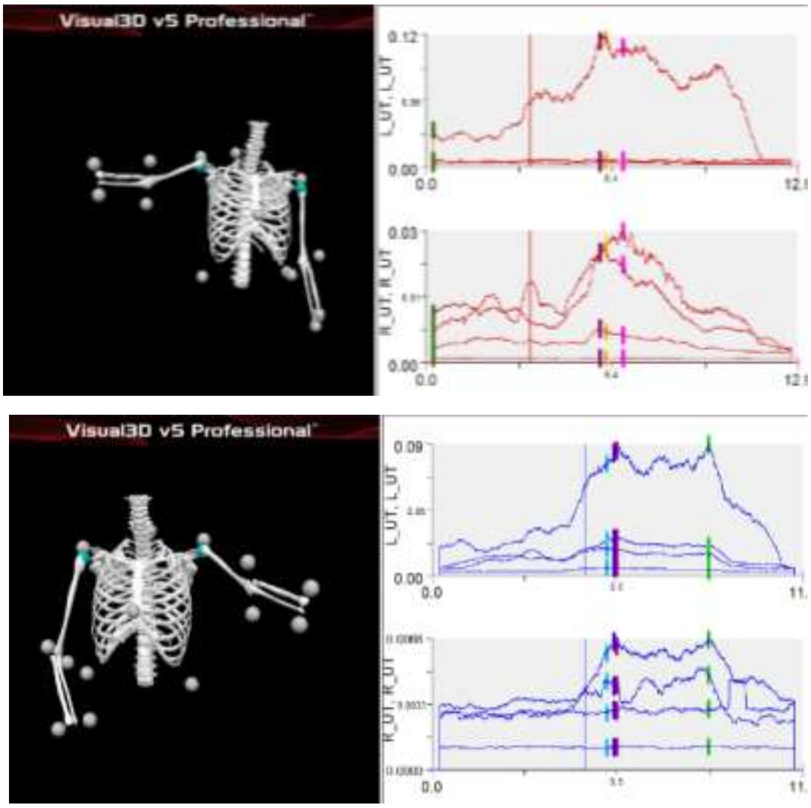


Figure 8.5 – EMG outputs of Empty Can test right and left upper limb on Visual3D.

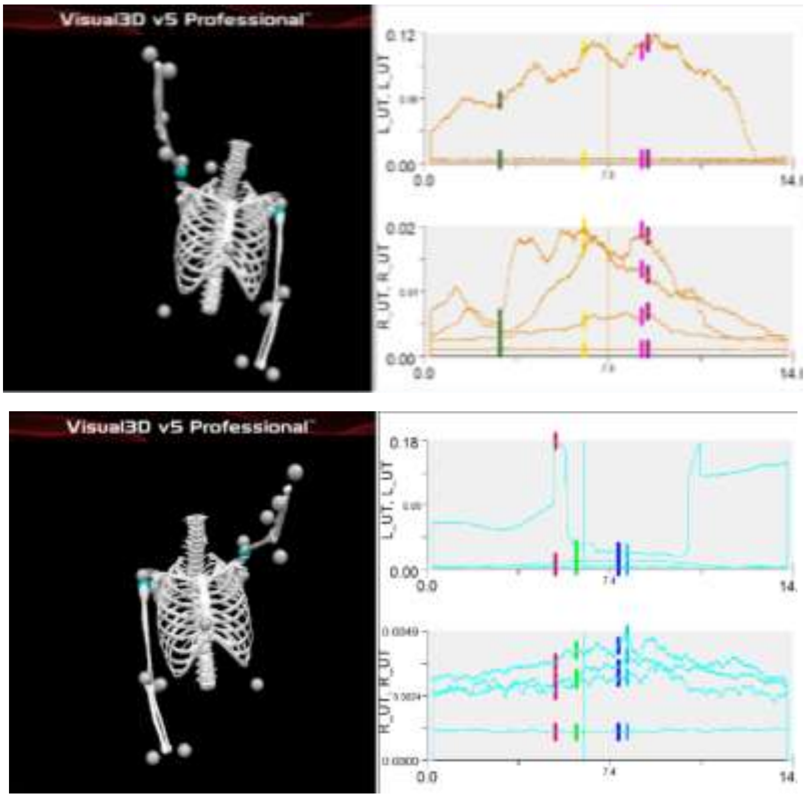


Figure 8.6 – EMG outputs of Neer test right and left upper limb on Visual3D.

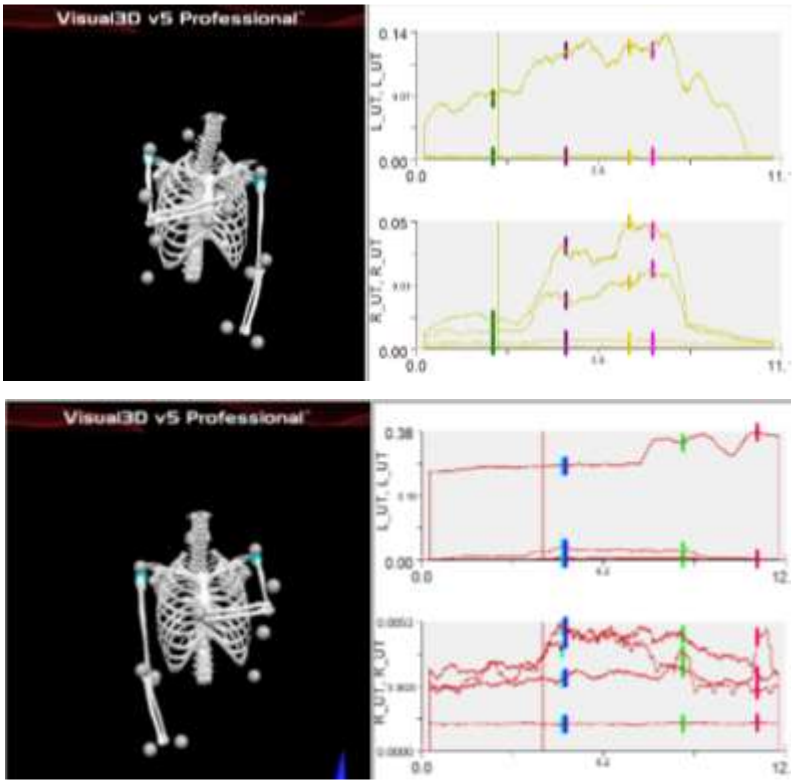


Figure 8.7 – EMG outputs of Hawkins test right and left upper limb on Visual3D

Table 8.1 – EMG results of the RC test.

Rotator cuff Tests	Total test time (s)	Time between start movement and the Peak EMG (s)				Activation sequence (n)				EMG Peak (V)							
		BB	IE	LT	UT	BB	IE	LT	UT	BB_R	IE_R	LT_R	UT_R	BB_L	IE_L	LT_L	UT_L
Bellypress_R	10.50	0.69	**0.22**	0.69	0.46	3	1	3	2	**0.041**	0.007	0.004	**0.001**	0.003	0.004	0.003	**0.021**
DropArm_R	7.44	**0.05**	**0.05**	**0.05**	0.97	1	1	1	2	**0.026**	**0.020**	0.007	**0.001**	0.003	0.005	0.005	**0.025**
Emptycan_R	12.90	0.53	0.48	0.47	**0.02**	4	3	2	1	**0.029**	**0.023**	0.008	**0.001**	0.007	0.005	0.004	**0.032**
Neer_R	14.00	0.59	0.43	0.61	**0.21**	3	2	4	1	**0.025**	**0.019**	0.007	**0.001**	**0.019**	0.003	0.004	**0.059**
Hawkins_R	11.10	0.65	0.59	0.41	**0.21**	4	3	2	1	**0.032**	**0.051**	0.004	**0.001**	0.003	0.004	0.004	**0.068**
Bellypress_L	8.06	0.52	0.75	0.13	**0.04**	3	4	2	1	0.003	0.003	0.003	**0.001**	0.012	**0.076**	0.003	0.007
DropArm_L	5.34	**0.05**	**0.05**	0.11	0.08	1	1	2	3	0.003	**0.014**	0.003	**0.001**	**0.014**	**0.019**	0.004	**0.072**
Emptycan_L	11.10	**0.47**	0.50	0.49	0.75	1	3	2	4	0.003	0.006	0.004	**0.001**	**0.020**	**0.027**	0.006	**0.094**
Neer_L	14.80	0.59	0.46	0.50	**0.02**	4	2	3	1	0.004	0.004	0.003	**0.001**	**0.014**	**0.180**	0.005	0.004
Hawkins_L	12.50	**0.39**	0.92	0.40	0.72	1	4	2	3	0.003	0.003	0.005	**0.001**	**0.040**	**0.382**	0.007	0.008

BB-*biceps brachii*; IE-*infraspinatus*; UT-*upper trapezius*; LT-*lower trapezius*; R-right; L-left

Table 8.2 – Kinematic results of the RC test

			Angle at the maximal activation moment				Velocity at the maximal activation moment			
			BB	IE	LT	UT	BB	IE	LT	UT
Belly press test Right upper	shoulder	Flexion (+)/Extention(-)	12.7	12.4	12.7	12.5	-0.9	3.3	-0.3	-0.1
		Aduction (+)/Abduction(-)	-14.7	-9.3	-14.7	-13.2	0.6	0.0	-0.2	-2.7
		Internal rotation (+)/External rotation(-)	75.3	60.1	75.2	69.8	1.7	18.6	1.4	3.5
Belly press test Left upper	shoulder	Flexion (+)/Extention(-)	10.6	10.1	16.3	10.3	-2.2	-0.8	-4.5	6.8
		Aduction (+)/Abduction(-)	-6.5	-7.4	1.0	3.4	-1.4	-1.5	-5.8	3.2
		Internal rotation (+)/External rotation(-)	73.6	74.1	62.0	75.9	3.3	1.3	3.8	-34.8
Drop arm test Right upper	shoulder	Flexion (+)/Extention(-)	13.4	13.4	14.0	0.0	2.8	2.8	1.2	0.0
		Aduction (+)/Abduction(-)	-62.7	-62.7	-62.6	0.0	-0.1	-0.1	-0.4	0.0
		Internal rotation (+)/External rotation(-)	3.4	3.4	4.4	0.0	-4.3	-4.3	-5.8	0.0
Drop arm test Left upper	shoulder	Flexion (+)/Extention(-)	34.2	34.2	33.3	34.1	-0.7	-0.7	-2.6	-1.0
		Aduction (+)/Abduction(-)	-54.0	-54.0	-53.0	-53.8	0.2	0.2	8.4	2.1
		Internal rotation (+)/External rotation(-)	33.2	33.2	32.8	33.4	1.4	1.4	0.3	0.8
Empty can test Right upper	shoulder	Flexion (+)/Extention(-)	38.1	39.3	38.6	17.7	0.9	4.8	-8.7	27.3
		Aduction (+)/Abduction(-)	-37.6	-38.5	-38.7	-1.7	3.5	0.5	-3.4	-8.3
		Internal rotation (+)/External rotation(-)	48.9	49.6	48.7	57.1	-1.5	3.5	6.2	-12.9
Empty can test Left upper	shoulder	Flexion (+)/Extention(-)	44.7	45.1	44.8	44.0	-3.1	3.8	2.2	2.0
		Aduction (+)/Abduction(-)	-29.8	-29.4	-29.6	-27.5	0.7	2.2	-0.1	-1.1
		Internal rotation (+)/External rotation(-)	74.0	74.3	74.4	73.0	-1.2	-0.5	4.4	0.8
Hawkins test Right upper	shoulder	Flexion (+)/Extention(-)	44.9	45.7	47.2	49.5	0.0	-2.3	-1.0	-3.1
		Aduction (+)/Abduction(-)	-5.9	-5.7	-5.5	-5.3	0.2	-2.1	3.2	4.4
		Internal rotation (+)/External rotation(-)	58.7	58.2	57.4	71.4	-1.4	2.2	-0.8	0.0
Hawkins test Left upper limb	shoulder	Flexion (+)/Extention(-)	51.9	11.0	51.8	49.5	2.7	-10.4	-2.1	0.2
		Aduction (+)/Abduction(-)	1.3	3.1	1.2	0.8	6.4	2.0	12.6	0.1
		Internal rotation (+)/External rotation(-)	71.2	82.1	70.1	70.3	-6.3	-5.5	-8.4	-0.1
Neer test Right upper limb	shoulder	Flexion (+)/Extention(-)	97.4	104.0	104.0	95.3	7.8	5.0	5.0	-15.1
		Aduction (+)/Abduction(-)	-31.6	-33.4	-33.4	-30.7	-1.5	2.6	2.9	5.4
		Internal rotation (+)/External rotation(-)	72.9	72.8	72.8	72.6	-3.4	-1.3	-1.2	8.0
Neer test Left upper limb	shoulder	Flexion (+)/Extention(-)	93.6	73.2	93.0	83.6	0.0	13.9	5.3	9.1
		Aduction (+)/Abduction(-)	-7.1	-2.0	-7.2	-5.6	0.2	7.6	1.3	-2.2
		Internal rotation (+)/External rotation(-)	86.8	90.6	86.8	86.5	1.1	-5.7	-0.1	-3.9

BB-biceps brachii; IE-infraspinatus; UT-upper trapezius; LT-lower trapezius; R-right; L-left

Falla (2004) studied the complexity of muscle impairment in chronic neck pain, and identified deficits in the motor control of the deep and superficial cervical flexor muscles in people with chronic neck pain. This was characterized by a delay in onset of neck muscle contraction associated with movement of the upper limb. Further Falla et al. (2004) compared activation patterns of neck muscle, during and after a repetitive upper limb task between patients with neck pain caused by whiplash, idiopathic and a healthy control group.

The greatest EMG amplitude was seen in the *sternocleidomastoid, anterior scalenes*, and *left upper trapezius* muscles for the whiplash-associated disorders group, followed by the idiopathic group, with lowest EMG amplitude recorded for the control group. An opposite effect appeared for the right upper trapezius muscle. The level of perceived disability (Neck Disability Index score) had a significant effect on the EMG amplitude recorded between neck pain patients. Our clinical case had symptoms for the neck muscles, and the associated contracture of upper trapezius.

Boettcher et al. (2009) studied the EC and Ne, their findings showed that during the EC and Ne muscle tests nine and eight other shoulder muscles, correspondingly, were as highly activated as the *supraspinatus*, up to levels approximately 90%. This included other rotator cuff muscles (*infraspinatus* and *upper subscapularis*), scapular positioning muscles (*upper, middle* and lower *trapezius*, and *serratus* anterior), and abduction torque producing muscles (anterior and middle *deltoid*) were activated to similarly high levels. Furthermore, *supraspinatus* and *posterior deltoid* were activated to equally high levels in the EC test. As would be normal, for both EC and Neer tests the main movers for adduction (*pectoralis major* and *latissimus dorsi*) were only recruited at low levels between18 – 39% maximal voluntary contraction (MVC).

The rigorous normalization procedures and statistical analysis used in this study allowed to conclude that the EC and Neer tests do not selectively activate *supraspinatus*. Additionally, this study has confirmed that the EC test activates the anterior rotator cuff (*subscapularis*) and another scapular positioning muscle (*trapezius*) to levels greater than 70% MVC, and except for *posterior deltoid*, the EC and Ne test equally activate all muscles tested. Therefore, EC and Neer tests do not satisfy the stated criteria to be valid diagnostic tools for *supraspinatus* pathology, i.e. the EC and Neer tests do not primarily activate *supraspinatus* with 15 minimal activations from other shoulder muscles (Boettcher et al., 2009). In the current study cannot compare % of MVC because our patient is unable to be assessed, because of pain.

Kai et al. (2015) findings firstly showed there was more infraspinatus activation in the sagittal plane compared to the scapular plane, secondly confirmed the relatively increased infraspinatus activity in the sagittal plane compared with the scapular or coronal planes. The measurements were limited to an external load level of 3 kg, which is equivalent to 10-20% of the maximum muscle strength. The neighbouring shoulder muscles comparatively were activated when the external resistance more than half of the maximum strength is applied and compared with the rotator cuff muscles. They considered that the external load of 3 kg was the most appropriate for evaluating rotator cuff muscle activity. With our patient we cannot assessed this relation, because the load is manual and examiner load is not quantified.

For measurement position, Kai et al. (2015) was limited to 45º and 90º of arm elevation, because the *supraspinatus* elevation arm increased with the arm at the side (0º position). They had limitations, because did not confirm whether the tests were performed during the isometric movement and did not analyse the *teres minor* in the rotator cuff. However, their findings, demonstrated that the rotator cuff muscles perform different activities according to the EC and Neer tests positions and the plane of elevation. For the *supraspinatus* and *lower/upper subscapularis*, the muscle activities were influenced by the EC position and the elevation plane; although for the *infraspinatus*, the activities were associated exclusively with the elevation plane. Suggesting that the rotator cuff muscles are influenced by arm position and the elevation plane during the EC and Neer tests.

Based on Proprioceptive Neuro Facilitation’s principles, irradiation is a useful aspect for patients with muscle weakness in areas that cannot be directly stimulated (strengthened). This principle is based on the fact that stimulation of strong and preserved muscle groups produces strong activation of injured and weak muscles, facilitating muscle contraction (Kofotolis et al., 2005).

These weak muscles can develop an increase by the synergistic muscle inhibition response to stimulation. Carroll et al. (2006) findings showed the most significant effects of training and strengthening were seen in contralateral limb muscles. This explained our findings in the contralateral muscles, e.g. the *upper trapezius* left when we examined the injured upper limb (peak EMG between 0.021 V and 0.068 V). For the recruitment order, our findings in four muscles, with a specific role on the *scapula thoracic* stabilization, like upper and lower *trapezius*, and on the upper limb functional reach and elevation, as *biceps brachii* and *infraspinatus*, provide a simple analysis to understand the main role of the synergic muscles. Table 1 shows how all tests on right upper limb caused the activation of left upper *trapezius*, suggesting the irradiation based on the PNF's principles.

The report case pointed out important findings, we can see on the right BP test, in a resisted movement, had the bigger peak EMG on the biceps brachii at the end of the recruitment of activation order. The first muscle was the *infraspinatus*, which had a lower activation; at the end of the test, *biceps brachii* had stronger activation with the lower *trapezius* apparently at same time and same side. For the BP left the recruitment pattern starts with the upper *trapezius* and ends with the *infraspinatus*. This suggests that pain symptom occurs in the right, confirming the positive test.

For the right DA test, as an eccentric movement, all three muscles (*biceps brachii, infraspinatus* and *lower trapezius*) worked at the same time and with higher EMG peak for the *biceps brachii* (0.026 V). The contralateral muscles had a higher EMG peak at the *upper trapezius* (0.025 V), suggesting that was working to stabilize the *scapula*. On the left DA test the more active are also the *biceps brachii* and *infraspinatus*, the opposite recruitment right *infraspinatus* (0.014 V) suggesting irradiation activity. The recruitment order was similar for both tests.

The right EC test is a resisted test where the highest EMG peak is *biceps brachii* (0.029 V) followed for *infraspinatus* (0.023 V). On the contralateral muscles, a larger EMG peak occurs at the *upper trapezius* (0.032 V). The recruitment order on the right EC test started with the trunk muscles and ended with the *biceps brachii*, the contralateral test activation pattern is the opposite, starts with the *biceps brachii* and ends with the *upper trapezius*, which reinforces the assumption that patients avoid the periarticular muscles because of pain on the right upper limb.

The right Neer test activated the same muscles as left Neer test. For right the larger EMG peak is on *biceps brachii* (0.025 V) followed by *infraspinatus*, and in the contralateral muscles, the EMG peak occurs in the *biceps brachii*. The left side showed the EMG peak in the *infraspinatus* followed by *biceps brachii* and nothing occurs at the contralateral muscles. For the recruitment order, both sides started with *upper trapezius.* The higher EMG peak of *biceps brachii* (0.025 V) for the right upper limb are related with braking of the movement due to pain.

Finally, the right Hawkins test showed the highest EMG peak from the *infraspinatus* muscle, followed by the *biceps brachii* with a contralateral highest activation of the *upper trapezius*. The recruitment order at the right Hawkins test ends with the *biceps brachii*; the left Hawkins test ends with the *infraspinatus*. However right *infraspinatus* (0.051 V) had the biggest EMG peak of all. As a passive test, this suggests that the *infraspinatus* recruitment is to avoid the impingement with painful symptoms.

The kinematic analysis suggests the angle at maximal activation of each muscle, are in synchrony with the EMG and compatible with the health condition of the s. As the first biomechanical approach for this health condition through these measurements, the discussion of the results were limited. However, the EMG pattern suggested to be related with the kinematic pattern. Looking for the expected combined movements, the lower internal rotation and the higher abduction for right Drop arm test is compatible with the EMG, where the injured shoulder was with adaptation to support the test.

In summary, the case showed important findings on EMG and kinematic analysis. Firstly, the right *upper trapezius* had always the same EMG peak, suggesting a continuous contraction to protect disability. The higher EMG peak was at the *biceps brachii*, except for the Hawkins test where was the *infraspinatus*. Interesting was the activation of the left *upper trapezius* in all tests, which suggests that the pain symptom occurs in the right, confirming the positive test. Secondly, the left side tests had the higher EMG peak on the *infraspinatus* (for BP, Neer and Hawkins) and *upper trapezius* (DA and EC) suggesting the natural muscle co-activation for the tested movements. Thirdly, the higher abduction and lower flexion or internal rotation suggests to be an adaptation for pain relieve.

Limitations of the case study

Despite the interesting findings reported in this clinical case, we must acknowledge some limitations. The uniqueness of the data usually means that it cannot be replicated. There are concerns about the reliability, validity and generalizability of the results. Another limitation of the current study is the lack of investigation of the deeper muscles; however, these muscles are difficult to assess with surface EMG during these varied dynamic tasks.

Conclusion

The *upper trapezius* was always less active than the *infraspinatus*, which was consistent with the evidence and the studied reports. Especially interesting was the finding related to moderate activity in tested *biceps brachii*, which may have compensated for the relatively low activity found in opposite *subscapularis* during the resistance tests. The higher abduction angle at the maximal activation moment could be related with less internal rotation as an adaptation to pain relieve. These findings should inspire further studies to better understand motor control in RC injury patients with a large sample.

Conflicts of interest statement

The authors declare no conflict of interest.

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CHAPTER IX

GENERAL DISCUSSION

Rotator cuff injury is one of the most disabling problems of the shoulder complex, causing functional impairments, especially in the elderly (Downie & Miller, 2012). Over the last 30 years, clinicians have developed rehabilitation strategies for this injury and studied patient outcomes, however without reaching consensus (Pegreffi et al., 2011). In addition, effective health promotion has led to increased exercise by healthy aging persons (Alikhajeh et al., 2012; Avelar et al., 2018). On other hand, Aquatic therapy (AT) exercise is an increasingly popular option, enabling inactive subjects to return to an active lifestyle (Kang et al., 2007). Despite being progressively prescribed, however, therapists have limited knowledge about this therapeutic solution and patient responsiveness (Bartels et al., 2016).

Unfortunately, the available studies have used a variety of rehabilitation protocols, times of assessment, samples and outcome measurements (Maria et al., 2018). It is imperative to know more about the quality of motion in water, which is particularly relevant in deep-water therapeutic exercises, where the feet do not have solid support on the pool floor and a pool noodle or buoyancy belt are used to support the patient. The immediate effects of AT also remain unclear. For example, what precautions are needed for first time users, can we expect quick results, which factors stimulate to continue? The effects of training and detraining of this special population are not known, nor their expectations or levels of satisfaction. This thesis analysed the outcomes of AT strategies for treating painful shoulders in older adults using biomechanical methods.

The main findings of this thesis were: (i) the literature does not provide a strong conclusion regarding of the effects of AT due to the high heterogeneity of rehabilitation protocols, times of assessment, samples included and outcome measurements used within the available studies on AT for rotator cuff injury; (ii) there are differences in the kinematic parameters associated with different buoyancy conditions, and we suggest using the buoyancy belt for horizontal shoulder extension, as a device promoting better alignment and movement contralateral symmetry; (iii) the smoothness coefficient and the angular velocity output means that horizontal shoulder extension is performed with the best quality of motion when using the buoyancy belt and for shoulder abduction the pool noodle was the better solution; (iv) the ROM asymmetry in the underwater phase, and the moderate peak velocity, with a better smoothness coefficient in the transitory phase, suggests that the pool noodle is the best buoyancy device for shoulder abduction when performed in dual-media conditions; (v) the highlighted differences in smoothness coefficient in the transitory phase for the pool noodle suggests that it is the best device, resulting in minimum impact during shoulder abduction; (vi) the correlation between DASH and FPS with BMI, HPB, the use of more than four medications and a fear of falls may be predictive factors for greater difficulties with water adaptation and successful interventions, looking the expectations for older adults with upper limb dysfunction, the greatest are promoting wellbeing and relaxation; (vii) the immediate changes following AT program observed in this sample did not clarify the importance of patients with upper limb dysfunction repeating AT annually; the immediate improvement was no significant differences; (viii) the comparison of the effects of detraining and training using the AT program for older adults with upper limb disability confirms that older adults with upper limb disability had a positive effect of AT intervention, so they need to maintain their AT program for continue success; (ix) the detraining effects suggest that these community programs have an important impact on activities of daily life and the safety of older adults with upper limb disability; (x) the rotator cuff injury, had a *supraspinatus* of the injured side always less active than *infraspinatus*, which was consistent with the evidence and studied reports; (xi) the findings related with the *biceps brachialis* activity and the angle at the maximal activation moment suggest adaptations for pain relieve.

Shoulder injury is one of the most common dysfunctions to result in disability in daily activities, especially in the older population. Symptoms such as pain, limitations to limb elevation, and muscle weakness are consistent with rotator cuff injury. Due to senescent aging, the degeneration of rotator cuff tendons may be asymptomatic, and a single event may trigger symptomatology and functional disability. When we look for AT evidence for painful shoulder, we find in post-surgery rehabilitation, unfortunately, there is no strong evidence due the lack of replicability in protocols, samples, measurements and outcomes (**Chapter 2**).

We found three studies involving rotor cuff injuries, but they were all-different and were not comparable as regards procedures, however results suggested good outcomes for pain, strength and functionality. Hultenheim-Klintberg et al. (2009) studied 14 subjects with rotator cuff injuries, post-surgery, assigned randomly into two groups to compare traditional with combined intervention, and after two years of follow-up the combined intervention group demonstrated differences ($\infty = p < 0.05$) in pain, functionality, sleep and satisfaction with health. Brady et al. (2008) used a feasibility study to compare an additional AT program with a traditional protocol, and after a 12 week follow-up, found no differences between the groups. The intervention did not include any follow-up, however, making it impossible to determine whether the rehabilitation effects lasted during the following months. The case study by Burmaster et al. (2016) showed improvements in levels of functionality with minimal detectable changes, and minimal clinical differences in the pain levels, on an eight week follow-up. Only the pain outcomes used the same measure. All these issues can lead to bias within studies and provide low internal quality. As no dry land program seem to be better than any other, studies with combined AT programs should be emphasised, as they may relieve symptoms more effectively.

Scapular stability (without pain) is an important goal following rotator cuff injury, in order to perform reaching movements in a special task. Reaching tasks have been studied in persons with shoulder impingement syndrome. Castillo-Lozano et al. (2014) found that the *pectoralis* and *latissimus dorsalis* muscles showed higher activity during abduction and scapular plane elevation (scaption) in water, indicating a greater stabilisation function in this environment. The lack of literature on the use of aided buoyancy conditions to support particular body movements, for example, to achieve more activity of the trunk or upper limbs, justifies our study in deep-water (**Chapter 3**).

Was studied the horizontal extension and abduction of the shoulder with dominant and non-dominant upper limb movements, and compared the stability to the ROM and angular velocity symmetry. For the horizontal extension of the shoulder, the angular velocity was higher with the buoyancy belt than the pool noodle or with no aided buoyancy, suggesting that the greater angular velocity with a higher maximum angle gave more stability. When we compared the conditions of upper limbs dominance for each type of aided buoyancy, the results suggested differences in ROM with the pool noodle, which suggests instability for making this task.

Our results showed no differences for angular velocity and smoothness coefficient, which suggests that the participants had good motor control during the task, meaning that they were healthy. On abduction of shoulder on the buoyancy belt, for ROM and angular velocity with the non-dominant upper limb, results pointed out differences suggesting instability for the task. Further, the comparison between dominant and non-dominant upper limb showed differences between no aided buoyancy and the buoyancy belt. This suggests the pool noodle is more stable for this specific task. There were also differences found for the non-dominant upper limb for each type of aided buoyancy.

These findings should be understood as an important contribution to decision making regarding clinical intervention in dual-media. The choice of the buoyancy condition and the kind of floating device are determinant steps for achievement of the main goal of AT interventions. Nevertheless, more information is needed to validate treatment strategies for better rehabilitation or better health promotion in prevention programs. Specifically kinematic analyses can offer a better understanding of the patterns of daily life activities and functional recovery for upper limb impairment such as rotator cuff injury (Dunn et al., 2008; Vidt et al., 2016).

In **Chapter 4** we studied the case for a shoulder abduction movement performed initially underwater and, then, above the water. Underwater movements are constrained by hydrodynamic drag resistive force, and those above water are not (aerodynamic drag is negligible because of the low speed of movement above water). This movement is characterised by changes in velocity and smoothness due to dual-media changes, with intermittencies and instability occurring during the transitory phase. We used the spectral arc-length metric (smoothness coefficient) for this challenge, which seems to be a very suitable measure with which to assess motor recovery in neurological diseases, and motor learning in unhealthy people (Balasubramanian et al., 2012).

This measure is independent of temporal scaling and retains good sensitivity and reliability. Researchers analyse third fingertip kinematics to study smoothness (Balasubramanian et al., 2015; Hogan & Sternad, 2009) in global indicators of integer sensorimotor capacity, similar to a wide range of real-world activities in dryland activities, such as reaching for an object. The smoothness coefficient can be used for dryland as well as for underwater or dual-media movements to understand the quality of deep-water exercise.

Five points were determined, to define the dual-media phases, using a graph of linear velocity magnitude values over time. P1 is the starting point, P2 the point where the trajectory becomes instable, P3 the point of change – the surface – P4 is the highest point of velocity and, finally, P5 is the end of the movement, and so the velocity is low (Figure 3). We then characterised the movement, using the velocity information, in dual-media through four distinct phases: i) the first under-water phase (Uw Ph 1); ii) the second under-water phase (Uw Ph 2); iii) the first above-water phase (Aw Ph 1), and iv) the second above-water phase (Aw Ph 2). Finally, we determined the transitory phase based on the transitory point (P3), including the Uw Ph 2 and Aw Ph 1, where the shoulder abduction was between the two medium points. Considering the observed symmetry and lack of differences in the smoothness coefficient by repeated measures comparison, the results suggest a healthy sample, without any apparent dysfunction of shoulder motor control. This suggests that the approach used may discriminate between compromised and healthy limbs, or subjects. It seems reasonable that the current study results can only be considered comparable when analogous measuring methods are used, especially with respect to positioning and the environment in which the subject makes the movement (Mayer et al., 2001).

The smoothness coefficient is an important marker of movement analysis for a clinician/therapist who is planning and evaluating recovery on land. More studies are needed for AT. In addition to ROM asymmetry in the under-water phase, the moderate peak velocity, with a better smoothness coefficient in the transitory phase, suggests that the pool noodle can be the best buoyancy device with which to make this movement in dual-media. More evidence is needed about the relationship between healthy patients and those with painful shoulders.

Fortunately, effective health promotion is leading to increased exercise in healthy aging persons (Alikhajeh et al., 2012; Avelar et al., 2018) . AT exercise is an increasingly popular option (**Appendix C**), enabling inactive subjects and those with lower self-esteem (**Appendix D**) to return to an active lifestyle (Kang et al., 2007). Despite being progressively prescribed, however, therapists have limited knowledge about this therapeutic solution and patient responsiveness (Bartels et al., 2016). To evaluate practice and collect clinical evidence, researchers developed a functional perception scale (FPS) based on the ICF (**Appendix A**) for initial assessment in the older adult users (55 years and older) of group AT programs. The ICF is a worldwide tool for functional assessment and characterisation (Dibble et al., 2009). We therefore also studied (**Chapter 5**) the health problems and expectations of patients with disability of arm, shoulder and hand to understand the association between disability and perception of functionality (Beaton et al., 2001). Those dimensions seem to have an impact on adaptation to, and performance in, AT. The following common health problems were present in the sample: type 2 diabetes mellitus (DM2) - 19.40% -, high blood pressure (HBP) - 46.30% -, osteoarthritis (OA) - 57.40% - and high cholesterol (HC) - 6.20%. Only 13.9% had previous experience in a designated therapy pool and only 32.4% knew how to swim. Nearly 50% of participants took more than four medications daily, 50% had fallen during the previous year and 62% were afraid of falling. There were high expectations that participation in AT programs would increase their performance in activities of daily living (ADL) (81.5%), their well-being (8.6%) and relaxation (72.2%), and decrease pain (88.0%). Only

39.8% took part expecting to decrease their fall risk, and 44.0% expected to become stronger. These individuals were taking part in a group program in public pools led by physiotherapists rather than in sessions in a therapy pool. Despite this, they were positive about the program recommendations (Probably/Certainly 76.15% - 23.85%). The Spearman correlation used to understand the association between variables indicated a high association between DASH and FPS (0.708). This reinforces the idea that upper limb disability is related to motor control performance; our sample scores were lower in both scales, showing functional impairment. Health problems such as BMI, HBP and the use of more than four medications showed a strong association with DASH and FPS, indicating that this is a predictive factor for water adaptation. The fear of falls showed a stronger association with DASH and FPS (0.512 and 0.543), with a significant effect predicted for successful water intervention. This all suggests the importance of using DASH and FPS to evaluate patients, as well as their health problems, and the expectations questionnaire to identify problems in community-dwelling older adults, and thus provide adequate water adaptation to obtain real benefits and successful AT intervention.

Following the efficacy on AT, we need answers to questions such as: what are the precautions needed for first time users, or can we expect quick results, or what stimuli to continue? The aim of our exploratory study (**Chapter 6**) was thus to measure the immediate effects of a single session of AT as regards the balance, strength and functional reach of persons with chronic osteoarthritis, older than 55 years of age. A quasi-experimental trial was carried out. Participants were recruited from the hospital after ethical approval. An expert physiotherapist performed the aquatic therapeutic session (**Appendix B**). Another physiotherapist performed the lower limb strength measurements, dynamic balance and static balance tests, before and immediately after intervention (not more than 2 minutes from completion). The control group without AT intervention agreed to take part in the functional tests before and after 45 minutes of a rest period in a chair. The Intervention Group (n = 12) included those previously involved in an AT program and the remainder were included in the Control Group (n = 10). The Visual Analogic Scale for Pain (VAS_Pain), step test

(ST), functional reach rest (FRT) and the Global Balance Standing Test (GBST) were used as outcome measures. The results for the Intervention Group showed for the step test around seven steps before vs. after (7.0 ± 2.0 vs. 7.4 ± 1.8); these results suggests poor balance when standing one foot on the intervention group. The control group had better baseline results around 11 steps, before vs. after, 11.2 ± 3.1 vs.11.8 ± 3.3, and almost no changes between measurements.

Studies suggest that values between 25.5 and 28.9 cm in the functional reach test provide a reasonable standard for interpreting FRT performance in community-dwelling older adults (Bohannon et al., 2017; Duncan et al., 1990). Was observed that the Interventional Group results, before vs. after, 9.1 ± 2.8 vs.10.4 ± 3.8, were under the level required for stability and the capacity to protect from a lack of balance, compared to the control group, which had better scores, suggesting better balance control.

The current study results suggest that this population with fragile health conditions (11 vs. 1) and osteoarthritis (10 vs. 2) needs to be active in AT, where their performance shows a decrease in pain, and satisfaction with the developed program. They suggest that AT appears to help more when the activity is more dynamic, and perhaps when the starting point is lower. Importantly there were no adverse effects from an AT session. It is already known that AT has positive impacts on knee cartilage in women with mild knee osteoarthritis, shown by progressively increased resistance in a four month AT program; the randomised study showed positive impacts on the biochemical properties of knee cartilage and a strong cardiorespiratory effect for this kind of patient (Munukka et al., 2016). The same biomechanical studies of patients submitted to AT programs provided evidence of the effects when recovering from surgery or neurological diseases (Brady et al., 2008; Castillo-Lozano et al., 2014; Rodrigues de Paula et al., 2006).

It is also possible to find references to increased fall prevention through aquatic therapy, empowering balance, strength and mobility in elderly people (Cadore et al., 2013; Clemson et al., 2012). A longitudinal study with two different groups, the complete follow-up group was evaluated at three different time points: M1 – at the end of the therapeutic season (July); M2 – at the beginning of the next season (October); and M3 – 6 weeks after the second collection

(November). And the partial follow-up group was evaluated at phases M2 and M3. Three blind evaluators, who were not aware of the AT session structure, conducted the evaluation procedures. The AT session (**Appendix B**) was performed by the same physiotherapist with expertise in AT. The purpose of the study was to analyse the effect of training and detraining in older adults with upper limb disability. Two groups were studied to enable two questions to be answered simultaneously: i) are the deleterious effects of detraining perceptible and relevant for functionality and well-being? and ii) is the training effective?

The groups showed no differences ($p > 0.05$) regarding age, gender, weight, height, health conditions or osteoarthritis status. In the complete follow-up group, an analysis of detraining effects between M1 (end of annual intervention) and M2 (start of annual intervention) showed a correlation ($p<0.05$) between the ST with 95% IC and t[11] = 1.11. Between subject sphericity showed differences with $F_{11.1} = 14.75$ for the FRT. The training effects between M2 (start of annual intervention) and M3 (after six weeks of training) were studied separately for the complete follow-up group and the partial follow-up group. The correlation with 95% IC showed differences ($p<0.05$) for the complete follow-up group in ST with t[11] = 1.33, and GBST with t[11] = -3.32. For the sphericity between subjects, FRT and GBST showed differences, the latter for both groups. The current study of detraining effects suggested the negative impact of a lack of balance strategies and an increase in pain, as previously demonstrated by Bocalini et al. (2010) and Tomas-Carus et al. (2007).

Evidence confirms the negative impact of a lack of training on fitness and quality of life. Detraining has an impact, even during the summer break in order to have family time, which suggests that detraining always has a negative impact on pain, muscle response and sensorial adaptation for older adults. Deeper analysis of the clinically different outcomes should answered the question about the effectiveness of training. Lee et al. (2003) performed a study of the minimal clinically important difference (MCID) for pain, and found that 30 mm is a clinically important difference in pain severity that corresponds to patient perceptions of adequate pain control. The current study had no MCID for VAS pain.

The most disabling issue causing the functional impairment of the shoulder complex during ambulatory rehabilitation, especially in aging people, is rotator cuff (RC) injury (Murrell & Walton, 2001). Shoulder tests have been frequently used based on a clinical reasoning of anatomy and physiology, but their poor reliability and accuracy prompted clinicians to turn to ultrasound examination (Barratt, 2009; Castoldi et al., 2009; Dunn et al., 2014). As the literature is not conclusive about test reliability, even when using a controlled protocol, a clinical decision based on these clinical tests produces a very weak diagnosis due to the lack of uniformity, validity and reliability (May et al., 2010). On the other hand, some authors believe that a combination of three or more types of clinical tests make it possible to provide some evidence of shoulder dysfunction related to pain and incapacity (Michener et al., 2009).

Our study (**Chapter 8**) proposed analysing the kinematic response of a single patient to the five RC tests. The aim of this current study was to establish the pattern of muscle activation and motion for a disability of the patient's shoulder and understand the relationship between kinematic findings about pain and injury severity. One patient with an RC injury was randomly selected from a set of 18 participants for application of the procedures of EMG data processing and kinematic parameters in order to biomechanically analyse the *belly press* (BP), *drop arm* (DA), *empty can* (EC) *Neer* and *Hawkins* tests. This followed a previous clinical assessment using VAS_Pain, DASH and ultrasound examinations to make the diagnosis.

The patient was female, 60 years old, with 61.80 kg body mass, 1.52 m height, 26.75 kg/m^2 BMI, was right handed, with physiotherapy experience, and had experienced pain for at least 24 months due to right rotator cuff injury. The right shoulder ultrasound exam showed a partial rupture of the *supraspinatus,* with 19 mm of extension, and tendinosis on the *supraspinatus* and *infraspinatus*. There was also calcification on the *supraspinatus*. The subject was assessed biomechanically during muscular tests in both shoulders. The subject had Grade 9 on the VAS_Pain scale and 57.80 for the disability of arm, shoulder and hand scale (DASH).

The variables studied were: time spent in the test, sequence of muscle activation, time of EMG peak and estimated EMG peak value, and time until peak EMG occurs per muscle (*biceps brachial*, *infraspinatus*, *upper trapezius*, and *lower trapezius)*. The case had important findings. The right *upper trapezius* had always the same EMG peak, suggesting a continuous contraction to protect disability. The higher EMG peak was the *biceps brachial*, except for in the Hawkins test where it was the *infraspinatus.* The activation of the left *upper trapezius* in all tests was interesting. This suggests that pain symptom occur in the right, confirming the positive test. Second, the left tests had higher EMG peaks on the *infraspinatus* (for BP, Neer and Hawkins) and *upper trapezius* (DA and EC) suggesting natural muscle co-activation for the test movements.

Accepting all statements, the shoulder problem leads to other problems on global functionality and balance. There is why, the aquatic therapy for shoulder disability should have a deeper analysis, which should show a global vision for the patient's treatment. The results with aquatic therapy for chronic problem suggests aquatic therapy is a valuable resource to achieve the patient's goals.

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CHAPTER X

CONCLUSIONS

Following the findings in the studies presented in this thesis, it seems reasonable to stress the following conclusions:

i. There is few evidence for the efficacy of aquatic therapy on rotator cuff injury recovery, with a wide diversity of outcomes and intervention protocols, times of assessment, samples included and outcome measurements used within the available studies on AT for rotator cuff injury.

ii. In deep-water exercise, differences in kinematic parameters associated with different buoyancy conditions were found. For horizontal shoulder extension, the buoyancy belt was the device which promoted better alignment and contralateral movement symmetry.

iii. The smoothness coefficient and the angular velocity outputs reinforce the fact that shoulder horizontal extension was performed with the best quality of motion when using a buoyancy belt. For shoulder abduction, the pool noodle was the more stable solution. These findings should be considered to have an important contribution on decision making for clinical interventions in dual-media. The choice of buoyancy condition and kind of device are determinant steps for achieving the main goal for aquatic therapy interventions.

iv. Through the ROM, the peak velocity related to the coefficient of smoothness and the time spent, we could observe where the symmetry was. Based on the results, we suggest the use of the pool noodle for shoulder abduction performing in dual-media conditions, as it provides greater symmetry.

v. The highlighted differences in smoothness coefficient in the transitory phase for the pool noodle suggests that it is the best device, resulting in minimum impact during shoulder abduction.

vi. In older adults with upper limb dysfunction, the correlation between DASH or FPS and BMI, HPB, more than four medications and a fear of falls can be a predictive factor for greater difficulties with water adaptation and successful interventions. Looking the expectations for older adults with upper limb dysfunction, the greatest are promoting wellbeing and relaxation. The immediate changes following AT program observed in this sample did not clarify the importance of patients with upper limb dysfunction repeating AT annually; the immediate improvement was no significant differences;

vii. The comparison of the effects of detraining and training using the AT program for older adults with upper limb disability confirms that older adults with upper limb disability had a positive effect of AT intervention, so they need to maintain their AT program for continue success.

viii. The response to the program varies with the time spent in the AT program; the group previously engaged in aquatic therapy were faster responders to training, whereas the partial follow-up group had a lower response to the program with no important clinical differences. Through the detraining effects, we suggest that these community programs have an important impact on activities of daily life and the safety of older adults with upper limb disability.

ix. In rotator cuff injury, *supraspinatus* of the injured side was always less active than *infraspinatus,* which was consistent with the evidence and studied reports.

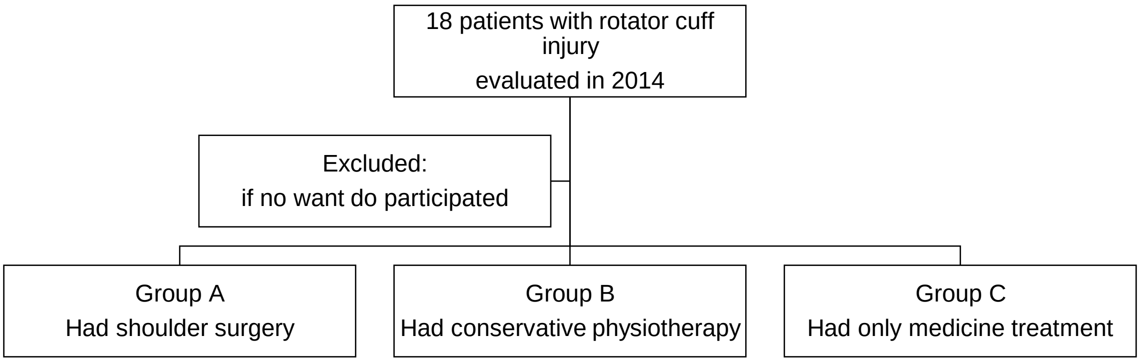
x. The moderate activity in the *biceps brachialis*, may have compensated for the relatively low activity found in opposite *subscapularis* during the resistance tests. Moreover, we found that the *supraspinatus* of the injured side was always less active, even when the test was on the opposite side.

xi. The recruitment order comparing right with left upper limb, it seems the last muscle on the injured upper limb was related with the pain and the main problem of the patient. The higher angle abduction at the maximal activation moment could be related with less internal rotation as an adaptation to pain relieve. The angle in the maximal muscle activation suggest that were related with the muscle chain.

CHAPTER XI

SUGGESTIONS FOR FURTHER STUDIES

Upper limb dysfunction related to rotator cuff pathology has a huge impact in public health politics. Due to this evidence, it is crucial to conduct a more cost-effective approach. Further research with older adults with this health condition should be planned based on all achieved knowledge through the studies of this thesis. Therefore, starting with using the first data collection, we suggest repeating the same protocol assessment for the five rotator cuff tests and making a follow up of the sample. After we will divide into three groups: (A) those who had shoulder surgery; (B) those who had conservative physiotherapy and (C) those who had only medicine treatment, which Study 1 design is presented at Figure 11.1. Furthermore, we would study the functional response of this patient's condition through an experimental method by the Study 2 which design is shown in Figure 11.2.



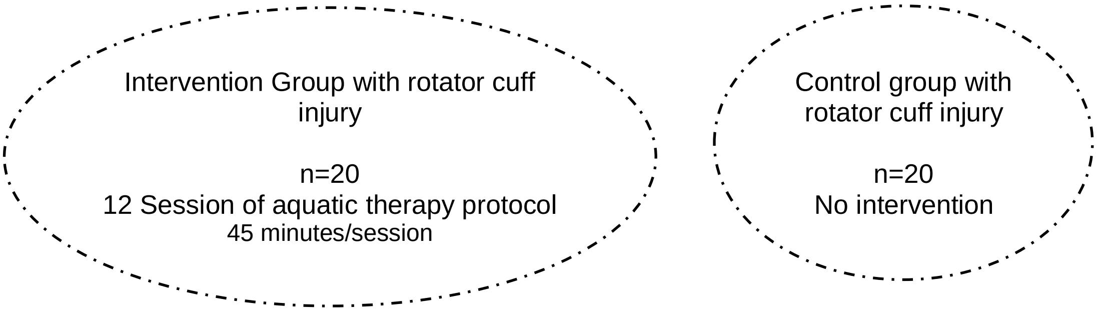
Aim: to compare the functional recovery and kinematic behaviour of the sample
Methods: kinematic collection protocol for rotator cuff test, with statistical study for comparison of groups based on the study VII.

Figure 11.1 – Study 1 flow chart.

With this study, we intent to answer to gaps and limitations in aquatic therapy research, like:

(i) How time influence the kinematic performance?

(ii) Did participants kinematically change with the clinical intervention?



Pre assessment: writing questionnaires for preferences and expectations, pain scale, functional tests and rotator cuff test kinematic collection

Post assessment: writing questionnaires for preferences and expectations, pain scale, functional tests and rotator cuff test kinematic collection

Figure 11.2 – Study 2 flow chart.

With this Study 2, we intent to answer to gaps and limitations in aquatic therapy research, like:

(i) What are the preferences and expectations of these patients upper limb dysfunction related to rotator cuff pathology?

(ii) What are the pain management through the aquatic therapy intervention?

(iii) How participants kinematically change with the aquatic therapy intervention?

(iv) What correlations between preferences, expectations and positive functional achievements?

APPENDIXES AND ANNEXES

Appendix A – Perception of functionality Scale based on ICF and related with the DASH

Perception of functionality Scale based on ICF and related with the DASH

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Abstract

Chronic patients usually appear at the pool with a prescription for long-term practice of aquatic therapy (AT). For this reason, initial assessment of these patients is crucial to meet expectations and reach functional goals specifically in the case of upper limb disability. Functional information can improve the interprofessional collaboration and may facilitate interdisciplinary disease treatment outcomes, which are very important to report to the patient’s doctor and for patient own understanding of functioning state. The aim of this study was to develop a functional measure to identify the patient’s main health problems, and expectations. It should allow prediction of success of the AT programs in older adults. A cohort study for validation of the Perception Functionality Scale (PFS) related with ICF was developed. The 96 AT participants completed a self-report concerning general problems, expectations, satisfaction with AT, the arm, shoulder and hand disability (DASH scale) and the functional perception scale in land and water based on the ICF. Ethical procedures were followed. The factor analysis was analysed (KMO = .859; Bartlett’s sphericity $p < .001$). Two factors were extracted, explaining 72.4% of variance, the FPS_1 (basic motor control) and the FPS_2 (advanced motor control). Cronbach's alpha was .94. Convergent validity of FPS was confirmed through correlation analysis values between item and each factor. Interclass correlation coefficient between land and water FPS return high values (ICC > .43 and <.89). Several studies confirmed the importance of AT programs for improvement of self-efficacy in daily life and in functional outcomes of older adults with osteoarthritis. On the other hand, often researchers studied and developed tools to predict important factors to help clinicians to prevent the risks for healthy aging. The current study developed a tool for health professionals to use as patients self-report. The Perception Functionality Scale (PFS) developed based on ICF can report the motor control level and the predictive factors: High Blood Pressure, more than 4 medications and fear of falls. In conclusion, this information suggests being helpful for the physiotherapist to make the decision on planning special needs and adjustments to the aquatic therapy program adapt to patients and get a well-succeeded intervention.

Keywords: Aquatic therapy, functionality, expectations, predictive.

Introduction

Before the physiotherapist intervention in swimming pools, chronic patients usually appear at the pool with a prescription for long term practice of aquatic therapy (AT). For this reason, initial assessment of these patients is crucial to meet expectations and reach functional goals specifically in the case of upper limb disability (Atroshi et al., 2000; Solway et al., 2002; Tiedemann et al., 2010). Functional information can improve the interprofessional collaboration and may facilitate interdisciplinary disease treatment outcomes, which are very important to report to the patient's doctor and for patient own understanding of functioning state (Brady et al., 2008; Hernandes et al., 2013; Landers et al., 2016). The physiotherapist still needs a self-reported functional evaluation of the patient to determine the degree of upper limb disability (Atroshi et al., 2000; Solway et al., 2002). This functional information can improve the interprofessional collaboration and achieve inter disciplinary disease treatment outcomes (Hawker et al., 2011), which is important to report to the patients doctor and to the patients understanding of their own functional state (Brady et al., 2008). The aim of this study was to develop a measure for perception of functionality associated with the main health problems and patient expectations, to predict the success of older adults on an AT programs. A cohort study was undertaken for validation of the Perception Functionality Scale (PFS) based on ICF and related to DASH (Figure A.1).

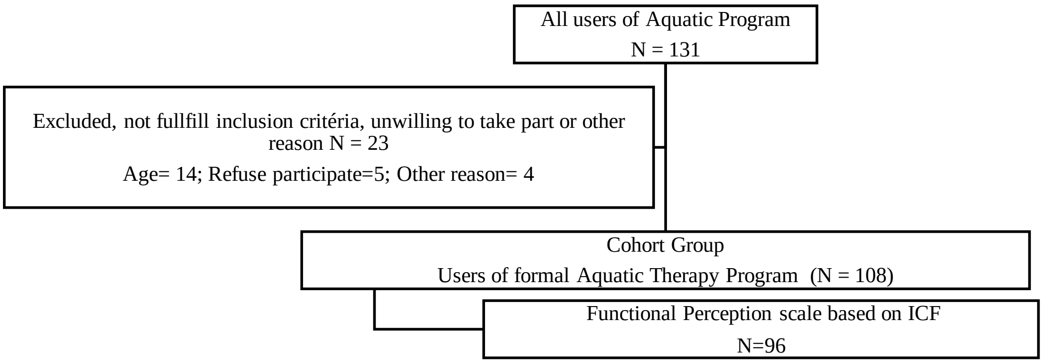

Figure A.1 - Reporting study participant's flow chart.

Material and Methods

To develop the measure four physiotherapists researched on the https://icf-core-sets.org and analysed the core set for Geriatrics comprehensive and Osteoarthritis comprehensive. Based on the practice of follow-up these chronic patients', physiotherapist's chose consensually 19 functional categories between two goals, the basic motor control and the advanced motor control. The basic such as daily activities, the advanced such as the activities less used during aging process due to the mobility decrease and self-challenge. With these 19 items, we achieved the land and water Function Perception Scale (FPS) (Table 1). The Functional Perception Scale based on ICF is an instrument composed of the domains of function taken from the geriatric core set related to the perception of essential functions for dynamic balance, upper limb function and fall prevention. It consists of 19 items, to be answered from 0 to 4 (0 – no difficulty, 1 – slight difficulty, 2 – moderate difficulty, 3– big difficulty, 4 – cannot execute). Scale development work was carried out in the context of functional health care in persons with chronic osteoarthritis pathology with 55 years and more. These participants' volunteers were users of an aquatic therapy program gave the written informed consent. All were satisfied with the program and answered positively to the recommendation question.

Table A.1 - Functional categories for functionality perception.

Functionality perception in land *Basic motor control*	Functionality perception in water *Basic motor control*	*ICF cod*
Move all joints in my body	Move all joints in my body	b7102
Do exercises without feeling fatigue in my muscles.	Do exercises without feeling fatigue in my muscles	b455
Carry out coordination movements	Carry out coordination movements	b7602
Move the front and back Gravity Center (25cm)	Move the front and back Gravity Center (25cm)	d4106
Move the right and left Gravity Center (25cm)	Move the right and left Gravity Center (25cm)	d4106
Stand erect (30 sec.)	Stand erect (30 sec.)	d4154
Remain seated (40sec)	Remain seated on an immersed bench (40sec)	d4153
Walk 6m or more	Walk 6m or more	d450
Walking: changing directions	Walking: changing directions	d450
Transporting objects	Transporting objects	d430
Advanced motor control	*Advanced motor control*	
Sit on the floor	Sit at the bottom of the pool	d4153
Lift off the floor	Lift from the bottom of the pool	d420
Lay on the floor	Lying on the bottom of the pool	d420
Rolling 360º right on the floor	Scroll 360º to the right for the bench press position in buoyancy	d4108
Rolling 360º left on the floor	Scroll 360º to the left for bench press position in buoyancy	d4108
Maintain one foot support	Maintain one foot support	d4158
Rotate 360o erect (<4 sec.)	Rotate 360o erect (<4 sec.)	d455
Run 6m or more	Run 6m or more	d4552
Jump (5x)	Jump (5x)	d4553

This instrument covers two domains: basic motor control (9 items), and advanced motor control (10 items). The participants completed separately the scale related to their perception of function land and function in water. The scale as similar evaluation for land and water, because researchers want to know the level of water adaptation, even when is asked to sit or lay on poll bottom, besides the difficulties with buoyancy, the measure intend to evaluate the strategy to deal with the challenge. Ninety-six participants completed a self-report about health problems, expectations, satisfaction and the disability of arm, shoulder and hand scale. The satisfaction was evaluated through the level of recommendation (0 – no recommendation; 1 – Maybe not; 2 – Probably; 3 – Probably yes; 4 – Certainly yes). Ethical approval was obtained.

Statistic study

Data analysis was performed using SPSS Statistics 24 software. The characterization of the sample and the distribution of the instrument values were given using descriptive statistics. Factor analysis was performed using the Kaiser-Meyer-Olkin Measure and Bartlett's Sphericity test. The internal consistency was analysed by Cronbach's Alpha and was considered as *very good* when α ≥ .9, *good* when .8 ≤ α < .9, *reasonable* when .7 ≤ α < .8 and weak when α <, 7. The analysis of association between variables was performed using the Spearmen and Pearson correlation coefficient. Results were compared between independent samples using the Mann-Whitney test. The level of significance was set at α = .05.

Results

After the baseline contact and assessments, all participants were included in the data analysis. Subsequently, 96 participants between 55 and 85 years old; 29.17 % male; 1.61 (.08) cm: 72.71 (12.48) kg; BMI 28.10 (4.56) voluntarily took part to develop the profile of older adults who were continuous users of an aquatic therapy program. All participants had one health problem, half of the sample taking more than four medications, hyper cholesterol and osteoarthritis were the main health problems. Majority were fear of falls, 47.92% had a fall in the last year. The satisfaction was expressed for the recommendation 73.96% would certainly made it (Table A.1).

Table A.2 - Characteristics of 96 participants.

	Mean / SD
Age	66.52 ± 6.84
Gender ♂/♀	28/68
Height	1.61 ± .08
Weight	72.71 ± 12.48
BMI	28.10 ± 4.56
Years of aquatic therapy	6.68 ± 5.10
More than four medications	50%
HBP	48.96 %
DM II	2.83 %
HC	59.38 %
Osteoarthritis	54.17 %
Fear of falls	59.38 %
Falls last year	47.92 %
Would probably recommend the program	26.04 %
Would certainly recommend the program	73.96 %

Follow the convergent validity of Functional Perception Scale results returned significance related with the same items, and the same concept of motor control. Through the factorial analyses, the Factor 1 pointed out items related with the basic motor control. The Factor 2 items were related with advanced motor control (Table A.2).

Table A.3 - Factorial and Internal consistency analyses for Functional Perception Scale – Aquatic.

	Factors		**Item-Total Correlation**	**Alfa de Cronbach item if deleted**
	Factor 1	**Factor 2**		
Move all joints in my body	**.750**		.668	.935
Do exercises without feeling fatigue in my muscles	**.639**	.465	.740	.934
Carry out coordination movements	**.908**		.608	.936
Move the front and back Gravity Centre (25cm)	**.922**		.625	.936
Move the right and left Gravity Centre (25cm)	**.918**		.663	.935
Sit on the floor from standing		**.868**	.796	.932
Lift off the floor to standing		**.861**	.771	.933
Lie down on the floor from standing		**.859**	.759	.933
Rolling 360° right on the floor		**.898**	.680	.935
Rolling 360° left on the floor		**.884**	.651	.935
Stand erect (30 sec.)	**.921**		.718	.934
Remain seated on an immersed bench (40sec)	**.798**		.564	.937
Maintain one foot support		**.76**	.475	.939
Walk 6m or more	**.764**		.525	.938
Walking: changing directions	**.862**		.651	.935
Rotate 360° while standing (<4 sec.)		**.597**	.558	.937
Run 6m or more		**.860**	.620	.936
Jump (5x)		**.818**	.660	.935
Transporting objects	**.749**		.651	.935
Eigen Value	9.3.9		4.5	
Variance explained	48.9		23.5	
Total Variance	**72.4**			
Alpha de Cronbach (19 items; α=.94)	.95		.94	

Then for inter-class correlation between results for the land and the water Functional Perception Scale, researchers found that the water answers pointed out results with a strong association between land and water (Table A.3).

Table A.4 - Inter-class correlation between land and water Functional Perception Scale – Aquatic Therapy.

Items	ICC	IC 95%
Item 1	.89	(.84-.93)
Item 2	.60	(.44-.72)
Item 3	.82	(.75-.88)
Item 4	.77	(.67-.84)
Item 5	.80	(.71-.86)
Item 6	.26	(.06-.44)
Item 7	.31	(.13-.48)
Item 8	.28	(.03-.49)
Item 9	.29	(.03-.53)
Item 10	.30	(-.03-.55)
Item 11	.74	(.63-.82)
Item 12	.43	(.24-.58)
Item 13	.31	(-.03-.55)
Item 14	.63	(.46-.73)
Item 15	.73	(.63-.82)
Item 16	.56	(.39-.69)
Item 17	.51	(.10-.72)
Item 18	.54	(013-.75)
Item 19	.58	(.42-.70)

For the convergent vality, through the items validation and answers distribution, findings pointed out the stronger correlation between the answers in the land scale and the water (Table A.4).

Table A.5 - Convergent vality and Items' Validation and answers distribution for Functional Perception Scale (Land).

		Factor 2	Factor 1			
	Items	**95**	**95**	**Mean**	**iq1-iq3**	**Min-Max**
Item 1	Move all joints in my body	.388**	**.818****	1	0-1	0-4
Item 2	Do exercises without feeling fatigue in my muscles	.545**	**.741****	1	1-2	0-4
Item 3	Carry out coordination movements	.207*	**.904****	0	0-1	0-4
Item 4	Move the front and back Gravity Centre (25cm)	.229*	**.910****	0	0-1	0-4
Item 5	Move the right and left Gravity Centre (25cm)	.281**	**.917****	0	0-1	0-4
Item 6	Sit on the floor	**.899****	.450**	2	1-3	0-4
Item 7	Lift off the floor	**.888****	.424**	2	1-3	0-4
Item 8	Lay on the floor	**.881****	.415**	2	1-3	0-4
Item 9	Rolling 360º right on the floor	**.891****	.276**	3	2-3	0-4
Item 10	Rolling 360º left on the floor	**.867****	.253*	3	2-3	0-4
Item 11	Stand erect (30 sec.)	.347**	**.926****	0	0-0	0-4
Item 12	Remain seated on an immersed bench (40sec)	.240*	**.776****	0	0-0	0-4
Item 13	Maintain one foot support	**.749****		2	2-3	0-4
Item 14	Walk 6m or more	.222*	**.743****	0	0-0	0-4
Item 15	Walking: changing directions	.311**	**.862****	0	0-0	0-4
Item 16	Rotate 360º erect (<4 sec.)	**.667****	.342**	2	1-3	0-4
Item 17	Run 6m or more	**.858****	.225*	3	2-3	0-4
Item 18	Jump (5x)	**.835****	.321**	3	2-3	0-4
Item 19	Transporting objects	.374**	**.804****	1	0-2	0-4

**The correlation is significant at the .01 level (bilateral). *The correlation is significant at the .05 level (bilateral).

In addition, the Pearson Correlation study of Land Functional Perception Scale with the FPS_Land_1 (group items for basic motor control) and the FPS_Land_2 (group items for advanced motor control) pointed out a stronger correlation with the basic motor control. The Functional Perception for basic motor control had a high association with the advanced motor control, and the total Functional Perception had a higher association with both. Looking the correlation between FPS_Land_total and the partial 1 and 2 show stronger with the DASH, the fear of falls, falls last year and more than four medication (Table A.5).

Table A.6 - Pearson correlation of FPS in land with FPS_Land_1 and FPS_Land_2.

	FPS_Land	**FPS_Land_1**	***FPS_Land_2***
FPS_Land		.812**	*.846***
FPS_Land_1			*.376***
FPS_Land_2		.376**	
+ 4 Medication	*.267***		*.322***
Fear of fall	*.536***	*.525***	*.390***
Falls last year	*.301***	*.298***	
DASH	*.696***	*.742***	*.517***

***.The correlation is significant at the .01 level (bilateral).*

Furthermore, analysing the Spearman Rô Correlation between Functional Perception in Land and other variables results returned a high association with DM 2, BMI, HBP, Medication (more than four different pills), fear of falls, years of aquatic therapy and DASH. In addition, for the FPS_Land, there is a high association with DM 2, Fear of Falls and DASH. On opposite a high association between DASH and FPS-Land with the expectation for get relax and get well-being (Table A.6).

Table A.7 – Spearman Rô between FPS-Land and DASH, Health factors, fear of falls, years of AT and expectations.

Spearman Rô	BMI	DASH score	HBP	DM2	HC	osteoarthritis	+ four medication	Falls last year	Fear falls	Years hydrotherapy	Decrease pain	Improve well-being	Get relax	Improve balance	Improve strength	Decrease falls	ADL	FPS score
BMI	1,000																	
DASH score	0.244*	1,000																
HBP	0.222*	0.230*	1,000															
DM2	**0.357****		**0.248****	1,000														
HC		0.244*			1,000													
osteoarthritis						1,000												
+ four medication		0.276**	**0.314****		0.193*		1,000											
Falls last year	0.240*	0.357**		0.209*			0.268**	1,000										
Fear falls	0.226*	0.521**	0.229*	0.191*	**0.299****		**0.348****	0.473**	1,000									
Years hydrotherapy		0.264**					0.277**			1,000								
Decrease pain						0.199*					1,000							
Improve well-being		-0.522**			-0.208*			-0.261**	-0.288**			1,000						
Get relaxation		-0.554**				0.302**			-0.315**			0.531**	1,000					
Improve balance				-0.202*					0.190*					1,000				
Improve strength						0.243*					0.274**		0.222*	0.416**	1,000			
Decrease falls	0.190*								0.246*			0.256**	0.209*	0.534**	0.643**	1,000		
ADL			0.251**	0.234*							0.190*		0.237*			0.193*	1,000	
FPS score	**0.289****	**0.705****	**0.299****	**0.280****			**0.282****	**0.317****	**0.540****	0.263*		**-0.335****	**-0.342****					1,000

**.The correlation is significant at the .01 level (bilateral). | *. The correlation is significant at the .05 level (bilateral). | c. Listwise = 95

Discussion

Physiotherapists have studied the self-efficacy of AT in daily life of older adults with osteoarthritis. and results confirm the importance of this special intervention for better functional and structural improvement of this patients (Kars Fertelli et al., 2018; Loeser et al., 2012). The evidence on fall risk model suggested the conversion to a “desk model.” consisting of the predictors postural sway. fall history. hand dynamometry. and depression. provides an added value in the identification of community-dwelling elderly at risk for recurrence (Sherrington et al., 2011). Several studies confirmed the importance of AT programs for improvement of self-efficacy in daily life and in functional outcomes of older adults with osteoarthritis (Atroshi et al., 2000; Kars Fertelli et al., 2018; Loeser et al., 2012). On the other hand. often researchers studied and developed tools to predict important factors to help clinicians to prevent the risks for healthy aging (Devereux et al., 2005; Hultenheim-Klintberg et al., 2009; Sheppard et al., 2016). The challenge of the current study was the missing evidence in literature about a measure with correlation to health problems and conditions to well-succeeded adaptation to the AT program. This tool demonstrated predictive proprieties when the users had HBP, DM2, taking more than four medication and fear of falls. Researchers suggests this measure can avoid constrain incidents on the first contact with patients before start the aquatic therapy, and can be used for exercises planning based on patient motor control, and can also be valid in the evaluation for follow-up the recovery based on the ICF activities.

Conclusion

The current study developed a tool for physiotherapists for use as self-report by patients looking for the predictive factors of kind of motor control. Which have influence in the aquatic therapy intervention: Hyper Blood Pressure. DM2. More than 4 medication and fear of falls. Higher values on the Functional Perception Scale for land activities was related with main health problems and conditions which compromise the well-successful of aquatic therapy intervention. Therefore this tool alert physiotherapist to the patient fragility for adaptation to water medial.

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Appendix B – Development of an aquatic therapy group's protocol program for older adults with upper limb dysfunction.

Development of an aquatic therapy group's protocol program for older adults with upper limb dysfunction

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Abstract

Aging is a natural phenomenon that affects the entire population and is characterized by biological changes such as decreased muscle mass, strength and loss of mobility, balance and motor coordination. All these factors increase the risk of falls in the elderly. Approximately 30% of the population over 55 years of age have at least one fall per year, and the risk of falls is higher in individuals with osteoarthritis. The evidence supports that physical exercise increases postural stability and reduces falls risk. Exercises in aquatic environment promote greater motor-sensorial stimulation that may contribute to balance increase. The aquatic environment allows for safe balance training, since it reduces the risk and the fear of falling. On the other hand, for individuals with pain, exercises in the aquatic environment are presented as an alternative to conventional exercises, since the reduce of the stress imposed to the joints and lower risk of worsening pain. The physical attributes of hydrodynamics such as density, buoyancy, hydrostatic pressure and viscosity promote an environment with conditions that improves motor and physiological activity. The aim of this study was to develop an aquatic therapy group's program protocol for older adults with upper limb disability, which could be used on further studies. The methodology used was based on PRISMA and AGREE II following two link of strategies: literature review and focus group of experts on aquatic therapy programs for older adults. Through the literature review findings and in the last five years of well-succeeded experience of the experts, the aquatic therapy group's program protocol for older adults with upper limb disability was prepared with 3 phases (warm-up, conditioning and cooling-down) content special exercises to each phase. Researchers followed the steps for the protocol preparation using PRISMA guidelines for good evidence for the protocol, and through those findings got the main issue for the real need of their framework. By, using the AGREE II domains, which are good predictors of outcomes associated with implementation of guidelines, authors followed the steps for the development of the protocol intended to be used in clinical practice. A pre-test was done to access the aquatic therapy protocol. On one hand, the functional outcomes of the patients (VAS; Step test; TUG; 10 m Walking; Hand dynamometer, Global Balance Standing

Test). On another hand, the perception of aquatic therapy session (PT ability to calm patient during the session; PT explanations about exercises of the session; feedback at the end of session for future; security feelings during the session; the session was adapted to patient problem). Finally, researchers concluded that this protocol could be repeated and performed in the clinical context.

Keywords: Aquatic therapy; osteoarthritis; older adults; protocol; functionality.

Introduction

Aging is a natural phenomenon that affects the entire population and is characterized by biological changes such as decreased muscle mass and muscle strength and loss of mobility, balance and motor coordination. All these factors increase the risk of falls in the elderly (Eun Jung et al., 2010; Oliveira et al., 2018). Approximately 30% of the population over 65 years of age have at least one fall per year, and the risk of falls is higher in individuals with osteoarthritis of the lower limb joints (Acree et al., 2006; Kaneda et al., 2008).The evidence supports that physical exercise increases postural stability and reduces falls risk. The exercises in aquatic environment promote greater motor-sensorial stimulation that may contribute to the increase of the balance (Crenshaw et al., 2018; Oliveira et al., 2018). The aquatic exercises have been used in physiotherapy programs for the treatment of several pathologies. The aquatic environment allows for safe balance training, since it reduces the risk of falling and the fear of falling (Cadore et al., 2013; Sherrington et al., 2011). On the other hand, for individuals with pain, exercises in the aquatic environment are presented as an alternative to conventional exercises, since the reduce of the stress imposed on the joints and the risk of worsening pain after the interventions is lower (Dinnes et al., 2003). The physical attributes of hydrodynamics such as density, buoyancy, hydrostatic pressure and viscosity promote an environment with conditions that improve motor and physiological activity (Clemson et al., 2012; Waller et al., 2013). On the other hand, in Oliveira’ program with female subjects older than 60 years, a force platform was used as an evaluation measure to evaluate participants' postural stability while performing certain tasks. Intervention modalities such as mini trampoline exercises, water exercises and conventional exercises were used in the intervention. After 12 weeks of treatment, researchers concluded that these methods are effective for increasing postural stability (Oliveira et al., 2018).

It is consensual that the effective benefits in pain reduction and falls prevention by an aquatic therapy program. The measurement have usually a follow up between six and 12 weeks. For the evaluation had been used several tools, based on land responsibility, and reliability of the measure. However, all the studies reviewed had no relation with the upper limb disability. Our study goal is to develop an aquatic therapy protocol to evaluate the immediate effects of aquatic therapy in the global standing balance, pain, strength and motor control (coordination) for patients with disability of the upper limbs.

Methods

To develop an aquatic therapy program protocol for a global intervention in older adults with disability of upper limb, researchers use two steps: (i) a literature review and (ii) focus group to stabilize the protocol based on expertises practical approaches.

The review of the existing literature was conducted by combining the keywords: "hydrotherapy" OR "aquatic therapy" OR "aquatic physiotherapy" OR "aquatic physical therapy" OR "water exercise" OR "water therapy" OR "water rehab" OR "water rehabilitation" OR "aquatherapy" OR "aquatic rehab" OR "aquatic rehabilitation" AND "aging" OR "elderly" AND "balance" OR "equilibrium" AND "strength" AND "pain". The databases used: PubMed and ScienceDirect.

The inclusion criteria were: (1) randomized experimental studies, (2) main subject related to balance, pain, strength and functional assessment, (3) study participants were individuals over 55 years of age and healthy, and (4) the article is in English. Exclusion criteria were: (1) not randomized experimental studies, (2) main subject unrelated to assessment of balance, pain, strength and functionality, (3) animal studies, (4) study participants were individuals under 55 years of age who present with neurological, cardiorespiratory or marked mental deficits, and (5) the article is not written in English.

The *methodological quality* of all randomized experimental studies was evaluated through the application of the PEDro scale, which was validated for this purpose. This scale is a checklist that presents 11 parameters with two possible scores for each 0 = no or 1 = yes. A score of 9 or 10 corresponds to an excellent methodological quality, 6 to 8 corresponds to good methodological quality and five or less corresponds to a poor methodological quality (Maher et al., 2003).

The *focus group meeting* (four expertises physiotherapist) promote the discussion of the literature review findings. The expertises discuss the method of management of the session, time of session and exercises distribution. Then, stabilized criterias based on the literature review findings and the last five years of well-succeeded aquatic therapy intervention with this kind of patients.

Selection of studies

Figure B.1 represents the literature search flowchart, based on the recommendations and structure of the PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher et al., 2009). Initial research revealed 397 results. After the application of the filter to select only experimental studies, 93 results were obtained and 304 were excluded. One study was doubled and 92 studies were selected. After reading the title, we obtained 26 results and after reading the abstract 9 results were obtained. Only 7 of the 9 studies fulfilled the inclusion criteria, being the final result of 7 studies included in this systematic review.

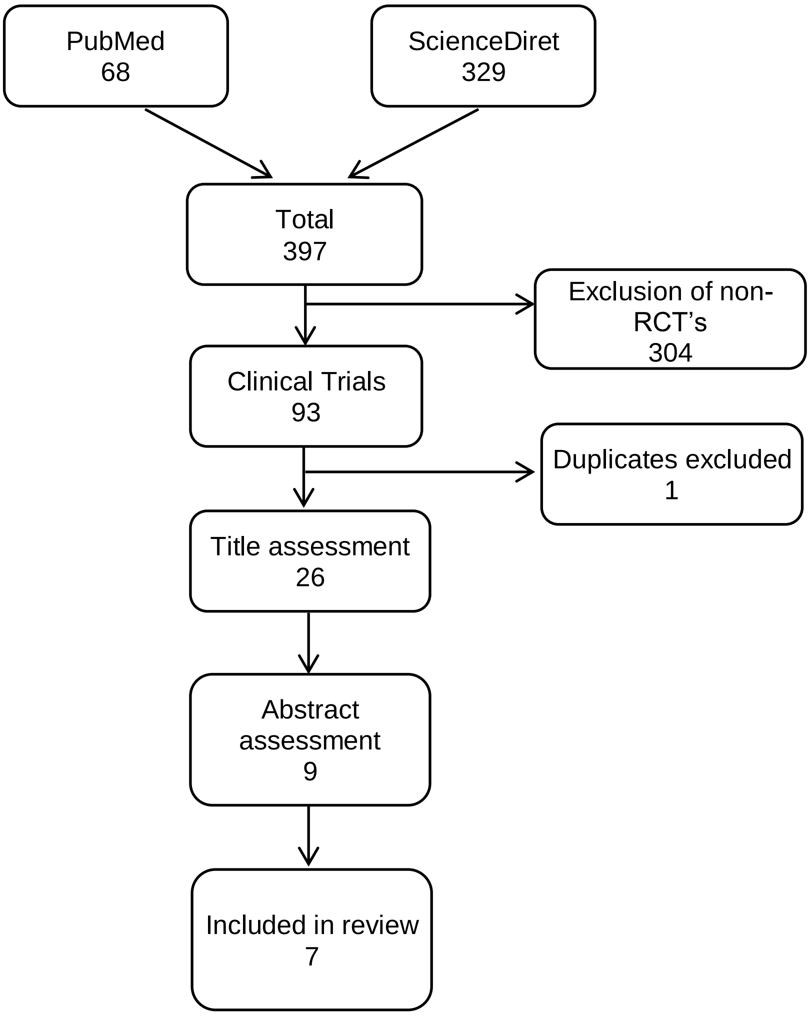

Figure B.1 - PRISMA flowchart

Methodological quality of literature review

The results of the methodological quality analysed using PEDro scale score for each question pointed on Table B.1. The mean score of the PEDro scale obtained was five. Experimental studies vary from poor methodological quality to good methodological quality, with two studies classified with good methodological quality. The parameters where the articles fail in the methodological quality analysis are: the subjects are not randomly distributed, the subjects 'distribution is not considered blind, the subjects' participation is not done blindly, the therapists who administered the therapy do not did blindly, and evaluators who measured at least one key outcome did not do so blindly.

Table B.1 - Evaluation of the methodological quality by the PEDro scale score.

Experimental Study	PEDro Scale
Bressel et al. (2014)	4
Alikhajeh et al. (2012)	4
Adsett et al. (2017)	7
Lord et al. (1993)	4
Jigami et al. (2012)	5
Sato et al. (2009)	5
Devereux et al. (2005)	7

The objectives of the experimental studies included in this review are to evaluate the efficacy of an aquatic exercise program or hydrotherapy program in individuals over 55 years of age. Two of the studies included in the review only assess the effects on women, and a study evaluates only men. The remaining studies included individuals of both sexes. Two studies included healthy individuals and two others included individuals with osteoarthritis. The remaining studies focused on subjects with heart failure, osteoporosis or osteopenia and dependent elderly.

Only an experimental study does not address any inclusion or exclusion criteria for participation in the study. In the remaining studies, for subjects to be included in the experimental study, in general, they should not present severe cardiovascular, metabolic, mental, neurological or incontinence cardiovascular diseases. Individuals, in virtually all studies, should not present against exercise indications and have functional ability to perform the proposed tasks. Of the seven articles included in the review, three articles set the criteria for inclusion to be 65 years or older. Only one article sets a lower age limit, 35 years or more, thus still covering the adult population.

Three studies in this review included in the intervention protocol a control group and an experimental group, and the control group was not subjected to any intervention and the experimental group was subjected to aquatic intervention. In the study by Bressel et al. (2014), only one intervention group was created subject to a period of control without any intervention and a period of intervention. In the remaining experimental studies two intervention groups were created. In the study by Adsett et al. (2017), both groups attended the same intervention but in different phases. In the study by Jigami et al. (2012), both groups were submitted to an intervention on land, followed by a 30-minute interval and consequent intervention in aquatic environment. In the study by Sato et al., 2011, both groups experienced the same intervention, however, one group had one session per week, while the other group had two sessions per week.

All studies included in the systematic review assess the balance or risk of falls and three studies assess quality of life and functionality and mobility in ADLs. Only two of the experimental studies analysed evaluated joint pain and another two assessed flexibility. Three studies have evaluated muscle strength, and the study by Adsett et al. (2017) evaluates palmar grip strength and the studies of Jigami et al. (2012) and Sato et al. (2009) evaluate the muscular strength of the lower limbs. The study by Adsett et al. (2017) also evaluated submaximal exercise capacity.

Through the analysis of all the experimental studies, included in the systematic review, the evaluation instruments used for each evaluated item were registered. To evaluate the functionality and activities of daily living, the KOOS - Knee Injury and Osteoarthritis Outcome Score and the Functional Independence Measure were used. In order to evaluate the quality of life, the SF-36 questionnaire - Medical Outcomes Survey Short Form-36 Questionnaire was adopted. The use of the pain evaluation scale and the visual analogue scale for the evaluation of pain were also registered. In order to evaluate the balance, a great diversity of instruments was used: dynamic computerized posturography, Sharpened Romberg test, Time Up and Go Test (TUG), 10 meter gait test, BOMER - Balance Outcome Measure for Elder Rehabilitation Time the fone-leg standing with open eyes, Functional Reach Test, Step Test, Modified Falls Efficacy Scale. For the evaluation of mobility, the use of the sit-to-stand, the 10-meter gait test, the Foward lunge test and the TUG were used. To evaluate submaximal exercise capacity and muscle strength, the 6-minute gait test and a dynamometer were used, respectively. In order to assess flexibility, the Sit and Reach Test was used, or a photograph was taken and then evaluated. In the study by Jigami et al. (2012) the score of Harris Hip evaluated the overall effects of the intervention program adopted in the experimental study.

In the study by Bressel et al. (2014), aquatic intervention was performed three times a week for 6 weeks. Each session lasted 30 minutes and consisted of balance disturbance exercises and high intensity interval training. In the study of Alikhajeh et al. (2012), the intervention was carried out for 8 weeks with the frequency of three times a week. The duration of the session was 60 minutes and each session consisted of three phases, where phase one comprises adaptation to the aquatic environment, phase two comprises the elongation phase and phase 3 comprises static and dynamic balancing exercises. In the study by Adsett et al. (2017), the intervention was performed once a week for 6 weeks. Each session lasted 60 minutes and was structured again in 3 phases. Phase one includes warming up with walking and stretching, phase two includes endurance and resistance exercises of the lower and upper limbs in interval training of moderate intensity, and phase three includes walking cooling and stretching. In the study by Lord et al. (1993), there is no reference to the duration of the program and frequency of the sessions, however we know that the session is structured in three periods: warm up with stretching, balancing exercises and tasks with the upper and lower limbs and cooling with stretches. In the study by Jigami et al. (2012), ten sessions with 40 minutes each were performed, including warming up with exercises of flexibility and mobility, walking, muscular strengthening, unipodal support, coordination exercises and muscle relaxation. In the study by Sato et al., 2011, the sessions lasting 60 minutes were divided into 10 minutes of warm-up exercises with onshore flexibility, 20 minutes of walking in the water, 10 minutes of simulation of activities of daily living in water and 10 minutes of stretching and strengthening and 10 minutes of relaxation. In the study of Devereux et al. (2005), lasting 10 weeks, the session was structured in two phases: phase one with warm-up, stretching, Tai Chi, strengthening, gait and balance exercises and proprioception, and phase two, which includes an educational component to participants.

Development of an aquatic therapy program protocol for older adults with upper limb disability

By the procedures of AGREE II the experts in aquatic therapy discuss the literature review findings and compared with the practice well-succeeded on the last five years with patients with 55 years and older with upper limb disability and osteoarthritis. The session lasted 45 minutes and included a warm-up (phase one), conditioning (phase two) and cooling-down period (phase three), described in detail in Table B.2. The warm-up included gait exercises in all directions, with rhythm alteration, gait with waist dissociation, and walking on nozzles feet and with the heels (Adsett et al., 2017; Adsett et al., 2015).

Based on the protocols of literature reviewed, through the AGREE II procedures, the focus group defined with consensual criteria the three phases for the protocol session (Table B.2): Warm-up, Conditioning and Cooling-down. Then, based also on the practical experience, they consensually draw a protocol with the main objective to act in the level of the balance with upper limb special movements (Methajarunon et al., 2016). Were included exercises such as bicycle with arms and legs, floating with feet on the floor and gliding with the support of the pool noodle (Munukka et al., 2016). Balancing exercises were also performed in the sitting and standing positions with float kickboard pool (Alikhajeh et al., 2012; Jigami et al., 2012; Lord et al., 1993). Cooling included gait exercises with dissociation of waists, Ai-chi movements for relaxation, exercises in unipodal or bipodal support according to participant tolerance, cervical movements and stretches, shoulder rotations and stretching movements (Devereux et al., 2005; Sato et al., 2009). The protocol had been tested and immediate outcomes with functional test (Step Test, TUG, Functional Reach Test, Global Balance Stand Test, VAS and upper limb dynamometer measure.

Table B.2 - Described aquatic therapy program protocol for older adults with upper limb disability.

+	**Aquatic exercises**
Warm-up	1. Walking forward (1min.) 2. Walking to the sides (2min.) 3. Backward movement (1min.) 4. Walking with the hand on the opposite knee alternately (1min.) 5. Walking with the hand on the opposite foot alternately (1min.) 6. Walking with heels (1.5min.) 7. Walk in toes (1.5min) 8. Forward walking with internal rotation of the hip (1.5min.) 9. Backward rotation with external rotation of the hip (1.5min.) 10. Walking with changes of direction and changes of pace (3min.) 1. With the pool noodle between the legs do forward running with arms and legs movement (2min.) 2. Bicycle with legs and hand rest on pool noodle (2.5min.) 3. Bicycle with arms forward (1min.) 4. Bicycle with arms back (1min.) 5. Float with your legs relaxed and in extension with foam roll around the armpits (2min.) 6. Previous slide with or without pool noodle(1min.) 7. Side glide with or without pool noodle(2min.) 8. Glide with rotation with or without pool noodle(2min.) 9. Seated balance with plates and lateral inclinations with arms at 90º abduction (0.5min.) 10. Seated balance with anterior and posterior plates and inclinations with movements of adduction and horizontal abduction of the arms (0.5 min) 11. Seated balance with plates and rotations of the trunk (0.5min.) 12. Static balance standing on the plate (1min.) 13. Static balance standing on top of the plate with upper limb movement (1min.)
Conditioning	1. With the pool noodle between the legs do forward running with arms and legs movement (2min.) 2. Bicycle with legs and hand rest on pool noodle (2.5min.) 3. Bicycle with arms forward (1min.) 4. Bicycle with arms back (1min.) 5. Float with your legs relaxed and in extension with foam roll around the armpits (2min.) 6. Previous slide with or without pool noodle(1min.) 7. Side glide with or without pool noodle(2min.) 8. Glide with rotation with or without pool noodle(2min.) 9. Seated balance with plates and lateral inclinations with arms at 90º abduction (0.5min.) 10. Seated balance with anterior and posterior plates and inclinations with movements of adduction and horizontal abduction of the arms (0.5 min) 11. Seated balance with plates and rotations of the trunk (0.5min.) 12. Static balance standing on the plate (1min.) 13. Static balance standing on top of the plate with upper limb movement (1min.)

+	Aquatic exercises
Cooling down	1. Bending of the hip and alternate knee (1min.) 2. Walking with hip flexion and alternating knee extension (1min.) 3. Ai-chi movements (3min.): - at 90º of flexion do horizontal abduction bilaterally (3 movements), at 90º of flexion do horizontal abduction one arm at a time alternating (6 movements), repeat previous exercise with rotation of the head to accompany the movement of the arm. 4. Unipodal support doing several flexion movements of the knee of the supporting limb (1min.) 5. Bipodal support with the feet together making several knee bending movements (1min.) 6. Cervical rotations performing 10 alternating movements (1min.) 7. Cervical inclinations performing 10 alternating movements (1min.) 8. Cervical stretching (1min.) 9. Rotation of the shoulders back and forward (1min.)

Test of the aquatic therapy program protocol for older adults with upper limb disability

30 volunteers users of aquatic therapy program accepted participated on a feasibility test for the protocol assessment. The sample had mean ± SD: age 65.80 ± 7.18 years old; 1.62 ± 0.08 m height; 77.20 ± 13.93 kg body mass. All participants provided written informed consent, made in accordance with the Helsinki Declaration and the Oviedo Convention. Local hospital ethics committee approved the study. The protocol had been tested through immediate outcomes with functional test with evidence (Step Test (Brauer et al., 2000) , Time Up and Go test, 10 m walking test), VAS (Hawker et al., 2011) and disability of arm, shoulder and hand scale (DASH) (Atroshi et al., 2000; Hunsaker et al., 2002).

Results

Results presented on Table B.3 and showed evidence only for pain scale (*p* < 0.05).

Table B.3 – T-test – repeated measures ∞=<0.05 (N=30).

MEASURES	Mean	SD	*P*
DASH score	3.0	0.7	
VAS initial	5.6	1.7	0.02*
VAS final	4.7	1.9	
TUG initial	8.8	2.0	0.12
TUG final	8.2	1.7	
ST initial	7.1	1.5	0.08
ST final	7.7	1.9	
10m Walking test initial	4.1	0.8	0.872
10m Walking test final	4.3	0.7	

Discussion

The aim of this study were to develop a AT protocol based on a systematic review, then using the AGREE II method, discuss the results of protocols, outcomes and measures to make a protocol for older adults with upper limb disability. The experimental studies included in the systematic review do not present significant results in all measures, which does not mean that the treatment is ineffective or has no benefit when applied in clinical practice. It is necessary to develop experimental studies that present larger and representative samples of the study population.

The included seven experimental studies evaluating the efficacy of an aquatic exercise program for adult or elderly users. In Bressel et al. (2014) all evaluation measures showed significant differences comparing the measures before and after the intervention (p <0.05). The KOOS score improved on the pre-intervention evaluation, values on the pain scale decreased significantly and the assessment of balance through computerized dynamic posturography also improved significantly. For our studied the pain and ST also improve, but only the pain with differences.

In the study of Alikhajeh et al. (2012), the hydrotherapy program showed significant improvements concerning balance. The results of the Sharpened Romberg static test with opened and closed eyes increased significantly (p

<0.002). In the TUG there was a significant decrease in the test execution time (p <0.001). There were no changes in the control group that were not subjected to any intervention. In the Adsett et al. (2017) study, the improvement in the 6-minute gait test is higher in the exercise period on land when compared to the aquatic environment (p <0.04). The remaining evaluation measures maintained their results or improved slightly but not significantly. There are no significant differences between the results of aquatic and terrestrial intervention.

The current study had also improvements in function and mobility tests, 10 m Walking test and TUG. In this way, this intervention seems to have positive results; however, it would be pertinent that these results had been compared with a control group not subject to any type of intervention in the same timing.

In the study by Lord et al. (1993), the aquatic intervention group showed improvements in all assessment measures except for neuromuscular control over initial assessment measures. In the intervention group, pain in the most painful joint decreases when compared to the control group that was not subjected to any intervention. However, the difference between the two groups is not significant.

In the study by (Jigami et al., 2012), there was improvement in muscle strength only in the weekly group when compared with the intervention group every 2 weeks. The Harris score and the SF-36 questionnaire did not show significant differences between the two groups. However, TUG on the more painful side showed significant improvements in both intervention group.

Sato et al. (2009), after six months found significant differences in muscle strength and only in the group with 2 weekly sessions, after 3 months. For flexibility and balance significant improvements were only observed in the group of 2 weekly sessions. In terms of functionality in daily activities, significant differences were observed after 3 months only in the group with two weekly interventions; however, after 6 months there were significant improvements in both groups, with no differences between groups. For our study, we only take one session, so no follow up.

However, the methodologies should contain a clear explanation of the description of the study population, how it was recruited, and the choice of participants should be made at random. The interventions described in the experimental studies should take into account their applicability anywhere in the practice whereby the costs have to be accessible and the complexity of the intervention protocol should not be a barrier to their practical application. As far as evaluation measures are concerned, they must be valid and reliable. Based on the protocols of literature reviewed, through the AGREE II procedures, the focus group defined with consensual criteria the three phases for the protocol session: Warm-up, Conditioning and Cooling-down (Brouwers et al., 2010). In addition, based also on the practical experience, they consensually draw a protocol with the best choice of exercises experienced by the patients under their responsibility five years ago.

The test of AT protocol had results similar of the actual evidence,

Limitations

This systematic review has limitations that may influence outcomes. In the literature there are few experimental studies that meet the eligibility criteria to be included in this systematic review.

Conclusion

This systematic review compares various interventions in the aquatic environment and reports that are the most commonly used measurement instruments for assessing balance, strength, upper limb functionality and pain. After analysing the results obtained after applying the aquatic intervention of the different experimental studies, it was concluded that this intervention brings benefits to users with joint pain, decreased muscle strength, functionality and balance. However, it was verified that the longer the intervention time, the greater the significant differences, obtained through the evaluation instruments, between the pre and post intervention.

The focus group discuss was concluded, therefore, that the aquatic intervention, brings improvements in the level of pain, muscle strength, functionality and balance, however, other exercise therapies in the terrestrial environment also seem to have a beneficial effect. It is necessary to carry out studies with the appropriate sample size and representative of the population, to evaluate the immediate effects and risks of aquatic intervention for people with this type of problem, as well as to carry out studies evaluating the long-term effects and stipulating treatment protocols with better methodological quality. This aquatic therapy protocol needs to be experimented to study aquatic therapy outcomes for older adults with upper limb disability.

Researchers found scientific and clinic evidences for the protocol as a point to study the immediate effects on pain, coordination and strength of lower limbs, balance functioning and balance standing. Researchers found good evidence for this protocol to achieve the study goals.

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Appendix C – Self-perceived health related with quality of life through aquatic therapy for ageing adults with disabilities – an exploratory study.

Self-perceived health related with quality of life through aquatic therapy for ageing adults with disabilities – an exploratory study

Short communication – 1st Evidence Based Conference in Izmir, 2013, Turkey

Self-perceived HEALTH RELATED WITH QUALİTY OF LİFE through AQUATIC THERAPY for AGEING ADULTS WİTH DİSABİLİTİES – an exploratory study

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1st European Conference on Evidence Based Aquatic Therapy

ECEBAT 2013
21-23 March, 2013
Izmir / TURKEY
Balçova Thermal Hotel

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Abstract

Aquatic therapy can be a good option for people in a ageing process, with proper diseases. The water provides an optimal resistance during the movement and the possibility of training at various speeds and is an excellent method for increasing resistance and muscular strength. We say optimal resistance because it results on a synergy between the water resistance and the capacity of the user. The kind of resources can have influence in the out puts of the intervention. Although the users choose the pool by the distance to home, we would like to know if it has significant value in their quality of life.

The aim of this study is to understand the perception of hydrotherapy in elderly patients about the influence of the aquatic therapy program in the health and quality of life. The sample size was 56 users who signed informed consent that data would be used we compare the results of a questionnaire about those own characteristics, the kind of therapy sessions and the quality of life questionnaire SF-36. It was found that the amount of pathologies may have an influence on patients' quality of life. It was also found that the use of music and stretching exercises in every session can have a positive association in the patients' perception of improvement in muscle strength and articular mobility. And the kind of pool doesn't have so influence. These results may be useful for planning the sessions according to people's needs in terms of pathology, preferences for exercises and activities with music.

Keywords: Aquatic Therapy, Quality of Life

Introduction

"Health " is a multi-dimensional concept that is usually and measured in terms of: 1) absence of physical pain, physical disability, or a condition that is likely to cause death, 2) emotional well-being, and 3) satisfactory social functioning. Some have advocated including the quality of an individual's physical environment in the definition of health, but this dimension is not at present included in the most widely used measures of health.

There is no single "standard" measurement of health status for individuals or population groups. Individual health status may be measured by an observer (e.g., a physician), who performs an examination and rates the individual along any of several dimensions, including presence or absence of life-threatening illness, risk factors for premature death, severity of disease, and overall health. Individual health status may also be assessed by asking the person to report his/her health perceptions in the domains of interest, such as physical functioning, emotional well-being, pain or discomfort, and overall perception of health. Although it is theoretically attractive to argue that the measurement of health should consist of the combination of both an objective component plus the individual's subjective impressions, no such measure has been developed.

Until a few decades ago quality of life was seen as the absence disease symptoms and survival after a diagnostic of disease. In 1994 the (WHO) (WHO) defined quality of life *as "the perception an individual has about his place in life, in the context of culture and value system in which he lives and in relation to their goals, expectations, standards and concerns (...) is a broad concept that can be influenced in complex ways by the physical state of the individual, the psychological state and level of independence, social relationships and relations with the essential elements of his environment"*.

According to this definition, it’s understood that for an individual with a disease, quality of life may assume different perspectives and really on satisfaction according to current possibilities that are conditioned by the disease and the treatment. Physical exercise has been shown to be an effective non-pharmacological method reducing physical difficulties in elderly people (Bocalini et al., 2010). In a simplified form, hydrotherapy is the use of water in the prevention and treatment of diseases. The use of water for medical therapy dates back to ancient cultures of China, Japan and Europe. A review of some studies showed positive results in maintaining functions in healthy individuals and improving skills in individuals with certain diseases. The exercises in water are well tolerated, especially in hot water because the warm environment helps reduce pain and muscle spasms (Reilly & Bird, 2001). Reilly e Bird (2001) demonstrated that hydrotherapy pool in a community group was more effective than individual treatment in a hospital pool. This is probably due to the focus on improving the health and wellbeing of people while encourage social interaction rather than focusing on the disease. Currently, hydrotherapy gained popularity because of studies that show the physical properties of water and physiological gains of aquatic exercises. The water provides gentle resistance during movements and also gives an opportunity to train at various speeds. These components make aquatic exercise an excellent method for increasing resistance and muscle strength (Campion, 2000).

Methods

Participants

The participants of this study were chosen by convenience. They are hydrotherapy users in two different pools, the pool A is 25m long with depths between 1,30m and 2m, and the pool B is 12,5m long with depths between 0,80m and 1.40m. The A is a public pool, with good environment, good assistance, and water between 28º and 30º. The B is a private pool, reduced environment, some lacks in assistance and water between 30º and 33º.

The Table C.1 presents the participants data of a total of 56 subjects.

Table C.1 – Participants data.

Participants	Male n (%) 8 (14.3)	Female n (%) 48 (85.7)	TOTAL n (%) 56 (100)
Age			
<46	1 (1.8)	5 (8.9)	6 (10.7)
46 a 55	3 (5.4)	13 (23.2)	16 (28.6)
56 a 65	1 (1.8)	16 (28.6)	17 (30.4)
66 a 75	3 (5.4)	12 (21.4)	15 (26.8)
>75	0	2 (3.6)	2 (3.6)
Marital Status			
Married	6 (10.7)	35 (62.5)	41 (73.2)
Divorced	1 (1.8)	4 (5.3)	5 (7.1)
Separated	0	1 (1.8)	1 (1.8)
Widow(er)	0	6 (10.7)	6 (10.7)
Single	1 (1.8)	2 (3.6)	3 (5.4)
Unmarried	0	1(1.8)	1 (1.8)
Pathologies			
OP Lower Limbs	5 (8.9)	15 (26.8)	20 (35.7)
OP Arms	2 (3.6)	7 (12.5)	9 (16.1)
OP Lumbar	5 (8.9)	20 (35.7)	25 (44.6)
OP Cervical	2 (3.6)	16 (28.6)	18 (32.1)
DH Lumbar	3 (5.4)	11 (19.6)	14 (25)
DH Cervical	2 (3.6)	7 (12.5)	9 (16.2)
DH Dorsal	2 (3.6)	2 (3.6)	4 (7.2)
Others	0	16 (28.6)	16 (28.6)
Number of Pathologies			
Less then 2	3 (5.4)	23 (41.1)	26 (46.4)
2 or more	5 (8.9)	25 (44.6)	30 (53.6)

OP – Ostheoarticular Pathology; DH – Discal Hernia

Instruments

The study was based on a questionnaire completed by one of the authors. The auto fill questionnaire has three parts. Part 1: the socio demographic data. Part 2: simple answer and multiple choices to collect the user's opinion regarding to physical and human resources of the pool, the physiotherapist care and self-perception about improvements occurred after the hydrotherapy program. The 3sd part: the generic questionnaire on quality of life SF-36.

This questionnaire consists of 36 questions, where are assessed eight domains: Physical Functioning (10 items) Role limitations due to physical health (4 items) Role limitations due to emotional problems (3 items), Energy / fatigue (4 items), Emotional well-being (5 items), Social Functioning (2 items), Pain (2 items) and General Health (5 items). The questionnaire presents a final score from 0 to 100, being 0 the worst overall health status and 100 the best overall health status.

Procedures

The data collection took place for during the last month of the 10 months program. The physiotherapist give to the users fill at home and after they collect and give to the researchers.

With regard to data processing at an early stage was a comparison between the average results of the SF-36 in our sample with the mean of the results of SF-36 of a population of 2471 participants in the Medical Outcomes Study (MOS) (Ware & Sherbourne, 1992).

Throughout this process were considered ethical issues, such as the confidentiality of the participants, by not identifying them in these surveys, and informed consent, obtained through a declaration of consent.

Results

The results indicate a greater number of females (85.7%) compared to males (14.3%). In regard to age, the majority of individuals is distributed relatively uniform way in the classes 46-55 (28.6%), 56-65 (30.4%) and 66-75 (26.8%). For both sexes, marital status tends to married (n = 41), being 10.7% of married couples male and 62.5% female. The widow's marital status is next more prevalent (n = 6), displayed only the sixth female representatives. Of the 56 participants the majority (44.6%) had degenerative lumbar spine (OP lumbar), followed by a percentage of 35.7 with degenerative disease of the lower limbs (OP of lower limbs). Is important to note that more than half the sample has more than one pathology (53.6%). Was used the parametric test for paired samples (t-test) to check for differences between the SF-36 of our participants with the participants of MOS SF-36.

By analysing Table C.2 seems to be a statistically significant difference between the study sample and the population in almost all MOS SF-36 domains: Physical Functioning ($p < 0.0383$). Role limitations due to physical health ($p < 0.0001$). Role limitations due to emotional problems ($p < 0.0001$). Emotional well-being ($p < 0.0001$). Pain ($p < 0.0001$). General Health ($p < 0.0015$). Only the domain Energy / fatigue. and Social Functioning showed no significant statistical differences ($p > 0.05$).

Table C.2 - Differences between the SF-36 of our participants with the participants of MOS SF-36.

	MOS Participants n=2471 $\bar{x}$(σ)	**Study Participants n=56 $\bar{x}$(σ)**	**p – value**
Physical functioning	70.61 (27.42)	62.95 (24.14)	0.0383
Role limitations due to physical health	52.97 (40.78)	23.66 (37.97)	0.0001
Role limitations due to emotional problems	65.78 (40.71)	43.45 (46.24)	0.0001
Energy/fatigue	52.15 (22.39)	48.75 (13.99)	0.2581
Emotional well-being	70.38 (21.97)	58.95 (18.12)	0.0001
Social functioning	78.77 (25.43)	74.11 (23.34)	0.1745
Pain	70.77 (25.43)	51.61 (19.97)	0.0001
General health	56.99 (21.11)	47.95 (18.87)	0.0015
Soma dos domínios	64.80 (9.69)	51.42 (14.92)	0.0001

In the sum of all areas the results also reveal significant differences between the two groups (p <0.0001).

In the Table C.3 presented the parametric test for paired samples (t-test) to check for differences between the doing an exercise always and sometimes in perceived improvements in body functions. This test was applied to all exercises: Stretching. Sliding. Relaxation. Use of Music and the Couple exercise. In this study we will only present those with satisfactory results. The t-test was also used to verify if the date of initiation of hydrotherapy program had a significant meaning in the perceived improvements and where found significant differences between starting the program less than 3 years ago and being on the program for 3 or more years.

Also areas of SF - 36 where. by the same method. related to several variables. number of pathologies. type of exercises performed in hydrotherapy. date of initiation of hydrotherapy program. Significant results were only found at the number of pathologies (between having only a disease or have more than one disease). There seems to be an association between perceived positive results in muscle strength in users that always practice with music (p <0.003). and also seems to be a relationship between results perceived as positive in joint mobility in clients who always perform stretches in hydrotherapy sessions (p <0.029). There seems to be a relationship between the activity time frequency (≥ 3 years) and perceived improvement in muscular strength (p <0.032). There seems to be an association between the number of diseases and the results in some domains of SF-36 *Physical Functioning* (p <0.023). *Role limitations due to physical health* (p <0.034) and *Pain* (p <0.039). where the participants with two or more diseases have worse outcomes in these areas.

Table C.3 - Relation between SF - 36 domains and perceived improvements in body functions with type of exercise. initiation time of hydrotherapy and number of pathologies.

	Stretching	**n**	$\bar{x}$	σ	***p***
Muscular strength	always	38	3.82	0.51	0.029
	some times	18	3.44	0.61	
	Use of Music	**n**	$\bar{x}$	σ	***p***
Muscular strength	always	24	3.92	0.62	0.003
	some times	31	3.45	0.51	
	Initiation time	**n**	$\bar{x}$	σ	***p***
Muscular strength	≥ 3 years	18	3.94	0.64	0.032
	< 3 years	38	3.58	0.55	
	Number of pathologies	**n**	$\bar{x}$	σ	***p***
Physical functioning	≥ 2	30	56.17	24.73	0.023
	1	26	70.77	21.29	
Role limitations due to physical health	≥ 2	30	13.33	27.65	0.034
	1	26	35.58	44.82	
Pain	≥ 2	30	46.5	18.29	0.039
	1	26	57.5	20.53	

Discussion and conclusion

Hydrotherapy can be composed of a variety of exercises. In the case our participants the sessions included stretching exercises. exercises in pairs. sliding. relaxation. use of floats and music in the sessions. As it turned out in the obtained results. stretching exercises and the use of music seem to have an influence on the results perceived as positive by the participants. Stretching is a form of work that aims to maintain levels of flexibility and the performance of the normal joint movements with minimal barring possible (Dantas, 2005). Thus. it is possible that stretching exercises in hydrotherapy sessions helps maintaining the flexibility allowing the accomplishment of joint moves with no restriction and without compensation of other corporal segments. This may be the reason why participants who always perform stretch at their sessions feel improvements in joint mobility.

To use music in activities is a way to motivate participants to continue the exercise or distract the practitioner of non-pleasurable feelings such as fatigue. pain or even psychological tension (Valin, 2007). In the process of analysing the results of this study. the music was spotlighted by the participant. as influent in improving muscular strength. It is possible that this takes place because music can establish the rhythm of a physical activity. and that way increase the amount of movement made during the exercise. Also the initiation date of the therapy program showed to have an importance in the results muscular strength in the users' perspective. Participants who perform the operation for three or more years reefer improvements at this level which may highlight the importance of a regular practice of sport. Finally. it was also found that participants with more than one disease had worse outcomes at SF-36 domains of *Physical Functioning*. *Role limitations due to physical health* and *Pain*. This evidence may serve as a basis in the choice of hydrotherapy programs. It is important to adjust the sessions to the type of disease and perhaps the number of pathologies.

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Appendix D – Self-esteem and self-safety through the upthrust point of Halliwick in aquatic therapy for adults with disabilities - an literature review.

Self-esteem and self-safety through the upthrust point of Halliwick in aquatic therapy for adults with disabilities - an literature review

Self-esteem and self-safety through the UPTHRUST POINT OF HALLIWICK IN AQUATIC THERAPY for ADULTS with disabilities

Introduction

Materials and Methods

Results

Conclusions

References:

Conceição Graça, MSc, PT[1,2,3], Carolina Henriques, MSc, PT[1]; Cristina Rei, PT[1,3]

1. Corpus Salut, Private pratice, 3880-259 Ovar
2. Physiotherapy Department, Francisco Zagalo Hospital, Avenida Dr. Nunes da Silva, 3880-113 Ovar
3. Health Science Superior School, Aveiro University, Campus de Santiago, 3810-193 Aveiro

Abstract

Background: Older adults with disabilities have a big challenge on mental adjustment and motor control throughout the 10 point programme of Halliwick. The most important point is upthrust or mental inversion. The physiotherapist has to be able to get involvement of the patients to achieve all aims and confidence on their motor control in water in terms of self-esteem and self-safety (Lambeck & Gamper, 2010). Also, the work in apnea has a good aim for health of lung (Ide et al., 2007). The slow inspiration and the apnea aim to match the time constants of the units whose peripheral pulmonary compliance and resistance are altered (Becker, 2010; Lepore et al., 1998). These alterations are responsible for the uneven distribution of ventilation, like ventilation inhomogeneous characteristic of asynchronous breathing (Kernis, 2005).**Methods:** In order to design a qualitative visual framework for self-esteem and self-safety, we performed a preparatory project, showing photos of persons during the Halliwick point of upthrust. This was to support the search for literature. The Scopus database of Fade-UP VPN (keywords: self-safety; self-esteem; water therapy; water exercises; Halliwick concept) and the book “Comprehensive Aquatic Therapy (CAT3) were accessed. **Results:** No references about self-esteem and self-safety could be retrieved. CAT3 however gave valuable information and could be used as basis for the qualitative visual project.

Discussion and conclusion: So we propose future studies to validate that this Halliwick point is important for the self-esteem and self-safety of aquatic therapy users.

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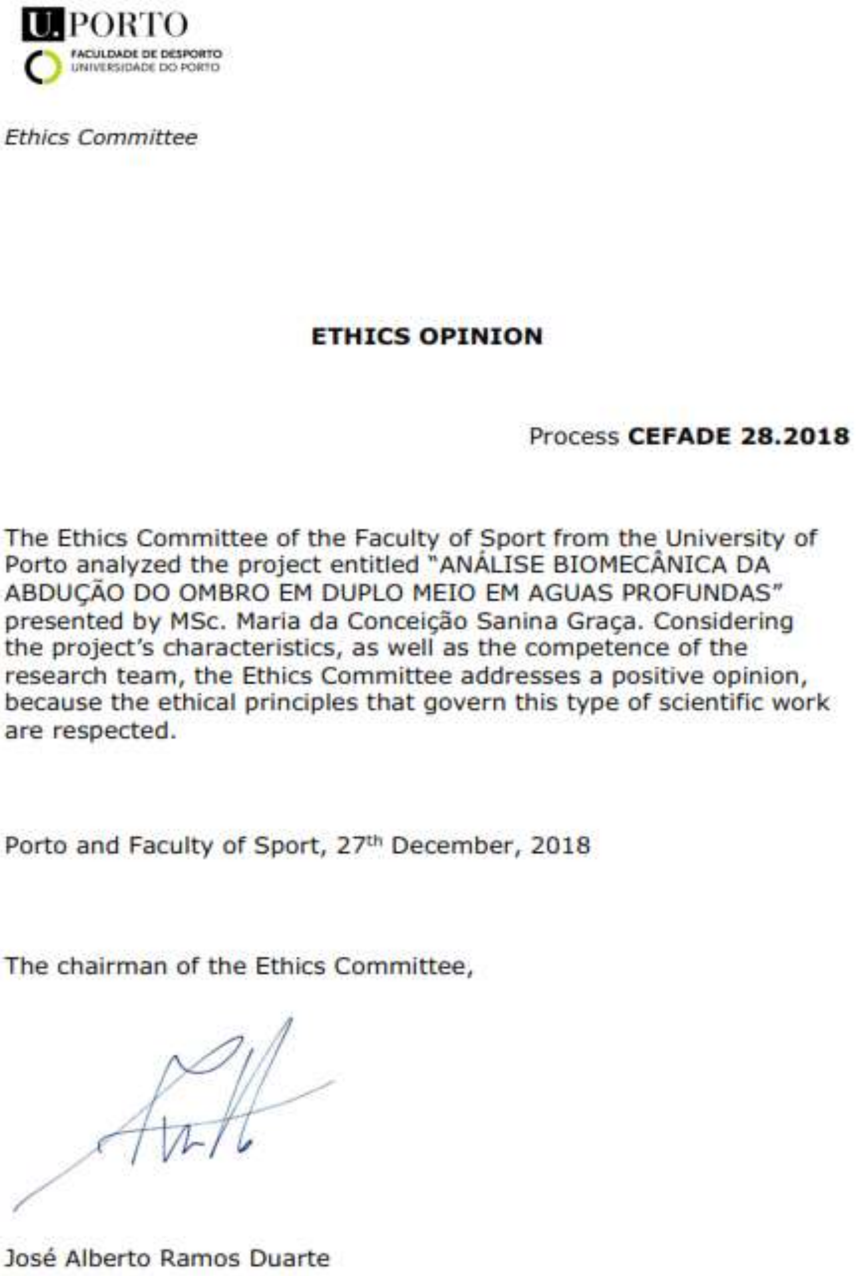
Annex A – The local Faculty Ethics Committee approved the research (code 28.2018).



U.PORTO
FACULDADE DE DESPORTO
UNIVERSIDADE DO PORTO

Ethics Committee

ETHICS OPINION

Process **CEFADE 28.2018**

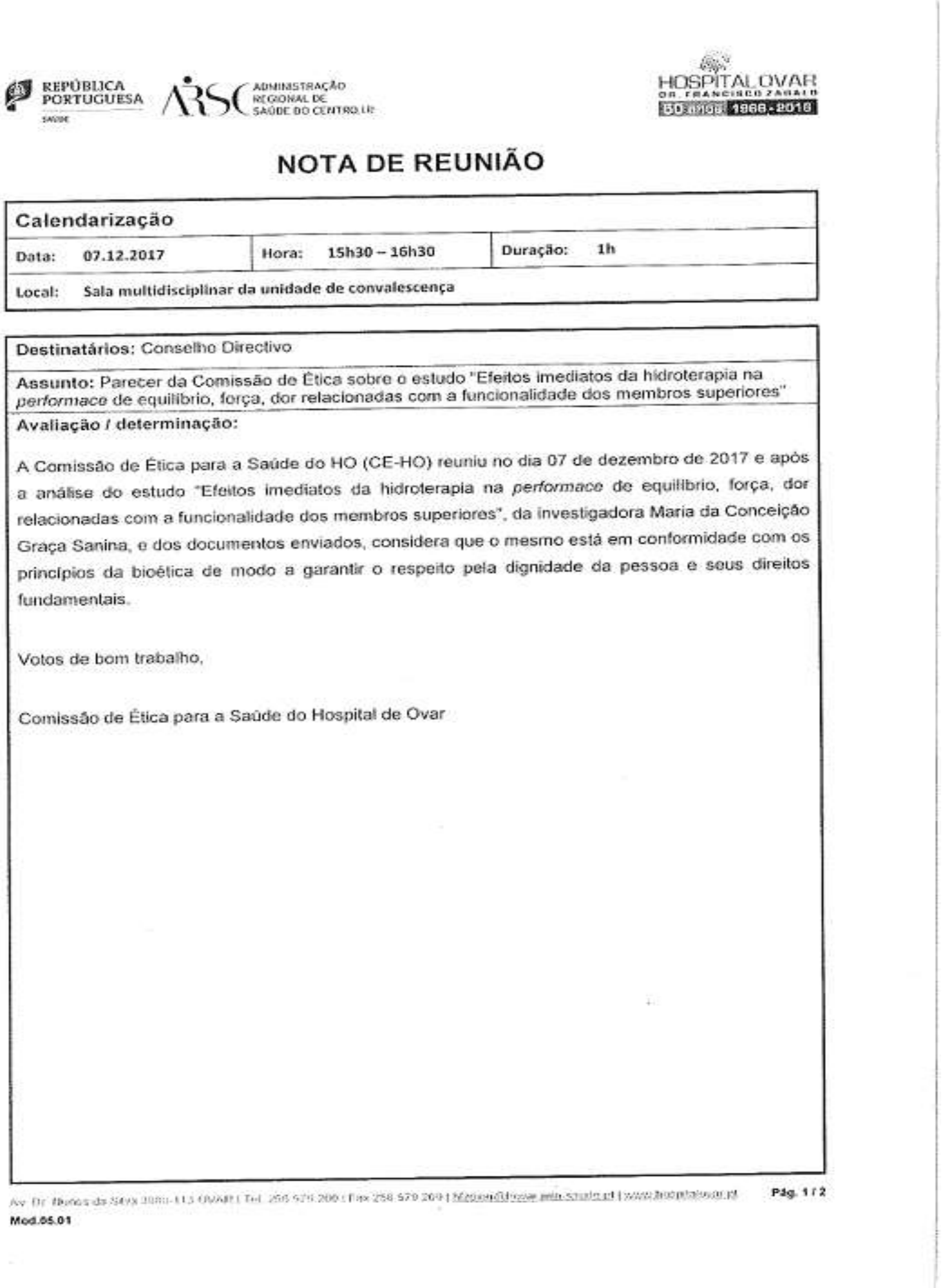
The Ethics Committee of the Faculty of Sport from the University of Porto analyzed the project entitled "ANÁLISE BIOMECÂNICA DA ABDUÇÃO DO OMBRO EM DUPLO MEIO EM AGUAS PROFUNDAS" presented by MSc. Maria da Conceição Sanina Graça. Considering the project's characteristics, as well as the competence of the research team, the Ethics Committee addresses a positive opinion, because the ethical principles that govern this type of scientific work are respected.

Porto and Faculty of Sport, 27th December, 2018

The chairman of the Ethics Committee,

José Alberto Ramos Duarte

Annex B – The local Hospital Ethics Committee approved the research (07/12/2017-CE)



REPÚBLICA PORTUGUESA
SAÚDE

ARSC ADMINISTRAÇÃO REGIONAL DE SAÚDE DO CENTRO, I.P.

HOSPITAL OVAR
DR. FRANCISCO ZAGALO
50 anos 1966-2016

NOTA DE REUNIÃO

Calendarização		
Data: 07.12.2017	**Hora:** 15h30 – 16h30	**Duração:** 1h
Local: Sala multidisciplinar da unidade de convalescença		

Destinatários: Conselho Directivo

Assunto: Parecer da Comissão de Ética sobre o estudo "Efeitos imediatos da hidroterapia na *performace* de equilíbrio, força, dor relacionadas com a funcionalidade dos membros superiores"

Avaliação / determinação:

A Comissão de Ética para a Saúde do HO (CE-HO) reuniu no dia 07 de dezembro de 2017 e após a análise do estudo "Efeitos imediatos da hidroterapia na *performace* de equilíbrio, força, dor relacionadas com a funcionalidade dos membros superiores", da investigadora Maria da Conceição Graça Sanina, e dos documentos enviados, considera que o mesmo está em conformidade com os princípios da bioética de modo a garantir o respeito pela dignidade da pessoa e seus direitos fundamentais.

Votos de bom trabalho,

Comissão de Ética para a Saúde do Hospital de Ovar

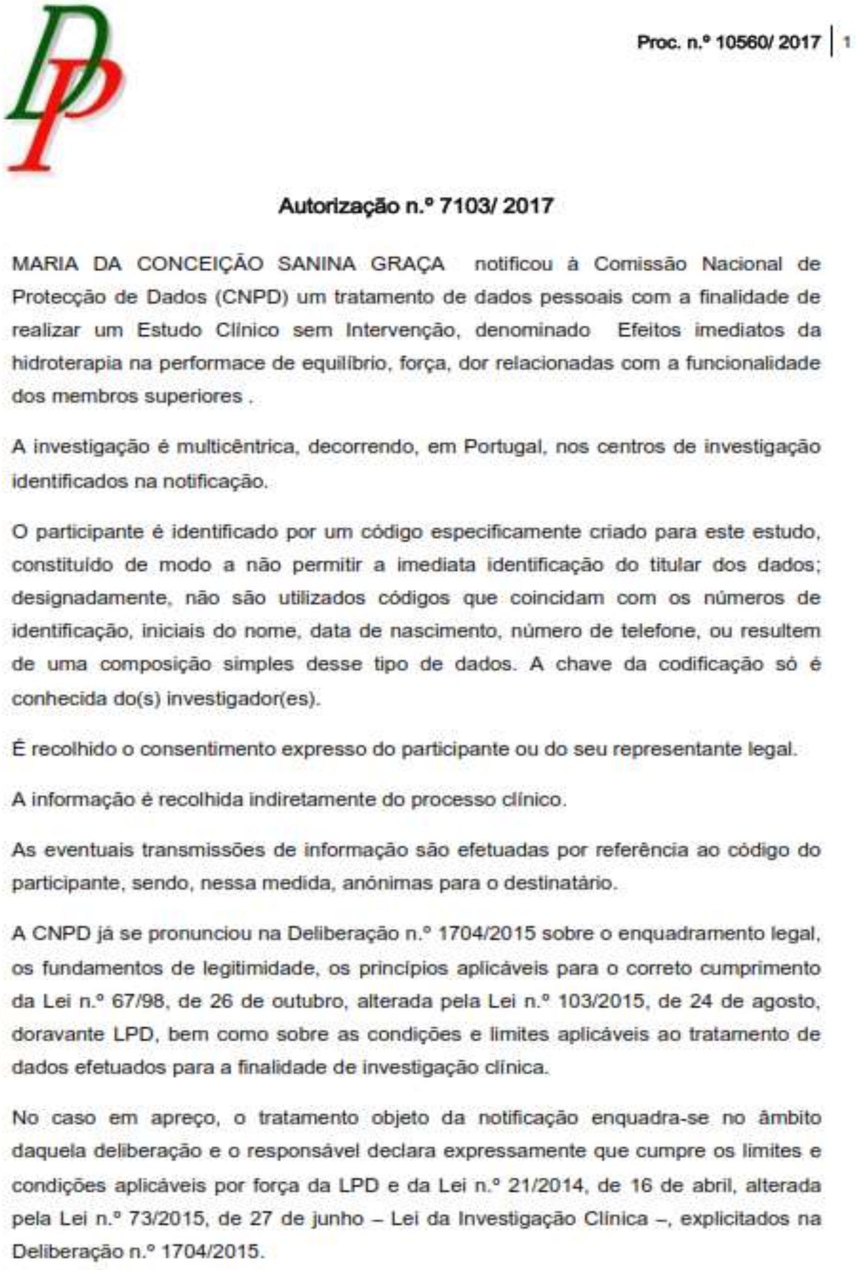
Av. Dr. Nunes da Silva 3880-113 OVAR | Tel. 256 579 200 | Fax 256 579 209 | [illegible] | [illegible] Pág. 1 / 2

Mod.05.01

LISTA DE PRESENÇAS E ASSINATURA DE NOTA DA REUNIÃO

NOME	RUBRICA
Judite Forte Carvalho	Judite Carvalho
Helena Alçada	Helena Alçada
Ana Oliveira	Ana Oliveira
Maria João Mautempo	

Annex C – The National Data Protection Commission (n. º 7103/ 2017) authorization to treat the data and publish the results



Proc. n.º 10560/ 2017 | 1

Autorização n.º 7103/ 2017

MARIA DA CONCEIÇÃO SANINA GRAÇA notificou à Comissão Nacional de Protecção de Dados (CNPD) um tratamento de dados pessoais com a finalidade de realizar um Estudo Clínico sem Intervenção, denominado Efeitos imediatos da hidroterapia na performace de equilíbrio, força, dor relacionadas com a funcionalidade dos membros superiores .

A investigação é multicêntrica, decorrendo, em Portugal, nos centros de investigação identificados na notificação.

O participante é identificado por um código especificamente criado para este estudo, constituído de modo a não permitir a imediata identificação do titular dos dados; designadamente, não são utilizados códigos que coincidam com os números de identificação, iniciais do nome, data de nascimento, número de telefone, ou resultem de uma composição simples desse tipo de dados. A chave da codificação só é conhecida do(s) investigador(es).

É recolhido o consentimento expresso do participante ou do seu representante legal.

A informação é recolhida indiretamente do processo clínico.

As eventuais transmissões de informação são efetuadas por referência ao código do participante, sendo, nessa medida, anónimas para o destinatário.

A CNPD já se pronunciou na Deliberação n.º 1704/2015 sobre o enquadramento legal, os fundamentos de legitimidade, os princípios aplicáveis para o correto cumprimento da Lei n.º 67/98, de 26 de outubro, alterada pela Lei n.º 103/2015, de 24 de agosto, doravante LPD, bem como sobre as condições e limites aplicáveis ao tratamento de dados efetuados para a finalidade de investigação clínica.

No caso em apreço, o tratamento objeto da notificação enquadra-se no âmbito daquela deliberação e o responsável declara expressamente que cumpre os limites e condições aplicáveis por força da LPD e da Lei n.º 21/2014, de 16 de abril, alterada pela Lei n.º 73/2015, de 27 de junho – Lei da Investigação Clínica –, explicitados na Deliberação n.º 1704/2015.

O fundamento de legitimidade é o consentimento do titular.

A informação tratada é recolhida de forma lícita, para finalidade determinada, explícita e legitima e não é excessiva – cf. alíneas a), b) e c) do n.º 1 do artigo 5.º da LPD.

Assim, nos termos das disposições conjugadas do n.º 2 do artigo 7.º, da alínea a) do n.º 1 do artigo 28.º e do artigo 30.º da LPD, bem como do n.º 3 do artigo 1.º e do n.º 9 do artigo 16.º ambos da Lei de Investigação Clínica, com as condições e limites explicitados na Deliberação da CNPD n.º 1704/2015, que aqui se dão por reproduzidos, autoriza-se o presente tratamento de dados pessoais nos seguintes termos:

Responsável – MARIA DA CONCEIÇÃO SANINA GRAÇA

Finalidade – Estudo Clínico sem Intervenção, denominado Efeitos imediatos da hidroterapia na performace de equilíbrio, força, dor relacionadas com a funcionalidade dos membros superiores

Categoria de dados pessoais tratados – Código do participante; idade/data de nascimento; género; dados da história clínica; dados de meios complementares de diagnóstico; medicação prévia concomitante; dados de qualidade de vida/efeitos psicológicos; relativos à atividade profissional com conexão com a Investigação

Exercício do direito de acesso – Através dos investigadores, presencialmente/ por escrito

Comunicações, interconexões e fluxos transfronteiriços de dados pessoais identificáveis no destinatário – Não existem

Prazo máximo de conservação dos dados – A chave que produziu o código que permite a identificação indireta do titular dos dados deve ser eliminada 5 anos após o fim do estudo.

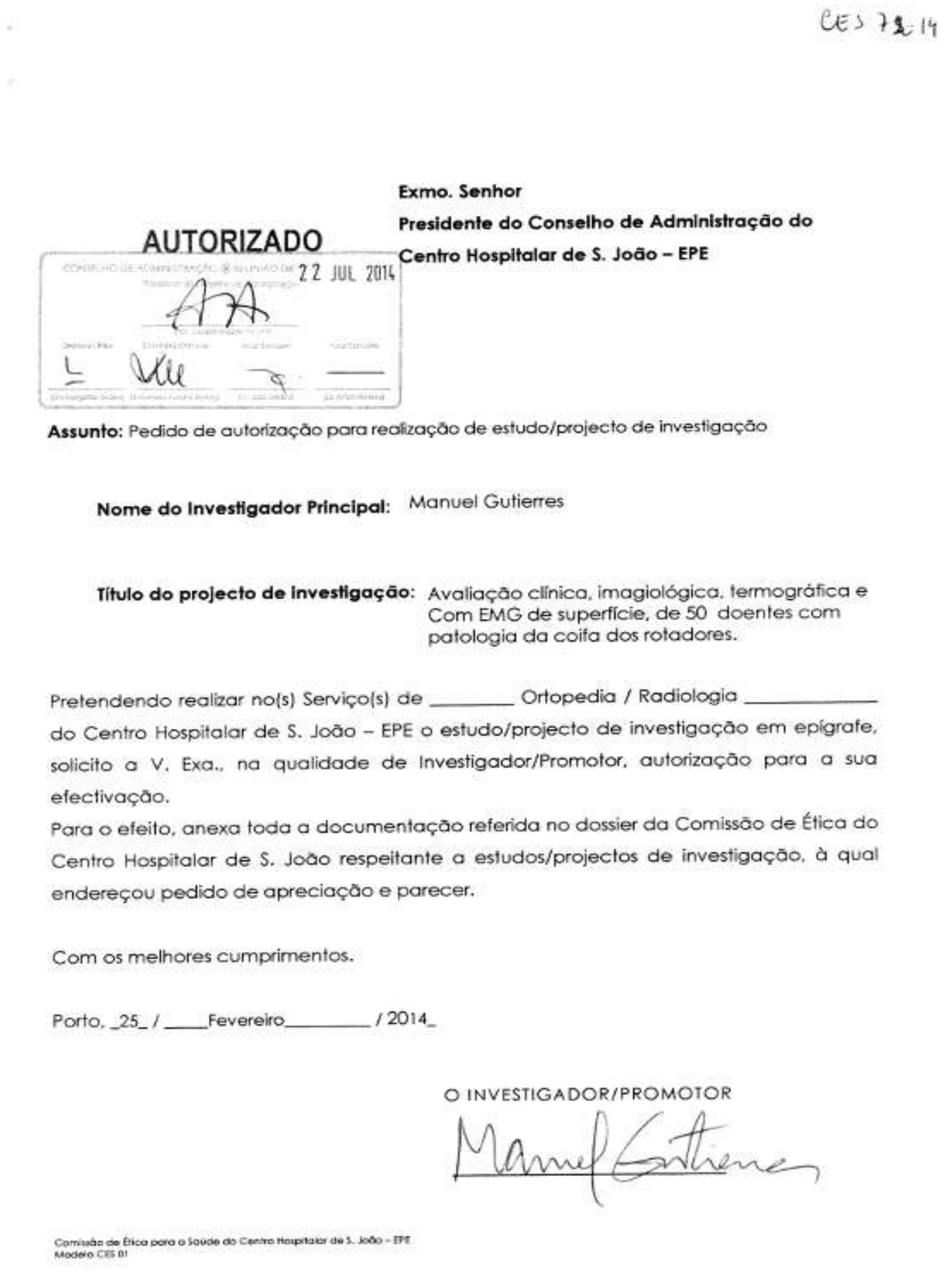
Da LPD e da Lei de Investigação Clínica, nos termos e condições fixados na presente Autorização e desenvolvidos na Deliberação da CNPD n.º 1704/2015, resultam obrigações que o responsável tem de cumprir. Destas deve dar conhecimento a todos os que intervenham no tratamento de dados pessoais.

Lisboa, 26-06-2017

A Presidente

Filipa Calvão

Annex D – A local Ethics Committee of the Community Hospital approved the research (code 22/07/2014-CES)



CES 72-14

Exmo. Senhor
Presidente do Conselho de Administração do
Centro Hospitalar de S. João – EPE

AUTORIZADO
22 JUL 2014

Assunto: Pedido de autorização para realização de estudo/projecto de investigação

Nome do Investigador Principal: Manuel Gutierres

Título do projecto de investigação: Avaliação clínica, imagiológica, termográfica e Com EMG de superfície, de 50 doentes com patologia da coifa dos rotadores.

Pretendendo realizar no(s) Serviço(s) de ________ Ortopedia / Radiologia ____________ do Centro Hospitalar de S. João – EPE o estudo/projecto de investigação em epígrafe, solicito a V. Exa., na qualidade de Investigador/Promotor, autorização para a sua efectivação.

Para o efeito, anexa toda a documentação referida no dossier da Comissão de Ética do Centro Hospitalar de S. João respeitante a estudos/projectos de investigação, à qual endereçou pedido de apreciação e parecer.

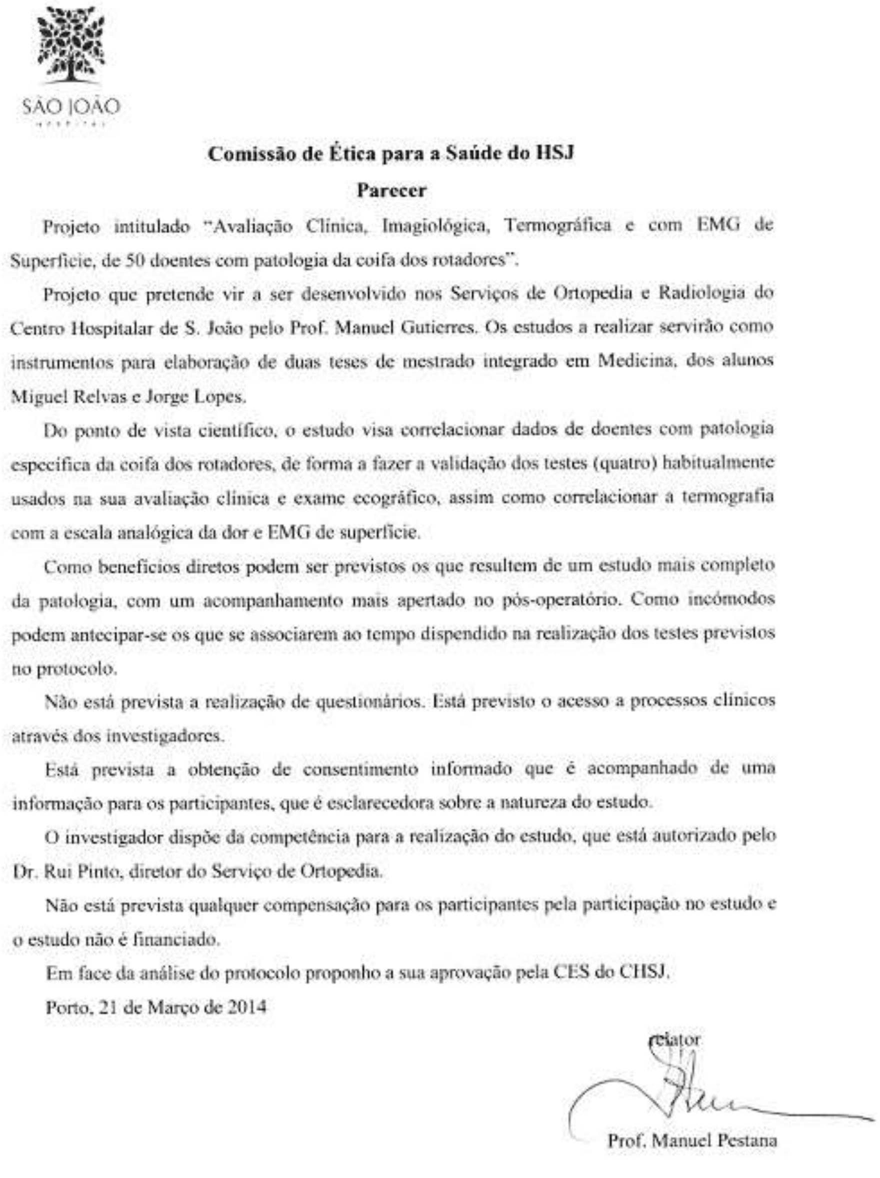
Com os melhores cumprimentos.

Porto, _25_ / ____Fevereiro________ / 2014_

O INVESTIGADOR/PROMOTOR

Manuel Gutierres

Comissão de Ética para a Saúde do Centro Hospitalar de S. João – EPE
Modelo CES 01



SÃO JOÃO

Comissão de Ética para a Saúde do HSJ

Parecer

Projeto intitulado "Avaliação Clínica, Imagiológica, Termográfica e com EMG de Superfície, de 50 doentes com patologia da coifa dos rotadores".

Projeto que pretende vir a ser desenvolvido nos Serviços de Ortopedia e Radiologia do Centro Hospitalar de S. João pelo Prof. Manuel Gutierres. Os estudos a realizar servirão como instrumentos para elaboração de duas teses de mestrado integrado em Medicina, dos alunos Miguel Relvas e Jorge Lopes.

Do ponto de vista científico, o estudo visa correlacionar dados de doentes com patologia específica da coifa dos rotadores, de forma a fazer a validação dos testes (quatro) habitualmente usados na sua avaliação clínica e exame ecográfico, assim como correlacionar a termografia com a escala analógica da dor e EMG de superfície.

Como benefícios diretos podem ser previstos os que resultem de um estudo mais completo da patologia, com um acompanhamento mais apertado no pós-operatório. Como incómodos podem antecipar-se os que se associarem ao tempo dispendido na realização dos testes previstos no protocolo.

Não está prevista a realização de questionários. Está previsto o acesso a processos clínicos através dos investigadores.

Está prevista a obtenção de consentimento informado que é acompanhado de uma informação para os participantes, que é esclarecedora sobre a natureza do estudo.

O investigador dispõe da competência para a realização do estudo, que está autorizado pelo Dr. Rui Pinto, diretor do Serviço de Ortopedia.

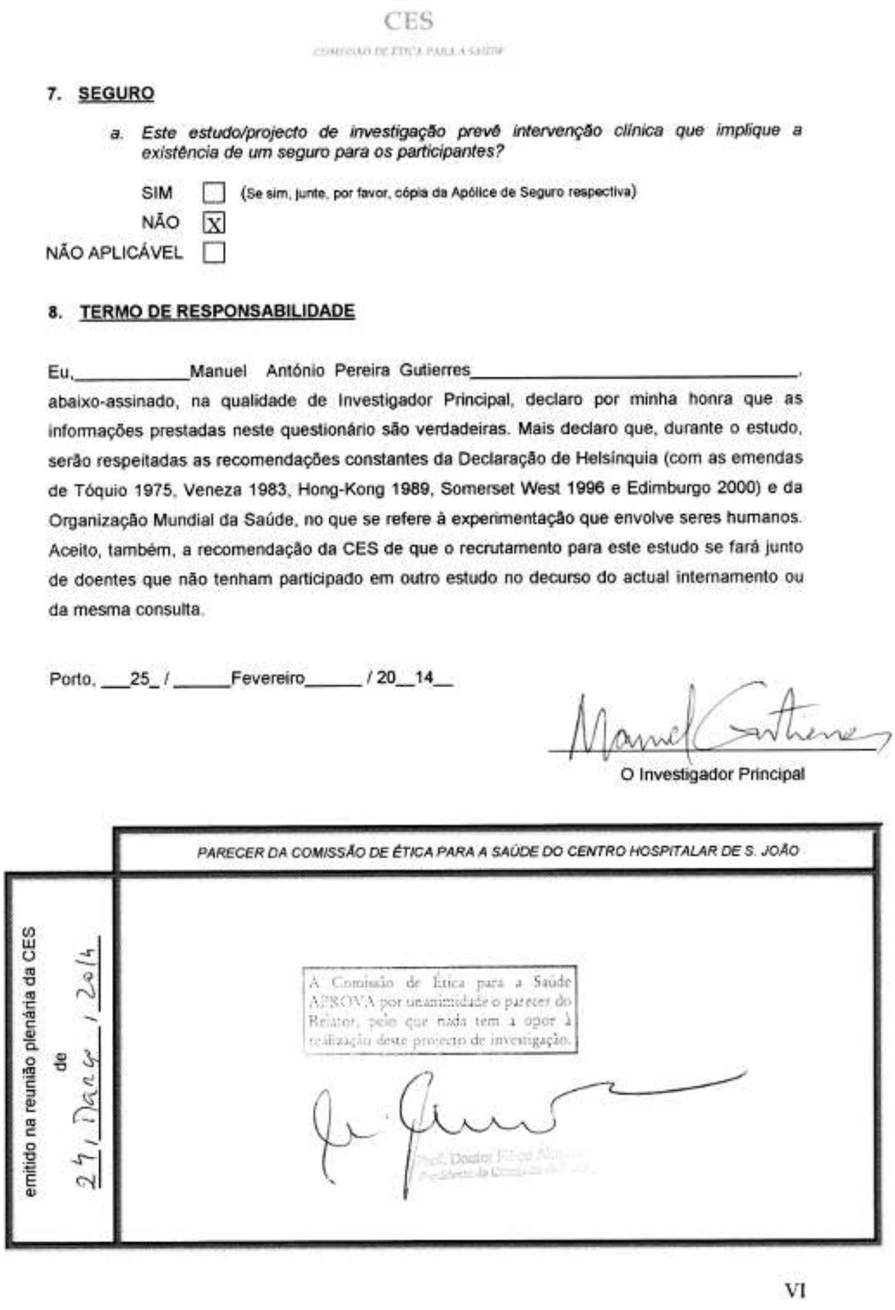
Não está prevista qualquer compensação para os participantes pela participação no estudo e o estudo não é financiado.

Em face da análise do protocolo proponho a sua aprovação pela CES do CHSJ.

Porto, 21 de Março de 2014

relator

Prof. Manuel Pestana



CES

COMISSÃO DE ÉTICA PARA A SAÚDE

7. SEGURO

a. *Este estudo/projecto de investigação prevê intervenção clínica que implique a existência de um seguro para os participantes?*

SIM ☐ (Se sim, junte, por favor, cópia da Apólice de Seguro respectiva)
NÃO ☒
NÃO APLICÁVEL ☐

8. TERMO DE RESPONSABILIDADE

Eu,__________Manuel António Pereira Gutierres__________, abaixo-assinado, na qualidade de Investigador Principal, declaro por minha honra que as informações prestadas neste questionário são verdadeiras. Mais declaro que, durante o estudo, serão respeitadas as recomendações constantes da Declaração de Helsínquia (com as emendas de Tóquio 1975, Veneza 1983, Hong-Kong 1989, Somerset West 1996 e Edimburgo 2000) e da Organização Mundial da Saúde, no que se refere à experimentação que envolve seres humanos. Aceito, também, a recomendação da CES de que o recrutamento para este estudo se fará junto de doentes que não tenham participado em outro estudo no decurso do actual internamento ou da mesma consulta.

Porto, __25_ / _____Fevereiro_____ / 20__14__

Manuel Gutierres
O Investigador Principal

PARECER DA COMISSÃO DE ÉTICA PARA A SAÚDE DO CENTRO HOSPITALAR DE S. JOÃO

emitido na reunião plenária da CES de 24 / Março / 2014

A Comissão de Ética para a Saúde APROVA por unanimidade o parecer do Relator, pelo que nada tem a opor à realização deste projecto de investigação.

Prof. Doutor Filipe Almeida
Presidente da Comissão de Ética

VI

Annex E – Certificate of Health and Well being Congress - Appendix A

Health
& Well-Being
Intervention
INTERNATIONAL
CONGRESS

CERTIFICATE

This is to certify that the Poster presentation entitle
Perception of Functionality Scale based on ICF and related with the DASH,
by Maria Graça, Joaquim Alvarelhão, Rui Costa, Andrea Ribeiro, Daniel Daly & João Paulo Vilas-Boas, was presented at the International Congress of Health and Well-being Intervention (ICHWBI 2019), organized by the RECI (Research in Education and Community Intervention) and the Jean Piaget Health School (ESS) / Viseu, which was held at the University Campus of Viseu of the Piaget Institute, Viseu, Portugal, on May 31 & June 01, 2019 (www.healthwellbeingcongress.ipiaget.org).

Gustavo Desouzart
ICHWBI 2019 *President of the Organizing Committee*

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Annex F – Certificate of Health and Well being Congress - Appendix B

Health
& Well-Being
Intervention
INTERNATIONAL
CONGRESS

CERTIFICATE

This is to certify that the Poster presentation entitle
Development of an aquatic therapy group's protocol program for older adults with upper limb disability, by Maria Graça, Ana Henriques, Joana Silva, Filipa Gual, Joaquim Alvarelhão, Rui Costa, Andrea Ribeiro, Daniel Daly & João Paulo Vilas-Boas was presented at the International Congress of Health and Well-being Intervention (ICHWBI 2019), organized by the RECI (Research in Education and Community Intervention) and the Jean Piaget Health School (ESS) / Viseu, which was held at the University Campus of Viseu of the Piaget Institute, Viseu, Portugal, on May 31 & June 01, 2019 (www.healthwellbeingcongress.ipiaget.org).

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