

Carolina Figueira

Physiotherapy after 12-week Arthroscopic Rotator Cuff Repair - Use of EMG Biofeedback

**Projeto elaborado com vista à obtenção
do grau de Mestre na Escola Superior de Saúde do Alcoitão,
na Especialidade de Fisioterapia em Condições Músculo-Esqueléticas**

Orientador: Professor Mestre José Esteves, Professor Adjunto, Fisioterapeuta

Coorientador: Professor Doutor Hugo Gamboa, Professor Auxiliar, Engenheiro Eletrotécnico e Informático

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Dezembro, 2019

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Abstract

Introduction: The rotator cuff tears are one of the most common musculotendinous ruptures, constituting the main cause of shoulder pain and instability. Due to the great development of shoulder surgery, and considering the frequency of these ruptures, the volume of postoperative patients in a physiotherapy clinic tends to increase, and there is a need to improve the efficiency and quality of treatment in physiotherapy in this population.

Objectives: To investigate the efficacy of manual therapy with or without the presence of electromyographic (EMG) biofeedback in patients with a 12-week after arthroscopic rotator cuff repair (RCR) for pain, active range of motion, muscle activation and functionality.

Methods: A randomized controlled trial was performed between February and June of 2018 and the participants were performing physiotherapy at a clinic in Lisbon. After the sample selection, patients were randomized into two groups: the control group that underwent manual physiotherapy and specific exercises (FtM group) and the experimental group (FtM + biofeedback group), where EMG biofeedback during the specific exercises was added to the same program as the FtM group. On data collection (evaluated before and after 3 weeks of intervention), each subject was submitted to four outcome measures: subjective pain perception at the maximum active range of motion supported by the patient, measure through Visual Analogue Scale (VAS); active range of motion (ROM), measure by goniometer; muscle activation time measure through biofeedback electromyography system PhysioPlux®; and functionality, measure with Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire. Between these two evaluations it was applied the physiotherapy intervention according group allocation.

Conclusions: The physiotherapy intervention, consisting of combined manual therapy with exercises using EMG biofeedback, resulted in greater improvements in inter-group group comparison.

Key words: physiotherapy, electromyography (EMG) biofeedback, arthroscopic rotator cuff repair, shoulder

Resumo

Introdução: As roturas da coifa dos rotadores são uma das roturas musculotendinosas mais comuns, constituindo a principal causa de omalgia e instabilidade do ombro. Devido ao grande desenvolvimento da cirurgia do ombro e tendo em conta a frequência destas roturas, o volume de pacientes em pós-operatório nas clínicas de fisioterapia tende a aumentar, existindo a necessidade de melhorar a eficiência e qualidade de tratamento em fisioterapia nesta população.

Objetivos: Investigar a eficácia da terapia manual com ou sem o *biofeedback* eletromiográfico (EMG) em utentes com 12 semanas após a artroscopia da coifa dos rotadores, relativamente à dor, amplitude de movimento ativa, ativação muscular e funcionalidade.

Metodologia: Estudo experimental randomizado controlado, foi realizado entre os meses de fevereiro e junho de 2018, numa clínica de fisioterapia em Lisboa. Após a seleção da amostra, os doentes foram distribuídos aleatoriamente em dois grupos: o grupo de controlo, que realizou fisioterapia manual e exercícios específicos (grupo FtM), e o grupo experimental, que realizou fisioterapia manual e exercícios específicos com *biofeedback* EMG (grupo FtM + *biofeedback*). Todos os doentes foram submetidos a uma avaliação antes e depois de três semanas da intervenção. Esta avaliação consistiu na percepção subjetiva de dor na máxima amplitude de movimento ativa suportada pelo utente, medida através da Escala Visual Análoga (EVA), na amplitude de movimento ativa, medida através do goniómetro, no tempo de ativação muscular, medido através de um sistema de *biofeedback* electromiográfico PhysioPlux®, e na funcionalidade medido através do questionário Disabilities of the Arm, Shoulder and Hand (DASH).

Conclusões: A intervenção em fisioterapia, consistindo na combinação da terapia manual com a realização dos exercícios específicos utilizando o *biofeedback* EMG, sugere melhores resultados na comparação entre os dois grupos.

Palavras-chave: fisioterapia, *biofeedback* electromiográfico (EMG), reparação da coifa dos rotadores por artroscopia, ombro

Introduction

The shoulder is a complex joint that has the greatest freedom of movement of the human body, thanks to the coordinated movements of the various joints, their capsuloligamentous structures and muscles that compose it (1). During the elevation of the arm (sagittal, frontal and scapular planes), all joints constituting the shoulder complex - scapulothoracic, glenohumeral, sternoclavicular and acromioclavicular- are involved. Specifically, during elevation of the arm at 180°, among three elevation planes, 60° occurs by scapulothoracic movement and 120° by glenohumeral movement. The overall scapulohumeral ratio is 2:1 (humeral elevation: scapulothoracic rotation). Therefore, the movement of the scapulothoracic joint results from coordinated movements of the sternoclavicular and acromioclavicular joints, which adjust according to the plan of elevation of the arm. There is a consensus that when active elevation of the arm is initiated, activity in trapezius and serratus anterior muscles each make important contributions to producing the upward rotation of the scapula (2). Whenever the rotator cuff (supraspinatus, infraspinatus, subscapularis and teres minor) and the deltoid muscles work in appropriate synergy, they keep the humeral head centered on the glenoid fossa, and little superior displacement occurs (2,3).

The rotator cuff tears are one of the most common musculotendinous ruptures, constituting the main cause of shoulder pain and instability (4,5). When the tear(s) occurs, the torque needed to move the shoulder as well as the force to stabilize this complex joint will be disturbed. In the review of Phadke *et al.* (2009), they found many studies which show the over-activity of the upper trapezius combined with reduced activity of the lower trapezius and the serratus anterior, in patients with shoulder pathology (6).

The development of rotator cuff tears could be associated with intrinsic mechanism (tissue degenerative / biochemical) or extrinsic mechanism (subacromial impingement / physical) or a combination. They may also be associated with traumatic (when the stress exceeds the failure strength / acute) or non-traumatic (when rotator cuff tears are asymptomatic and progress to rotator cuff arthropathy / sub-acute)(7).

According to the literature, rotator cuff tears are defined as small (<1 cm), medium (1 to 3 cm), large (3 to 5 cm), and massive (>5 cm) (4). Other classifications have considered a tear as massive if there involves two or more tendons (1). Rotator cuff tears can also be classi-

fied as a partial-thickness (which could involve bursal or articular side) or a full-thickness (when they reach more than 50% of the tendon thickness).

The incidence of rotator cuff tears increases with age, and the prevalence of massive rotator cuff tears ranges from 10% to 40% of all rotator cuff tears (8)(9). In addition, high rates of repaired cuffs re-tear were associated with increased age and rupture size (4). It is also known that the treatment with arthroscopic RCR is more frequent than open surgery, and also becomes more prevalent than conservative management for symptomatic full-thickness rotator cuff tears (10)(11). In 90% of arthroscopic rotator cuff repair (RCR) it is possible to find a full-thickness tears (4). Once that 76% of the rotator cuff tears are associated with an injury to the biceps long head tendon, tenodesis or tenotomy of biceps long-head tendon may be performed in RCR (12)(4).

There are several variables that influence patient recovery and predict the risk of re-tear. These involve the type of patient (age, profession, among others), rupture time before surgery, rupture size, tissue quality (degree of muscle atrophy and fatty degeneration), tendon mobility, repairs performed during surgery and the presence or absence of pathologies within the shoulder complex (13)(11)(14)(15). In the study of Shane, et al. (2009), which purpose was to identify potential predictors of function and tendon healing after an arthroscopic RCR, they conclude that the age (greater than 60 years old), the tear size (large and massive), biceps tenotomy or tenodesis, acromioclavicular joint procedures and a poor tendon tissue quality were the most significant independent factors that influence successful outcomes (have more tendon defects) (11,13). Still, in a recent review on rehabilitation treatment and complications of RCR, it is concluded that in most cases patients are advised to start physical therapy shortly after the first week of arthroscopic surgery to minimize the risk of postoperative rigidity and / or repair of failures (14).

This study took into account the current evidence-based on rehabilitation following arthroscopic RCR (10,14). Those rehabilitation protocols are based on clinical criteria and / or the elapsed time (Fig1). One of the fundamentals of the physiotherapy program on 12-week postoperative RCR (phase III- early strengthening phase) is to gradually increase strength, power, and endurance, gradual return normal functional activities of daily living, full work and modified recreational activities. Another goal in this rehabilitation stage is to maintain or to improve pain-free joint range of motion, promote dynamic shoulder stability, and optimize

neuromuscular control. In order to optimize the overall outcome, it is important in this phase, to invest in patient education.

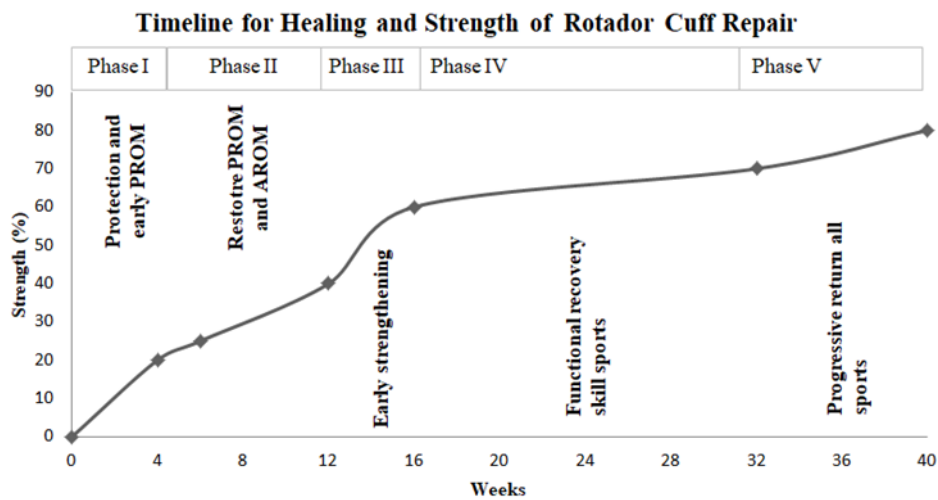


Figure 1 The successful rehabilitation program must be based on assessment so clinical goals can be achieved taking into account histological cure schedules. These data were from McCormick *et al.* study (14).

Biofeedback allows, through surface electromyography, an assessments and treatment more accurate and rigorous to the physiotherapist on the patient situation.

Several studies have demonstrated that the use of electromyographic (EMG) biofeedback has strong impacts in subjects with subacromial conflict syndrome (16). Thus, they conclude that there is greater effectiveness in muscle activation, learning or relearning of movement, improvement in motor control, improvement in proprioception and facilitates the reduction of muscular tension and, therefore, restoring pain-free motion and function (3,16–19). However, there is still no evidence of the effectiveness of EMG biofeedback in patients undergoing RCR.

Thus, this study intends to investigate the efficacy of manual therapy with or without the presence of EMG biofeedback in patients with a 12-week after arthroscopic RCR for pain, active range of motion, muscle activation and functionality.

Methods

Participants

This study involved eight participants (3 men and 5 women), aged between 47 and 67 years old (mean 55 years old SD 9,20 for the experimental group and mean 59,25 years old SD 7,15 for the control group), who had been submitted to an arthroscopic RCR. The data collection for the study was carried out between February and June of 2018 and the participants were performing physiotherapy at a clinic in Lisbon.

In order to carry out the research, it was necessary to contact the clinic's management to request permission to perform this study. Each participant was informed about the purpose, as well as who organizes and guides the study, procedures, information about their participation, the confidentiality of their information and duration of the study. In addition, they were also informed that they had the right to refuse participation in the study, at any time (either because they preferred to use other forms of shoulder treatment or ingestion of anti-inflammatory drugs, or for any other reason), without jeopardizing the assistance provided to them. The participants were also informed that there is no guarantee of continuity of treatment with EMG biofeedback. Lastly, the subjects were aware that in recent studies, the use of EMG biofeedback did not put any kind of risks to the participants, both during use and in the discontinuation of the study (16,17,20).

After the subjects aware of the information mentioned above, they were given an Informed Consent to sign, expressing their free will to participate in the study.

Potentially eligible participants were invited for an interview at the clinic where the physiotherapist filled in an application form for the study (that can be found in the supplementary material). The inclusion criteria were: participants had an arthroscopic rotator cuff repair; completed a 12 week period since the day of the surgery; beginning of physiotherapy before three weeks after surgery. Exclusion criteria were: patients diagnosed with rheumatoid arthritis; presence of fracture of the same upper limb; patients diagnosed with cognitive impairment; patients diagnosed with neurologic deficits; patients undergoing other forms of shoulder treatment besides the physiotherapy performed in the clinic where the study is taking place; and patients who take analgesic or anti-inflammatory medication.

Subjects were randomly allocated to one of two groups (control group or experimental group) by a simple randomization method. This was done by the subjects randomly removing one of the two balls that were inside a black bag. Each of the balls had written “control group” or “experimental group”.

Design overview

This study was a randomized controlled, correlational and longitudinal experimental study. Participants included in the 12-week postoperative period of the rotator cuff after fulfillment the inclusion and exclusion criteria were randomly separated for two groups: the control group that underwent manual physiotherapy and specific exercises (FtM group) and the experimental group (FtM + biofeedback group), where EMG biofeedback during the specific exercises was added to the same program as the FtM group.

On data collection (evaluated before and after 3 weeks of intervention), each subject was submitted to four outcome measures: subjective pain perception at the maximum active range of motion supported by the patient, active range of motion, functionality and muscle activation. Between these two evaluations it was applied the physiotherapy intervention according group allocation (Fig 2).

All procedures at the clinic (measurements and interventions) were conducted by a certified physiotherapist.

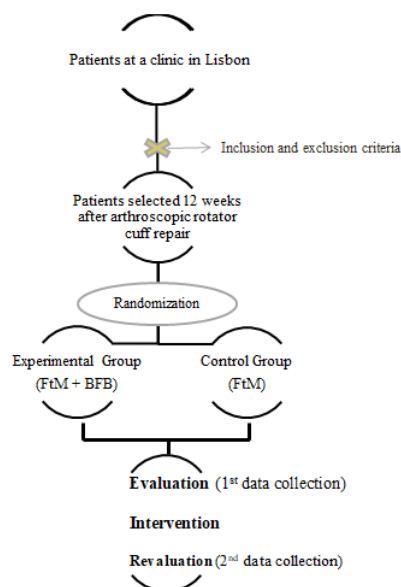


Figure 2 Design overview

Interventions

Physiotherapy lasted three weeks and was administered three times per week at least with a 48h interval to reduce fatigue and any carry-over effect. The treatment plan for both groups included manual physiotherapy where passive joint mobilization was employed to mobilize and stretch the soft tissue and supervised exercises taking into account a post-surgical rehabilitation protocol for the rotator cuff. The supervised exercises consisting of active shoulder girdle mobilization, stretching, strength and endurance exercises, stabilization exercises, neuromuscular control, pain relieving modality as per patient's requirement and education (appendix 1).

In addition, experimental group subjects performed the same exercises as control group but with EMG biofeedback during the specific exercises. The EMG biofeedback system used was the PhysioPlux® (PLUX, Lisbon, Portugal) that assists the physiotherapist and the patient in assessment and treatment.

The PhysioPlux® measures and collects the electromyography signals (EMG) of the intended muscles, during muscle contraction, through Ag-Cl electrodes located on the surface of the skin of the subject. Those sensors are connected to a device that has four EMG channels - biosignalsplux hub - and makes the acquisition of the signals, which sends them, in real time and via bluetooth, to a tablet. Biosignalsplux hub has four EMG channels that support up to 16-bit resolution and 1000 Hz sampling frequency per channel. The signals collected are processed and turned into graphics and animations by the PhysioPlux® software installed on the tablet. During the exercises, the patient and therapist receive that visual and/or auditory feedback presented by the software with the previously defined parameters by physiotherapist (21).

For the proper monitoring of electromyography signal the recommendations by PhysioPlux® user manual were followed to ensure an adequate signal-noise ratio and to minimize crosstalk from adjacent or underlying muscles (22). This involves preparing the subject (preparation of the skin - was shaved, swabbed with alcohol, and gently abraded with sandpaper -, electrodes placement and EMG signal verification) and measuring the timing of muscle activation (first while resting then with movements at a comfortable velocity for

maximal range of motion during sagittal, frontal and scapular planes, and third during resisted contractions of each of the four muscles - using manual muscle testing positions) (22).

The electrodes' placement was over the belly's muscle, on the skin and with a distance of two centimeters between each center, with a parallel orientation to the muscle fibers. The monitored muscles for data collection and the place of respective electrodes were: anterior deltoid, two centimeters distal and anterior to the acromion orientation; serratus anterior, below the axilla and anterior to the latissimus dorsi parallel to the muscle fibers over the sixth or seventh rib, with the shoulder flexed to 90°; upper trapezius, midway between the acromion and the cervical spine, and lower trapezius, inferior and medial to the inferior angle of the scapula. Those monitored muscles have a stabilizing goal for the scapulothoracic joint. The ground electrode was located on spinous process of C7.

The muscles that were monitored during the intervention sessions were just the upper and the inferior trapezius for three reasons: 1. those are the most functional muscles in this population, 2. because the subjects performed in an open space (not suitable for female conditions because it would imply standing in underwear), and 3. because they represent one of the local stabilizers -inferior trapezius- and one of global stabilizers -superior trapezius- of shoulder complex (23).

Outcome measures

All evaluation measures, except functionality, were obtained from ensemble averages of three trials.

The active range of motion of the shoulder was evaluated through a universal goniometer. The measuring techniques with the goniometer and the active movements requested were described by Palmer & Epler (2000). Those movements were flexion, extension, abduction, adduction, internal rotation and external rotation of the upper limb in question (24).

Participant-reported outcomes include pain levels through a subjective perception of pain with a visual analogue scale (VAS) from 0 to 10cm, where 0 suggests the absence of pain and 10 the maximum pain that the user experienced. This measurement was documented at the end of each movement sagittal plane, elevation in the plane of the scapula and in the

frontal plane. This scale is considered by several authors as one of the best methods of subjective measurement of pain intensity, presenting a moderate to good reliability (20,25).

The Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire reveals the symptoms and physical disabilities of the upper limb (s). It is intended for any disease, disturbance or injury to the upper limb (s), impacting on the individual's functionality at any age. The score is displayed on a scale ranging from 0 (maximum functionality) to 100 (maximum disability). This questionnaire proved to be reliable and valid for the Portuguese population (26) and received the best ratings for its clinimetric properties compared with another 16 condition-specific questionnaires for the evaluation of physical functioning in patients with shoulder disorders (27).

Muscle activation time is the period of time between the beginning of the contraction of the reference muscle (anterior deltoid) and the beginning of the contraction of the other muscles (serratus anterior, lower and upper trapezius). If the muscle activation time is negative it means that there was a pre-activation, which means that the muscle contraction started before the beginning of the anterior deltoid contraction. Whenever it's positive, muscle contraction starts after the onset of anterior deltoid contraction. It was evaluated with the biofeedback electromyography system PhysioPlux® (28). Patients were asked to perform movements at a comfortable velocity for maximal range of motion during the movement. Three planes were tested: sagittal plane, scapular and frontal planes up to a maximum of 45° high of the member in question (29). Muscle activity was assessed using temporal features. The PhysioPlux ® system has an automatic onset detection algorithm that enables the analysis of each individual muscle activation event, in addition to the overall analysis of the recording session (21,22,28). For those tests it was used a computer algorithm based on Hodges & Bui (1996), to identify the onset of EMG activity of each of the muscles (30). To identify the muscle activation time, the threshold was calculated based on EMG activity at rest. The threshold corresponds to the EMG activity mean at rest plus 3 times the value of the standard deviation of that mean. When analyzed signal exceeds predefined value of the threshold and maintains for at least a period of 12 ms, the time is detected as muscle activity region (onset muscle).

Statistical analysis

Before and after three weeks of physiotherapy intervention, the groups were compared in terms of muscle activation, active range of motion, subjective pain perception, and functionality.

Statistical analysis was performed using SPSS software version 24.0. Descriptive statistics were used to characterize the two groups, namely a frequency analysis. The Fisher test was used to verify the existence of significant differences between the two groups on baseline demographics.

The Wilcoxon non-parametric test with Bonferroni correction and the Effect Dimension calculation (standardized measure not influenced by the sample size) were used to determine intra-group differences between the first and last measurements. The Bonferroni correction was used to know if there were differences statistically significant (when $\text{sig}/p < 0,025$). The Effect Dimension calculation ($r = Z / \sqrt{n}$) was used to determine whether there were high differences ($r \geq 0,50$), moderate differences (0,30 to 0,49), or low differences (0,10 to 0,29) between the two assessment moments (31).

To perform inter-group comparison, the difference between second moment result and first moment result was first carried out for each variable, thus obtaining a score corresponding to the evolution of each subject. The Mann-Whitney test was then used to determine inter-group group differences in each variable. The mean and standard deviation for the scores for each variable were presented for both groups. Differences were considered statistically significant when $p \leq 0,05$. In the inter-group comparison the Effect Dimension was also calculated, using the same formula already used for the Wilcoxon test ($r = Z / \sqrt{n}$) and also the same reference values (31).

Results

All subjects (a total of eight patients, 3 men and 5 women) completed the intervention program study. The mean age of the patients in the experimental group ($n=4$) was 55 years old (SD 9,20) and the mean in the control group ($n=4$) was 59,25 years old (SD 7,15). The dominant arm in both groups was the right side. The surgery in the experimental group was 75% on the right side and 25% on the left side and in the control group 50% was on the right

side and 50% on the left side. None of them performed physiotherapy before the surgery or underwent other forms of shoulder treatment besides the physiotherapy performed in the clinic where the study is taking place or take analgesic or anti-inflammatory medication. Either rheumatoid arthritis presence or a family history of rheumatoid arthritis disease was reported as absent.

According to the literature, the tears were medium (1 to 3 cm) in 25% of experimental group participants, and massive (>5 cm or if involves two or more tendons) in 75% of experimental group (three participants) and 100% of control group (4)(1). In experimental group three patients (75%) were submitted to a tenotomy or tenodesis of the long head of the biceps, while in the control group all patients were also submitted. All patients in experimental group didn't undergo shoulder arthroplasty or hemiarthroplasty however in control group one of the participants did (25%).

By Fisher test analysis no statistically significant differences were found between the two groups on baseline demographics (table 1).

Table 1 Baseline demographics for the dependent for each group.

	Experimental Group (n=4)	Control Group (n=5)	Inferencial Statistics
Gender			Fisher test
Female	25% (1)	100% (4)	p =0,143
Male	75% (3)	0% (0)	
Age			Fisher test
46-55 years old	50% (2)	50% (2)	p=1,00
56-65 years old	25% (1)	25% (1)	
≥66 years old	25% (1)	25% (1)	
	Mean =55 SD =9,20 Min =46 Max =67	Mean =59,25 Sd =7,15 Min =55 Max =66	
Hand Dominance			
Right	100% (4)	100% (4)
Fisical Activity			Fisher test
Yes	50% (2)	0% (0)	p=0,429
No	50% (2)	100% (4)	
Involved Shoulder			Fisher test
Right	75% (3)	50% (2)	p=1,00
Left	25% (1)	50% (2)	
Performed Physiotherapy before surgery			
No	100% (4)	100% (4)
Take analgesic or anti- inflammatory medication			
No	100% (4)	100% (4)
Presence of rheumatoid arthritis disease			
No	100% (4)	100% (4)
Family History of rheumatoid arthritis disease			
No	100% (4)	100% (4)
Cuff Tears			
Large(3-5 cm)	25% (1)	0% (0)	Fisher test
Massive (> 5 cm/2 or more cuff tears)	75% (3)	100% (4)	p = 1,00
Tenodesis/tenotomy			Fisher test
Yes	75% (3)	100% (4)	p = 1,00
No	25% (1)	0% (0)	
Artroplasty/Hemiartroplasty			Fisher test
Yes	0% (0)	25% (1)	p = 1,00
No	100% (4)	75% (3)	

Abbreviations: EG = experimental group; CG= control group; SD= standard deviation; Min= minimum; Max= maximum

The Wilcoxon non-parametric test with Bonferroni correction and the Effect dimension calculation (standardized measure not influenced by the sample size) were used to compare the two moments of evaluation within each group in the variables under study - intra group differences. By Bonferroni correction ($0,05/2 = 0,025$), differences were considered statistically significant when $\text{sig}/p < 0,025$. The Effect Dimension calculation ($r = Z/\sqrt{n}$) was

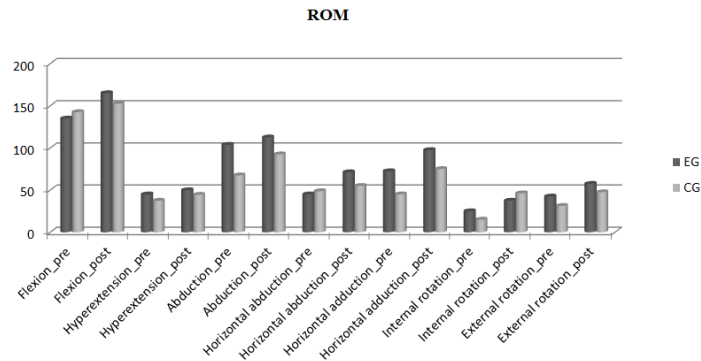
used to determine whether the differences between the two assessment moments were high ($r \geq 0,50$), moderate (0,30 to 0,49), or low (0,10 to 0,29) (31).

Although the Wilcoxon test revealed no significant differences the Effect Dimension revealed some high and moderate differences.

In intra-group range of movement variable analysis, on flexion (mean pre $135,00 \pm 5,77$ and mean post $165,00 \pm 12,91$, $r = 0,65$), hyperextension (mean pre $45,00 \pm 5,77$ and mean post: $50,00 \pm 0,00$, $r = 0,50$), horizontal abduction (mean pre $45,00 \pm 23,80$ and mean post $71,25 \pm 21,75$, $r = 0,65$), horizontal adduction (mean pre $72,50 \pm 12,58$ and mean post $97,50 \pm 17,08$, $r = 0,65$) ROM outcome a high differences between the first and last measurements was observed in experimental group. In control group, was observed a high differences on flexion (mean pre $142,50 \pm 28,72$ and mean post $152,50 \pm 23,63$, $r = 0,58$), hyperextension (mean pre $37,50 \pm 12,58$ and mean post $44,50 \pm 9,71$, $r = 0,58$), abduction (mean pre $67,50 \pm 28,72$ and mean post $92,50 \pm 37,75$, $r = 0,67$), horizontal adduction (mean pre $45,00 \pm 33,17$ and mean post $75,00 \pm 41,23$, $r = 0,65$), internal rotation (mean pre $15,00 \pm 12,91$ and mean post $46,25 \pm 14,93$, $r = 0,65$), and external rotation (mean pre $31,25 \pm 21,75$ and mean post $47,50 \pm 15,00$, $r = 0,57$).

Moderate differences were observed on internal (mean pre $25,00 \pm 20,82$ and mean post $37,50 \pm 12,58$, $r = 0,46$) and external rotation (mean pre $42,50 \pm 20,62$ and mean post $57,50 \pm 25,00$, $r = 0,33$) in the experimental group. In the control group only on horizontal abduction (mean pre $48,75 \pm 32,76$ and mean post $55,00 \pm 26,46$, $r = 0,48$) have revealed moderate differences.

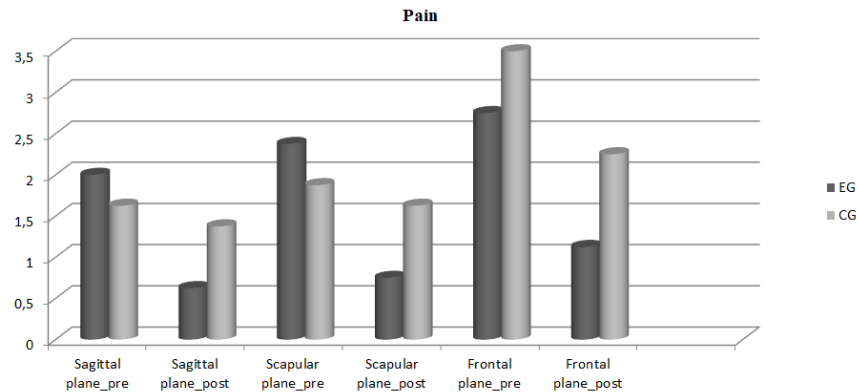
The only variable that showed no differences was on abduction in the experimental group (mean pre $103,750 \pm 24,2813$ and mean post $112,50 \pm 37,749$, $r = 0,05$), however also improved from the first to the last measurement.



Abbreviations: ROM= range of movement; EG = experimental group; CG= control group

Figure 3 ROM outcomes between initial and final moment.

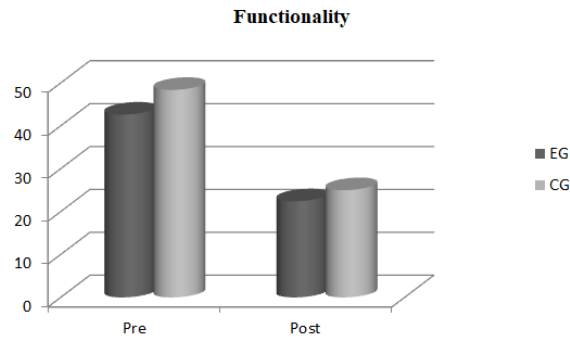
Only high differences between the first and last measurements were obtained in both groups on Pain variable. In experimental group, on sagittal plane (mean pre $2,00 \pm 2,16$ and mean post $0,63 \pm 0,48$, $r=0,57$), scapular plane (mean pre $2,36 \pm 1,80$ and mean post $0,75 \pm 0,65$, $r=0,65$) and frontal plane (mean pre $2,75 \pm 2,53$ and mean post $1,13 \pm 0,63$, $r=0,65$). In control group, there were obtained high differences just in two planes: on scapular plane (mean pre $1,88 \pm 1,93$ and mean post $1,63 \pm 2,02$, $r=0,50$) and on frontal plane (mean pre $3,50 \pm 2,38$ and mean post $2,25 \pm 1,55$, $r=0,65$).



Abbreviations: EG = experimental group; CG= control group

Figure 4 Pain outcomes between initial and final moment.

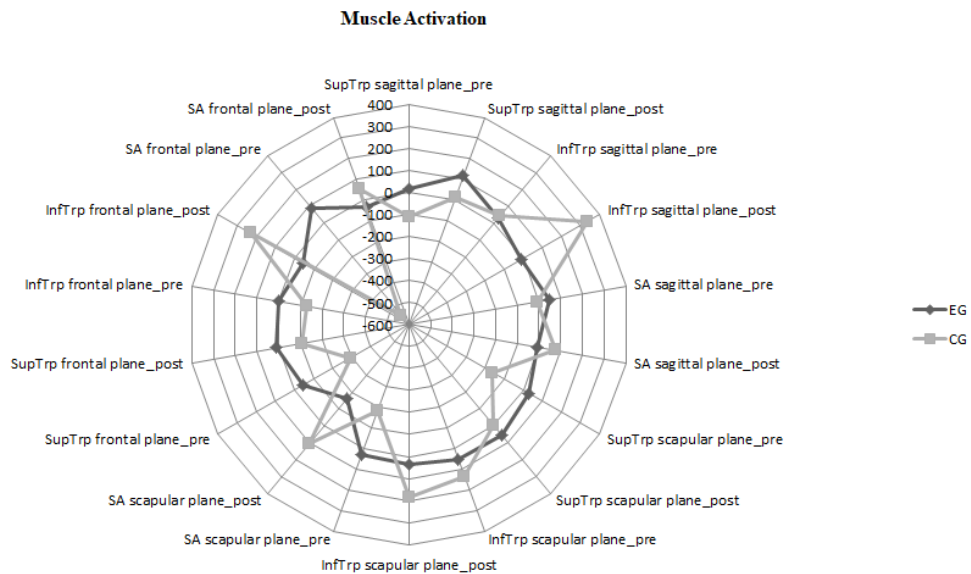
The DASH questionnaire showed intra-group high differences in the experimental group (mean pre $42,63 \pm 18,85$ and mean post $22,43 \pm 7,58$, $r=0,65$) and in control group (mean pre $48,39 \pm 12,36$ and mean post $25 \pm 9,79$, $r=0,65$).



Abbreviations: EG = experimental group; CG= control group

Figure 5 Functionality outcomes between initial and final moment.

Intra-group high differences were found on serratus anterior in scapular (mean pre -184,00±441,55 and mean post 103,50±200,78, $r=0,52$) and frontal (mean pre -545,00±517,11 and mean post 58,25±264,07, $r=0,65$) planes of control group. Also, there were found differences on superior trapezius activation in both groups. In the experimental group were observed moderate differences on sagittal plane (mean pre 16,00±46,48 and mean post 121,25±153,56, $r=0,39$) and on frontal plane (mean pre -44,50±49,40 and mean post 8,75±99,04, $r=0,39$), while in control group were on scapular plane (mean pre -161,50±320,88 and mean post -2,75±60,68, $r=0,39$). Thus, from the theoretical point of view, both groups improved in terms of neuromuscular coordination (the upper trapezius contracted later than the first measures).



Abbreviations: EG = experimental group; CG= control group; SupTrp= superior trapezius; InfTrp= inferior trapezius; SA= serratus anterior

Figure 6 Muscle activation outcomes between initial and final moment

The difference of results between the last and the first measurement for each variable was used to compare the two groups. The Mann-Whitney U test was used to analyze the inter-group comparison. On the variables that didn't show significant differences, the Effect Dimension calculation was used to determine whether there were high ($r \geq 0,50$), moderate (0,30 to 0,49) or low differences (0,10 to 0,29) (table 2).

The Mann-Whitney U test revealed a statistically significant difference ($p \leq 0,05$) between the two groups group comparison on Pain (scapular plane), Range of Movement, (flexion) and Muscle Activation (serratus anterior in frontal plane) variables. In the variable Pain (scapular plane) the result decreases more in the experimental group than in the control group, on Range of Movement (flexion) the result increases more in the experimental group than in the control group, and in Muscle Activation (serratus anterior in frontal plane) decreases in the experimental group and increases in the control group.

In inter-group analysis, was used the Effect Dimension calculation on the variables that didn't show significant differences. There were observed high differences on Range of Movement in horizontal abduction (the result increases more in the experimental group than in the control group) and internal rotation (the result increases less in the experimental group than in the control group). There were moderate differences on Functionality (in the experimental group they revealed less improvement on functionality than in the control group), on Pain (in sagittal plane the patients revealed less pain than in the experimental group than in the control group), and on Muscle Activation (the inferior trapezius in sagittal plane contract earlier than the control group). There were low differences on Pain (in frontal plane the patients revealed less pain in the experimental group than in the control group), Range of Movement (the result increases less in the experimental group than in the control group in hyperextension, horizontal adduction and external rotation movements) and on Muscle Activation (both in the sagittal plane- serratus anterior-, and in the scapular plane- superior trapezius, inferior trapezius, and serratus anterior- contract earlier than the control group).

Table 2 Inter-group group comparison using Mann-Whitney and the Effect Dimension tests

	Group	N	Mean	Std. Deviation	Mann-Whitney	Effect Dimension ($r = Z / \sqrt{n}$)
Functionality	EG	4	-20,20	11,92	U=4,00	r = -0,41
	CG	4	-23,39	5,39	Z=-1,16, p = 0,248	
Pain: Sagittal plane	EG	4	-1,38	1,80	U=5,00	r = -0,31
	CG	4	-,25	1,04	Z=-0,87, p = 0,381	
Pain: Scapular plane	EG	4	-1,63	1,31	U=1,00	r = -0,74
	CG	4	-,25	,29	Z=-2,08, p = 0,037*	
Pain: Frontal plane	EG	4	-1,63	1,93	U=7,00	r = -0,11
	CG	4	-1,25	,87	Z=-0,30, p = 0,762	
ROM: Flexion	EG	4	30,00	8,16	U=0,50	r = -0,78
	CG	4	10,00	8,16	Z=-2,20, p = 0,027*	
ROM: Hyperextension	EG	4	5,00	5,77	U=7,00	r = -0,11
	CG	4	7,00	4,76	Z=-0,32, p = 0,752	
ROM: Abduction	EG	4	8,75	23,94	U=7,50	r = -0,05
	CG	4	25,00	30,00	Z=-0,15, p = 0,878	
ROM: Horizontal abduction	EG	4	26,25	22,87	U=2,50	r = -0,57
	CG	4	6,25	9,46	Z=-1,61, p = 0,108	
ROM: Horizontal adduction	EG	4	25,00	23,80	U=6,50	r = -0,16
	CG	4	30,00	24,49	Z=-0,44, p = 0,659	
ROM: Internal rotation	EG	4	12,50	17,08	U=2,00	r = -0,62
	CG	4	31,25	8,54	Z=-1,75, p = 0,080	
ROM: External rotation	EG	4	15,00	31,09	U=6,50	r = -0,15
	CG	4	16,25	13,77	Z=-0,44, p = 0,663	
MA: SupTrp sagittal plane	EG	4	105,25	156,87	U=8,00	r = 0,00
	CG	4	125,25	227,52	Z=-0,00, p = 1,00	
MA: InfTrp sagittal plane	EG	4	-41,75	156,57	U=4,00	r = -0,41
	CG	4	296,25	599,08	Z=-1,16, p = 0,248	
MA: SA sagittal plane	EG	4	-58,25	189,55	U=7,00	r = -0,10
	CG	4	86,75	416,72	Z=-0,29, p = 0,773	
MA: AD sagittal plane	EG	4	,00	,00 ^a	U=8,00	r = 0,00
	CG	4	,00	,00 ^a	Z=-0,00, p = 1,00	
MA: SupTrp scapular plane	EG	4	29,75	52,24	U=7,00	r = -0,10
	CG	4	158,75	309,49	Z=-0,29, p = 0,773	
MA: InfTrp scapular plane	EG	4	-14,00	79,60	U=6,00	r = -0,20
	CG	4	51,50	594,13	Z=-0,58, p = 0,564	

MA: SA scapular plane	EG	4	-144,50	477,14	U =6,00	r =-0,20
	CG	4	287,50	401,51	Z =-0,58, p = 0,564	
MA: AD scapular plane	EG	4	,00	,00 ^a	U =8,00	r =0,00
	CG	4	,00	,00 ^a	Z =-0,00, p = 1,000	
MA: SupTrp frontal plane	EG	4	53,25	93,06	U =8,00	r =0,00
	CG	4	185,50	563,51	Z =-0,00, p = 1,000	
MA: InfTrp frontal plane	EG	4	-50,75	158,51	U =4,00	r =-0,41
	CG	4	361,00	661,57	Z =-1,16, p = 0,248	
MA: SA frontal plane	EG	4	-120,25	308,23	U =1,00	r =-0,71
	CG	4	603,25	406,04	Z =-2,02, p = 0,043*	
MA: AD frontal plane	EG	4	,00	,00 ^a	U =8,00	r =0,00
	CG	4	,00	,00 ^a	Z =-0,00, p = 1,000	

Abbreviations: MA: muscle activation; EG = experimental group; CG= control group; SupTrp= superior trapezius; InfTrp= inferior trapezius; SA= serratus anterior; AD= anterior deltoid; * $P \leq 0,05$

Although the differences weren't statistically significant for all variables, the overall results appear to be favorable to biofeedback use.

Discussion

In the present study, the randomization increased the internal and external validity. The preparation of the records, as the evaluation proceeded, or immediately after the evaluation, allowed minimizing / avoiding the memory bias. The subjects did not participate in the study blindly, neither was the application of the techniques and methods by the physiotherapist, thus increasing the risk of bias. However, instruments with high validity were selected and different sources of information were used (20,24–27,30).

Regarding the baseline demographics of the subjects, although the sample was randomized, there was the same number of participants in both groups but there weren't homogeneous groups as to their characteristics.

There were observed higher percentage of male gender in experimental group (75%) unlike the control group where all participants were female. However, Shane and colleagues (2009) observed in their study that there were no statistically significant differences between gender and post-operative tendon integrity.

In the studies of Shane, et al. (2009), they conclude that after an arthroscopic RCR the age (greater than 60 years old), the tear size (large and massive), biceps tenotomy or te-

nodesis, acromioclavicular joint procedures and a poor tendon tissue quality were the most significant independent factors that influence successful outcomes (13)(11). In the present study there were two patients in the experimental group (EG) and one patient in the control group (CG) who have more than 60 years old. All of them have a large or massive rotator cuff tear, one patient in EG haven't been submitted to a biceps tenotomy or tenodesis and one patient in CG have been submitted to an arthroplasty or hemiarthroplasty procedure.

The information of the tissue quality haven't been included but it is closely related with the greater age (2 EG patients and 1 CG patient >60 years old), absence of physical activity before the cuff tears (50% in EG and 100% in CG) , time of the cuff tears before surgery (none of them performed physiotherapy before surgery), and presence of rheumatoid arthritis disease (none of them) (32). Still, Shane et al (2009), refer that pathology involving the long head of the biceps (75% in EG and 100% in CG) and acromioclavicular joint (none in EG and 25% in CG) has been associated with massive rotator cuff tears and likely reflects the severity of rotator cuff degeneration (11).

By Fisher test analysis no statistically significant differences were found between the two groups on baseline demographics.

By Bonferroni correction in intra-group repeated-measurement analysis indicated that subjects in the two intervention groups had no significant differences on pre to post intervention period. Although, the Effect Dimension calculation revealed some high and moderate differences.

The Mann-Whitney test was used to determine inter-group differences on active range of motion, subjective pain perception, functionality and muscle activation and revealed some significant differences. Also, in inter-group comparison by Effect Dimension showed high, moderate and low differences on the other variables.

Results suggest that the group receiving biofeedback had the higher changes in most measurements. However, this study might have shown more significant results if the sample size were larger.

Effects on ROM

In intra-group analysis, there were some high and moderate differences on range of motion by Effect Dimension calculation. Both groups have high differences on flexion, hyperextension and horizontal adduction movements. In addition, in EG there were also high differences on horizontal abduction and in CG on abduction and on rotations movements. The other movements in each group had moderate differences in the first to the second data collection except on abduction movement in EG that hadn't any differences.

In inter-group comparison, EG have better improvements on flexion ($p \leq 0,05$) and on horizontal abduction (mean EG $26,25 \pm 22,87$ and mean CG $6,25 \pm 9,46$, $r = 0,57$) movements. Low improvement differences were observed in CG on hyperextension, horizontal adduction and on external rotation movements. The lower significance of this variable could be related on the fact that range of movement was almost normal on subjects of both groups. For these reason it could be interesting, in further studies, to investigate the influence of this variable on patient recovery at initial time-frame with or without EMG biofeedback.

In other studies using EMG biofeedback training of the shoulder girdle, there were observed improvements on range of movement and also they suggest that gains in range of motion are associated with pain relief (33,34). In a Cochrane systematic review leading by Woodford & Price (2009), they search for a randomized and quasi-randomized studies comparing EMG biofeedback with a control group for motor function recovery in stroke patients. Although this systematic review wasn't directly related to the clinical condition of the current study, they found one trial suggested a benefit in ROM at the shoulder (35).

Effects on pain

In intra-group analysis, results suggest that the two intervention groups had high differences on pain relief between the first and last measurements, however didn't reach statistical significance.

In inter-group comparison, the EG had more pain relief compared to CG. There was a significant difference on scapular plane ($p \leq 0,05$), high difference on sagittal plane (mean EG $-1,38 \pm 1,80$ and mean CG $-0,25 \pm 1,04$, $r = -0,31$) and low difference on frontal plane (mean EG $-1,63 \pm 1,93$ and mean CG $-1,25 \pm 0,87$, $r = -0,11$).

The above results suggest that gains on pain relief are more associated with motor control increase, because the group that received EMG biofeedback showed better results than the group who performed exercises without EMG biofeedback. Our results are in agreement with the study of Gisbon and colleagues (2004), who demonstrated that altered dynamic control appears to be a significant contributing factor in musculoskeletal dysfunction and further that the function of deep stabilizers is compromised in the presence of pain.

Effects on functionality

In intra-group analyses, the DASH questionnaire revealed high differences in each groups. In the inter-group group differences the control group reported a moderately different improvement in functionality than in the experimental group (mean EG $-20,20 \pm 11,92$ and mean CG $-23,39 \pm 5,39$, $r = 0,41$). However, there were no statistically significant differences in both intra-group and inter-group group differences. Despite the fact that in the present study there are no significant differences, the results are in agreement with the study by Shane et al (2009) which shows that although the experimental group (higher percentage of men) had better functionality score at first (mean pre $42,63 \pm 18,85$) and in the second (mean post $22,43 \pm 7,58$) evaluations, the group control (only female gender) had a greater improvement from the first to the second evaluations (13). These results could also be due the fact that just as in the baseline the two groups did not have same scores (better score in the EG). Thus the CG had more opportunity to improve because the score was higher, i.e., worse functionality than the EG. Even so, when the DASH scores are observed in the two evaluations, the EG always has better results.

Effects on muscle activation

High and moderate differences were observed in intra-group comparison. CG showed improvements on anterior serratus (contracted later than the first measures) in scapular and frontal planes. Also in intra group differences, both groups have moderate improvement on superior trapezius (contracted later than the first measures).

In inter-group, there was a significant difference ($p \leq 0,05$) on anterior serratus improvement in frontal plane of EG. In this analysis comparison, the results showed high, moderate and low differences in almost all muscle activation and planes in EG.

In the present study, gains of local and global scapulothoracic muscle activation in the concentric and eccentric movements of MS elevation are related with motor control improvement. As expected through the review of Phadke *et al.* (2009), in the first measures was observed an over-activity of the upper trapezius combined with reduced activity of the lower trapezius, resulting in abnormal scapulothoracic muscle activation (6).

The results on muscle activation are in agreement with other authors which conclude that motor control mechanisms can be trained. This means that when a correct movement is repeated and experienced, the neuromuscular mechanism by feedback gives way to activation by feedforward, also allowing correct timings of muscle activation (16).

The greater improvement of neuromuscular coordination in the EG of this study is in agreement with other studies using EMG biofeedback on recovery of shoulder instability and subacromial conflict syndrome (3,16–18). Also, some studies conclude that this improvement is related with better pain-free motion and function.

Conclusion

This study design was a randomized controlled, correlational and longitudinal experimental to determine the efficacy of manual therapy with or without the presence of EMG biofeedback on pain, active range of motion, muscle activation and functionality after arthroscopic RCR. It was used a validated, shoulder-specific outcome measures.

The physiotherapy intervention, consisting of combined manual therapy with exercises using EMG biofeedback, resulted in the greatest improvements (statistically significant) in inter-group comparison on pain, active flexion ROM and on muscle activation of serratus anterior in frontal plane, compared to manual therapy with exercises without EMG biofeedback.

Although this study demonstrates that the use of manual techniques and the specific exercises of the shoulder complex performed with EMG biofeedback had the best results, there were also improvements in the other group. This may be due to the fact that the post-surgical rehabilitation protocol for the RCR taking into account the current evidence-based on

rehabilitation protocols could influence those improvements results. So it would be interesting to investigate the influence of several protocols with or without EMG biofeedback combined with other techniques.

The results of present study seem to conclude that greater restoring of scapulothoracic muscles is more effective when using electromyographic Biofeedback in performing specific exercises. Further studies are needed to confirm the trend of the results obtained in this study, using larger samples and longer intervention times. It would be interesting to have further studies with larger samples allowing a large arthroscopic RCR patient population in Portugal. Also, it would be important to provide data of longer intervention time (during more time frames) and also, a two or more years of follow-up to verify the effectiveness of gains during the intervention period, as well as monitorizing other dimensions of pain and functionality.

Bibliography

1. Frankle M. Rotator Cuff Deficiency of the Shoulder. Gumpert E, editor. New York: Thieme; 2008. 1-201 p.
2. Ludewig PM, Phadke V, Braman JP, Hassett DR, Cieminski CJ, Laprade RF. Motion of the shoulder complex during multiplanar humeral elevation. *J Bone Jt Surg - Ser A*. 2009;91(2):378–89.
3. Levangie P, Humphrey E. The shoulder girdle: Kinesiology review. *CEU Polit Sci J*. 2000;8(12):15.
4. Cartucho A, Espargueira-Mendes J. O Ombro. Lidel. Lisboa; 2009. 171-176 p.
5. Panzina A, Gutierrez M. Rutura maciça da coifa dos rotadores. *Rev Port Ortop Traum*. 2013;21(3):297–312.
6. Phadke V, Camargo P, Ludewig P. Scapular and rotator cuff muscle activity during arm elevation: A review of normal function and alterations with shoulder impingement. *Rev Bras Fisioter*. 2009;13(11):1–9.
7. Aboelmagd T, Rees J, Gwilym S. Rotator cuff tears: pathology and non-surgical management. *Orthop Trauma*. 2018;32(3):159–64.
8. Bedi A, Dines J, Warren RF, Dines DM. Massive Tears of the Rotator Cuff. *J Bone Jt Surgery-American Vol*. 2010;92(9):1894–908.
9. Rousseau T, Roussignol X, Bertiaux S, Duparc F, Dujardin F, Courage O. Arthroscopic repair of large and massive rotator cuff tears using the side-to-side suture technique. Mid-term clinical and anatomic evaluation. *Orthop Traumatol Surg Res*. 2012;98:S1–8.
10. Thigpen CA, Shaffer MA, Gaunt BW, Leggin BG, Williams GR, Wilcox RB. The American Society of Shoulder and Elbow Therapists' consensus statement on rehabilitation following arthroscopic rotator cuff repair. *J Shoulder Elb Surg*. 2016;25(4):521–35.
11. Nho SJ, Brown BS, Lyman S, Adler RS, Altchek DW, MacGillivray JD. Prospective analysis of arthroscopic rotator cuff repair: Prognostic factors affecting clinical and

- ultrasound outcome. *J Shoulder Elb Surg.* 2009;18(1):13–20.
12. Azevedo C, Vinga S. Reinservação artroscópica do supra-espinhoso: O que fazer com a longa porção do bicípito braquial? Estudo prospetivo de 42 doentes. *Rev Port Ortop e Traumatol.* 2012;20(1):45–56.
 13. Nho SJ, Shindle MK, Adler RS, Warren RF, Altchek DW, MacGillivray JD. Prospective analysis of arthroscopic rotator cuff repair: Subgroup analysis. *J Shoulder Elb Surg.* 2009;18(5):697–704.
 14. McCormick F, Wilcox RB, Alqueza A. Postoperative Rotator Cuff Repair Rehabilitation and Complication Management. *Oper Tech Orthop.* 2015;25(1):76–82.
 15. Gibson JC. (iii) Rehabilitation after shoulder instability surgery. *Curr Orthop.* 2004;18(3):197–209.
 16. Ma C, Szeto GP, Yan T, Wu S, Lin C, Li L. Comparing biofeedback with active exercise and passive treatment for the management of work-related neck and shoulder pain: A randomized controlled trial. *Arch Phys Med Rehabil.* 2011;92(6):849–58.
 17. Giggins OM, Persson UMC, Caulfield B. Biofeedback in rehabilitation. *J Neuroeng Rehabil.* 2013;10(1):11.
 18. Voerman GE, Sandsjö L, Vollenbroek-Hutten MMR, Larsman P, Kadefors R, Hermens HJ. Effects of ambulant myofeedback training and ergonomic counselling in female computer workers with work-related neck-shoulder complaints: A randomized controlled trial. *J Occup Rehabil.* 2007;17(1):137–52.
 19. Aksac B, Aki S, Karan A, Yalcin O, Isikoglu M, Eskiyurt N. Biofeedback and pelvic floor exercises for the rehabilitation of urinary stress incontinence. *Gynecol Obstet Invest.* 2003;56(1):23–7.
 20. Boonstra AM, Preuper HRS, Reneman MF, Posthumus JB, Stewart RE. Reliability and validity of the visual analogue scale for disability in patients with chronic musculoskeletal pain. *Int J Rehabil Res Zeitschrift fur Rehabil Int Rech Readapt.* 2008;31(2):165–9.
 21. PLUX Wireless Biosignals S.A. Biosignalplux user manual. SpringerReference.

- Lisboa; 2013.
22. PLUX Wireless Biosignals S.A. Physioplux user manual. Lisboa; 2016.
 23. Santos C. Protocolo de fisioterapia, com auxílio de Biofeedback electromiográfico, em utentes com disfunções do ombro: efeitos na dor, funcionalidade e estabilidade dinâmica. Instituto Politécnico de Setúbal. Escola Superior de Saúde; 2011.
 24. Palmer & Epler. Fundamentos das Técnicas de Avaliação Musculoesquelético. Guanabara. Rio de Janeiro: Lippincott-Raven Publishers; 2000. 372 p.
 25. Taddio A, O'Brien L, Ipp M, Stephens D, Goldbach M, Koren G. Reliability and validity of observer ratings of pain using the visual analog scale (VAS) in infants undergoing immunization injections. *Pain*. 2009;147(1-3):141-6.
 26. Santos, J. e Gonçalves R. Adaptação e validação cultural da versão portuguesa do Disabilities of the Arm Shoulder and Hand – DASH. *Rev Bras Ortop Port Ortop e Traumatol*. 2006;14(3):29-44.
 27. Bot SDM, Terwee CB, Van Der Windt DAWM, Bouter LM, Dekker J, De Vet HCW. Clinimetric evaluation of shoulder disability questionnaires: A systematic review of the literature. *Ann Rheum Dis*. 2004;63(4):335-41.
 28. Sung P, Hilario J, Amitani I, Baskin RJ, Kowalczykowski SC, Pellegrini L, et al. User Manual. *Curr Opin Chem Biol*. 2010;14(1):71-9.
 29. Oliveira C. Biofeedback Electromiográfico. 2016.
 30. Hodges PW, Bui BH. A Comparison of Computer-Based Methodes for the Determination of Onset of Muscle Contration Using Electromyography. *Electroencephalo Clin Neurophysiol*. 1996;101(6):511-9.
 31. Cohen J. Statistical Power Analysis for the Behavioral Sciences. Vol. 506, Nature. 1988. 1-567 p.
 32. Lipman K, Wang C, Ting K, Soo C, Zheng Z. Tendinopathy: Injury, repair, and current exploration. *Drug Des Devel Ther*. 2018;12:591-603.
 33. San Juan JG, Gunderson SR, Kane-Ronning K, Suprak DN. Scapular kinematic is

- altered after electromyography biofeedback training. *J Biomech.* 2016;49(9):1881–6.
34. Marques J, Matias R. Programa de exercícios escapulotorácicos para utentes com disfunção do complexo articular do ombro : desenvolvimento e aplicação num software para biofeedback cinemático. Escola Superior de Saúde do Instituto Politécnico de Setúbal; 2015.
 35. Woodford H, Price C. EMG biofeedback for the recovery of motor function after stroke (Cochrane review). *Cochrane Database Syst Rev* 2007;Issue 2. 2009;(1):1–17.

Apêndices

1. Formulário para aplicação do estudo experimental

Data da entrevista inicial: ____/____/_____

1. ID:
2. Nome
3. Idade
4. Género: F _ M _
5. Peso (Kg)
6. Altura (m)
7. Profissão?
8. Qual o mecanismo que despoletou a rotura?
9. Qual o membro superior dominante?
10. Qual o ombro lesionado?
11. Realiza / realizava antes da rotura alguma atividade física? Não _ Sim_ Qual?
12. Quando sofreu a rotura? Data: ____/____/_____
13. Quando foi operado? Data: ____/____/_____
14. Quando iniciou a fisioterapia após a cirurgia? Data: ____/____/_____
15. Quantas sessões de fisioterapia realizou após a cirurgia?
16. Realizou fisioterapia no mesmo local onde se encontra?
17. Realizou fisioterapia antes da cirurgia? Não _ Sim_ Quantas sessões?
18. Tem artrite reumatoide?
19. Tem alguém na família com artrite reumatoide?
20. Toma medicação? Não _ Sim_ Qual/quais?
21. Realiza outras formas de tratamento para o ombro fora da clínica?

Informação Médica

1. Diagnóstico clínico (tipo de cirurgia: artroscopia/cirurgia aberta, qual o(s) músculo(s) sujeito(s) a reparação cirúrgica, tamanho da rotura (tipicamente classificado em categorias: pe-

quena (<1cm), média (1-3cm), grande (>3-5cm), maciça (>5cm)), com/sem tenodese ou tenotomia):

2. Sofreu alguma fractura no membro superior do mesmo lado?

3. Realizou artroplastia ou hemiartroplastia do ombro? Sim _ Não_

2. Protocolo de Investigação

Collection Protocol:

1. Give an Informed Consent to sign, expressing their free will to participate in the study (1st collection only).
2. Physiotherapist filled in an application form for the study (1st collection only).
3. Subjects randomly removing one of the two balls that were inside a black bag. Each of the balls had written “control group” or “experimental group” (1st collection only).
4. Measuring active range of motion of the shoulder through a universal goniometer.
5. Measuring subjective perception of pain with a visual analogue scale (VAS);
6. Measuring Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire;
7. Preparing the subject: preparation of the skin (was shaved, swabbed with alcohol, and gently abraded with sandpaper), electrodes placement (anterior deltoid, serratus anterior, upper trapezius, lower trapezius and on spinous process of C7), and EMG signal verification.
8. Measuring the timing of muscle activation with the biofeedback electromyography system PhysioPlux®: first while resting then with movements at a comfortable velocity for maximal range of motion during sagittal, frontal and scapular planes, and third during resisted contractions of each of the four muscles - using manual muscle testing positions.

Intervention protocol:

1. Reevaluation of the subject: informal observation (observation of the patient in dynamic and static situations, assessing the quality of movement, as well as postural characteristics and facial expression), pain, behavior of symptoms during the day and at night.

2. Preparing the subject: preparation of the skin (was shaved, swabbed with alcohol, and gently abraded with sandpaper), electrodes placement (upper trapezius, lower trapezius and on spinous process of C7), and EMG signal verification) (experimental group only).
3. Measuring the timing of muscle activation with the biofeedback electromyography system PhysioPlux®: first while resting, then with movements at a comfortable velocity for maximal range of motion during sagittal, frontal and scapular planes, and third during resisted contractions of each of the four muscles - using manual muscle testing positions (experimental group only).
4. Exercises taking into account a post-surgical rehabilitation protocol for the rotator cuff.
5. Manual physical therapy where passive joint mobilization was employed to mobilize and stretch the soft tissue.

3. Protocolo de Exercícios

Exercises	Description
AAROM and AROM	<ol style="list-style-type: none"> 1. In sitting position, slide on the table with a roll (arms supported on the roll at the width of the shoulders)(1). 2. In standing position, slide both hands side by side on the wall with a paper(1). 3. Lying down with a cane grasped at chest height with the elbow almost fully extended (1): <ol style="list-style-type: none"> 3.1. carry the cane toward the head; 3.2. take the cane to the right and left; 3.3. twist the cane; 3.4. circles to the right and then to the left with the cane.
Stretch	<ol style="list-style-type: none"> 4. Internal Rotation stretch: In standing position, place operated arm behind at the waistline and use a towel to assist the same hand higher towards shoulder blade (1). 5. Abduction stretch: In standing position, bend both elbows and shoulders to 90 degrees. Place both hands and elbows on a door frame and keeping arms still, gently tilt the trunk ahead

	<p>(1).</p> <p>6. External Rotation stretch: In sitting position, with the elbow bent to 90° grasped a cane with supine hands and use the opposite hand to assist operated arm to rotate outwards (1).</p> <p>7. Cross body stretch: In standing position, support the elbow with opposite hand/arm. Gently bring the elbow toward the opposite shoulder across the body (1).</p>
Neuromuscular control for serratus anterior and lower trapezius in standing position	<p>8. “Corner” exercise (lower trapezius): with a corner in middle of the scapulas, retracted them and hold for 5 seconds and slowly return.</p> <p>9. Wall-slide with swiss ball (serratus anterior): ulnar border of the forearms in contact with the ball, and the shoulders and elbows at 90°, slide the ball up the wall and return (2)(6).</p> <p>1. Crush the medicine balls (serratus anterior and lower trapezius): with hands on 2 medicine balls at chest height and with the elbows straight, make full scapular protraction and retraction (3).</p>
Elastic resistance in standing position	<p>2. Shoulder extension- typing elastic overhead height: elastic grasped at chest height with the elbow almost fully extended and the shoulder externally rotated 45° (thumb up), and the scapula in a retracted position. With the arms kept at the side of the body, extend the both superior members and then slowly return to the starting position (4).</p> <p>3. Shoulder extension- typing elastic at waist-height: elastic grasped at waist height, elbows almost fully extended and the shoulder externally rotated 45° (thumb up), pull arms backwards keeping shoulders straight and then slowly return to the starting position (5).</p> <p>4. Shoulder Flexion- typing elastic at waist-height: elastic grasped at waist height, elbows almost fully extended and the shoulder externally rotated 45° (thumb up), raise arms in front at chest height keeping shoulders straight and then slowly re-</p>

	<p>turn to the starting position (5).</p> <p>5. Shoulder Scaption (abduction in scapular plane) - typing elastic at waist-height: elastic grasped at waist height, elbow almost fully extended and the shoulder externally rotated 45° (thumb up), lift the band with one arm slightly in front of the body (about 30°) and then slowly return to the starting position (5)(6).</p> <p>6. Shoulder internal rotation- typing elastic at waist-height: elastic grasped at waist height, pull hand inward (behind the back) flexing elbow at approximately 90° and then slowly return to the starting position (5).</p> <p>7. Shoulder external rotation- typing elastic at waist-height: elastic grasped at waist level, flexing elbow at approximately 90° and the shoulder externally rotated 90° (forearm parallel to the ground), pull forearm outward and then slowly return to the starting position. Some cases may place a towel roll under the arm (5)(6).</p> <p>8. Forward punch - typing elastic at chest-height: elastic grasped at chest height (mid back height) with elbows bent to the side. Extend elbows forward and push the band away from trunk and then slowly return to the starting position (4).</p> <p>9. Shoulder row - typing elastic at chest-height: elastic grasped at chest height and with the elbows almost fully extended, pull the ends of the bands towards the chest and elbows bent to the side. Then slowly return to the starting position (5).</p>
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Table 1: List of exercises. Each exercise performed in serials of 30 to 50 repetitions, with a moderate resistance and at comfort level (7). In elastic resistance is very important never shrug the shoulders and keep always back straight (6). The resistance can be easily adjusted by moving further away or by adding extra resistance bands.

Bibliography

1. Hospital W. Arthroscopic Rotator Cuff Repair Frequently Asked Questions : 2009;1–

- 29.
2. Hardwick DH, Beebe JA, McDonnell MK, Lang CE. A Comparison of Serratus Anterior Muscle Activation During a Wall Slide Exercise and Other Traditional Exercises. *J Orthop Sport Phys Ther* [Internet]. 2006;36(12):903–10. Available from: <http://www.jospt.org/doi/10.2519/jospt.2006.2306>
 3. de Oliveira AS, de Morais Carvalho M, de Brum DPC. Activation of the shoulder and arm muscles during axial load exercises on a stable base of support and on a medicine ball. *J Electromyogr Kinesiol*. 2008;18(3):472–9.
 4. Decker MJ, Hintermeister RA, Faber KJ, Hawkins RJ. Serratus anterior muscle activity during selected rehabilitation exercises. *Am J Sport Med* [Internet]. 1999;27(6):784–91. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/10569366>
 5. Mullaney MJ, Perkinson C, Kremenic I, Tyler TF, Orishimo K, Johnson C. Emg of Shoulder Muscles During Reactive Isometric Elastic Resistance Exercises. *Int J Sports Phys Ther* [Internet]. 2017;12(3):417–24. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/28593096>
 6. Gibson JC. (iii) Rehabilitation after shoulder instability surgery. *Curr Orthop*. 2004;18(3):197–209.
 7. McCormick F, Wilcox RB, Alqueza A. Postoperative Rotator Cuff Repair Rehabilitation and Complication Management. *Oper Tech Orthop* [Internet]. 2015;25(1):76–82. Available from: <http://dx.doi.org/10.1053/j.oto.2014.12.001>

Anexos

1. Declaração de consentimento informado

Conforme a lei 67/98 de 26 de Outubro e a “Declaração de Helsínquia” da Associação Médica Mundial (Helsínquia 1964; Tóquio 1975; Veneza 1983; Hong Kong 1989; Somerset West 1996, Edimburgo 2000; Washington 2002, Tóquio 2004, Seul 2008, Fortaleza 2013) – quando se aplicar

Designação do Estudo: Fisioterapia em doentes após cirurgia da coifa dos rotadores do ombro – utilização do *biofeedback* eletromiográfico.

Investigador Responsável: Carolina Gonçalves Figueira

Eu, _____, fui informado de que o Estudo de Investigação acima mencionado se destina a investigar qual a eficácia do *biofeedback* eletromiográfico no plano de intervenção, em utentes pós-cirúrgicos do ombro, sem quaisquer custos adicionais.

Sei que neste estudo está prevista a realização de uma avaliação antes e depois de três semanas de intervenção, no mesmo local onde realizo fisioterapia, e que esta intervenção poderá incluir ou não o *biofeedback* eletromiográfico, sendo esta seleção aleatória. Foi-me ainda explicado em que consiste a avaliação e o *biofeedback* eletromiográfico e que a aplicação dos mesmos não levantam riscos para o participante em estudo, tanto durante a sua utilização como na descontinuação do mesmo. Foi-me garantido que todos os dados relativos à identificação dos participantes neste estudo são confidenciais e que será mantido o anonimato.

Sei que posso recusar-me a participar ou interromper a qualquer momento a participação no estudo (tanto por preferir recorrer a outras formas de tratamento para o ombro ou à ingestão de medicamentos anti-inflamatórios, como por qualquer outro motivo), sem nenhum tipo de penalização por este facto.

Obtive ainda a informação de que não há garantia da continuidade do tratamento com o *biofeedback* eletromiográfico.

Compreendi a informação que me foi dada, tive oportunidade de fazer perguntas e as minhas dúvidas foram esclarecidas.

Aceito participar de livre vontade no estudo acima mencionado. Também autorizo a divulgação dos resultados obtidos no meio pedagógico ou científico, garantindo o anonimato.

Data e assinaturas de acordo com as características do estudo e respetivos requisitos legais

___/___/___

___/___/___

2. Questionário Disabilities of the Arm, Shoulder and Hand (DASH)

DISABILITIES OF THE ARM, SHOULDER AND HAND

DASH

Portugal

INSTRUÇÕES

Com este questionário pretendemos conhecer os seus sintomas, bem como a sua capacidade para desempenhar determinadas actividades.

Responda, por favor, a *todas* as perguntas e, com base na sua condição física na última semana, faça um círculo à volta do número que considere mais adequado.

Se, na última semana, não teve oportunidade de desempenhar uma determinada actividade, por favor seleccione a resposta com *maior probabilidade* de ser a mais adequada.

Não importa qual a mão ou braço que utiliza para desempenhar a actividade ou o modo como a realiza. Por favor, responda apenas com base na sua capacidade para realizar a tarefa.



DISABILITIES OF THE ARM, SHOULDER AND HAND

Por favor, classifique a sua capacidade para desempenhar as actividades seguintes na última semana, fazendo um círculo à volta do número à frente da resposta adequada.

	NENHUMA DIFICULDADE	POUCA DIFICULDADE	ALGUMA DIFICULDADE	MUITA DIFICULDADE	INCAPAZ
1. Abrir um frasco novo ou com tampa bem fechada.	1	2	3	4	5
2. Escrever.	1	2	3	4	5
3. Rodar uma chave na fechadura.	1	2	3	4	5
4. Preparar uma refeição.	1	2	3	4	5
5. Abrir e empurrar uma porta pesada.	1	2	3	4	5
6. Colocar um objecto numa prateleira acima da cabeça.	1	2	3	4	5
7. Realizar tarefas domésticas pesadas (por exemplo: lavar paredes, lavar o chão).	1	2	3	4	5
8. Fazer jardinagem ou trabalhar no quintal.	1	2	3	4	5
9. Fazer a cama.	1	2	3	4	5
10. Carregar um saco de compras ou uma pasta.	1	2	3	4	5
11. Carregar um objecto pesado (mais de 5 kg).	1	2	3	4	5
12. Trocar uma lâmpada acima da cabeça.	1	2	3	4	5
13. Lavar a cabeça ou secar o cabelo.	1	2	3	4	5
14. Lavar as costas.	1	2	3	4	5
15. Vestir uma camisola.	1	2	3	4	5
16. Usar uma faca para cortar alimentos.	1	2	3	4	5
17. Actividades de lazer que requerem pouco esforço (por exemplo: jogar às cartas, fazer tricô, etc.).	1	2	3	4	5
18. Actividades de lazer que exijam alguma força ou provoquem algum impacto no braço, ombro ou mão (por exemplo: golfe, martelar, ténis, etc.).	1	2	3	4	5
19. Actividades de lazer, nas quais movimenta o braço livremente (por exemplo: jogar ao disco, jogar badminton, etc.).	1	2	3	4	5
20. Utilizar meios de transporte para se deslocar (de um lugar para o outro).	1	2	3	4	5
21. Actividades sexuais.	1	2	3	4	5

DISABIL

22. Em que ombro o familiar? (Faça um

23. Em que ombro o familiar? (Faça um

Por favor

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25. Dor n uma

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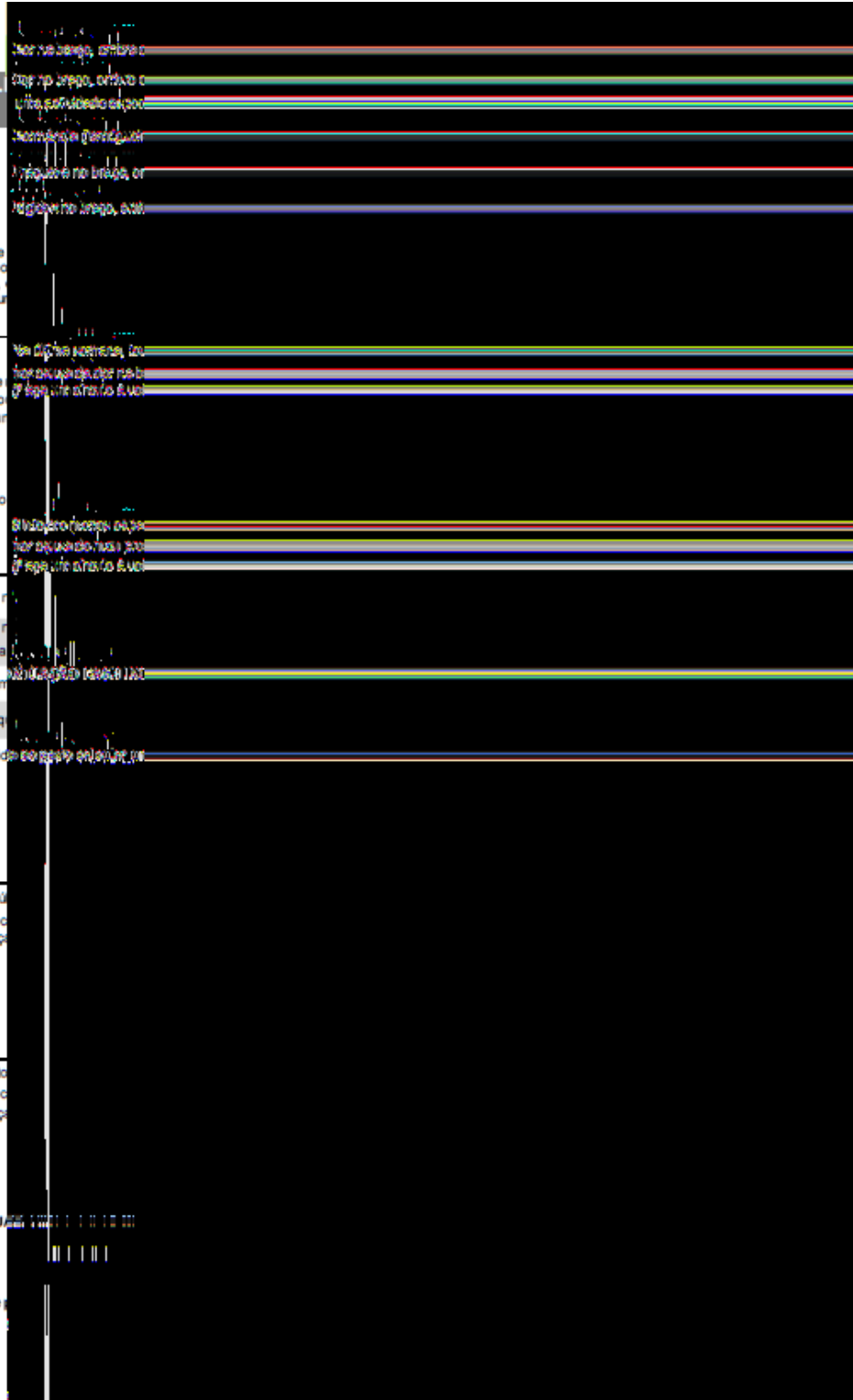
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 3. fazer co
 4. fazer co

MÓDULO

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3. tocar o B
desport
4. estar o t
instrum

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