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Isokinetic evaluation and treatment in the postoperative period of rotator cuff disease: a case report

Evaluación y tratamiento isocinético en el postoperatorio de la enfermedad del manguito rotador: un reporte de caso

Avaliação e tratamento isocinético no período pós-operatório do manguito rotador: um relato de caso

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ABSTRACT

INTRODUCTION: Even with a successful surgical procedure to repair the rotator cuff (RC), immobilization, pain, or muscle atrophy can lead to dysfunction and reduced RC strength, **PURPOSE:** This study sought to analyze the effects of physiotherapy through isokinetic exercises in these dysfunctions. **METHODOLOGY:** This is a case report of a 60-year-old male patient diagnosed with subluxation of the humeral head, and full-thickness tear of the supraspinatus tendon, with laceration, and tendinous retraction of approximately 2.4 cm. The patient underwent an open RC repair. After the failure of conventional physiotherapy, the individual was treated with isokinetic exercises. Functional status was evaluated using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire and an isokinetic dynamometer was used to evaluate muscle performance in concentric mode, at velocities of 60, 180, and 300 °/s, in flexion/extension and

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internal/external shoulder rotation movements. The minimum clinically important difference for functional status was reached. **RESULTS:** The peak torque (PT) for flexors showed improvement at all velocities; the extensor muscles improved only at 180 °/s. The external rotators showed an enhancement in the PT at 60 and 300 º/s. The agonist/antagonist ratio of extensors/flexors at 60 and 300 º/s showed percentages of improvement above 30 %. For internal/external rotators, the PT results also showed improvements in all velocities. **CONCLUSION:** In this case study, the isokinetic exercises prescribed in the postoperative period, after an open RC repair, resulted in a positive effect on the recovery of functional status and muscle performance.

KEYWORDS: muscle strength, rotator cuff injuries, shoulder pain, torque.

RESUMEN

INTRODUCCIÓN: Incluso con una cirugía exitosa para reparar el manguito rotador (MR), la inmovilización, el dolor o la atrofia muscular pueden provocar su disfunción y reducción de su fuerza. **OBJETIVO:** Este estudio buscó analizar los efectos de la fisioterapia mediante ejercicios isocinéticos en estas disfunciones. **METODOLOGÍA:** Se presenta el caso de un paciente masculino de 60 años con diagnóstico de subluxación de la cabeza humeral y desgarro de espesor completo del tendón del supraespinoso, con laceración y retracción tendinosa de aproximadamente 2.4 cm. El paciente se sometió a una reparación abierta del MR. Tras el fracaso de la fisioterapia convencional, se trató con ejercicios isocinéticos. El estado funcional se evaluó mediante el cuestionario DASH (Discapacidades del Brazo, Hombro y Mano) y se utilizó un dinamómetro isocinético para evaluar el rendimiento muscular en modo concéntrico, a velocidades de 60, 180 y 300 °/s, en movimientos de flexión/extensión y rotación interna/externa del hombro. **RESULTADOS:** Se alcanzó la diferencia mínima clínicamente significativa en el estado funcional. El torque máximo (TM) de los flexores mostró una mejoría a todas las velocidades; el grupo extensor mejoró solo a 180 °/s. Los rotadores externos mostraron una mejora en el TM a 60 y 300 °/s. La relación agonista/antagonista de extensores/flexores a 60 y 300 °/s mostró porcentajes de mejora superiores al 30 %. Para los rotadores internos/externos, los resultados del TM también mostraron mejoras a todas las velocidades. **CONCLUSIÓN:** En este estudio de caso, los ejercicios isocinéticos prescritos en el período postoperatorio, después de una reparación abierta de RC, tuvieron un efecto positivo en la recuperación del estado funcional y el rendimiento muscular.

PALABRAS CLAVE: fuerza muscular, lesiones del manguito rotador, dolor de hombro, torque.

RESUMO

INTRODUÇÃO: Mesmo com uma cirurgia bem-sucedida para reparar o manguito rotador (RC), a imobilização, a dor ou a atrofia muscular podem levar à disfunção e à redução da força. **OBJETIVO:** Este estudo buscou analisar os efeitos da fisioterapia com exercícios isocinéticos nessa disfunção. **METODOLOGIA:** Este é um relato de caso de um paciente do sexo masculino de 60 anos com diagnóstico de subluxação da cabeça do úmero e ruptura de espessura total do tendão supraespinhal, com laceração e retração do tendão de aproximadamente 2,4 cm. O paciente foi submetido a um reparo aberto do RC. Após o fracasso da fisioterapia convencional,

o indivíduo foi tratado com exercícios isocinéticos. O estado funcional foi avaliado usando o questionário DASH (Deficiências do Braço, Ombro e Mão) e um dinamômetro isocinético foi utilizado para avaliar o desempenho muscular em modo concêntrico, em velocidades de 60, 180 e 300 °/s, em movimentos de flexão/extensão e rotação interna/externa do ombro. **RESULTADOS:** A diferença mínima clinicamente significante na função foi alcançada. O pico de torque (PT) dos flexores mostrou melhora em todas as velocidades; o grupo extensor melhorou apenas a 180 °/s. Rotadores externos mostraram melhora no PT a 60 e 300 °/s. A razão agonista/antagonista de extensores/flexores a 60 e 300 °/s mostrou percentuais de melhora superiores a 30 %. Para rotadores internos/externos, os resultados do PT também mostraram melhorias em todas as velocidades. **CONCLUSÃO:** Neste estudo de caso, exercícios isocinéticos prescritos no período pós-operatório, após reparo aberto do RC, tiveram um efeito positivo na recuperação da função e do desempenho muscular.

PALAVRAS-CHAVE: força muscular, lesões do manguito rotador, dor no ombro, torque.

1. Introduction

Rotator cuff diseases (RCD) are among the musculoskeletal complaints with the highest prevalence of pain, mainly during abduction of the arm, within a range of motion of 60-120 ° (Anand et al., 2018).The incidence of this condition increases with age-related degenerative changes, so that 54 % of symptomatic individuals aged 60 years or older have partial or total ruptures confirmed by magnetic resonance imaging (MRI) (Sher et al., 1995; Tashjian, 2012). In a systematic review with 30 studies, including 6112 shoulders, 1452 presented rotator cuff injuries and the general prevalence of abnormalities ranged from 9.7 to 62 % in patients between 20 and 80 years of age or older, respectively, regardless of symptoms (Teunis et al., 2014). Although the lesions may be asymptomatic, they are able to progress with symptoms, such as pain and disability, which can result in a joint with degenerative chondral changes, called rotator cuff arthropathy, or evolve to an eventual increase in rupture, decreasing shoulder function and muscle performance (Chalmers et al., 2016; Moosmayer et al., 2017).

Surgery is a common intervention to improve physical function and pain. However, even with proper treatment, flaws in tendon healing can occur, reducing physical capabilities, productivity, and quality of life (Davies et al., 2017; Keener, 2012). Although surgical techniques have evolved to repair shoulder injuries, such as arthroscopy, some ruptures still require an open approach. Following success in the surgical procedure, after alteration of the tendon and/or muscle structure during the open surgical approach, immobilization, pain, or muscular atrophy may lead to compromised physical function and reduced shoulder strength (Cho et al., 2015; Parada et al., 2015). Up to 70 % of patients with large RCD present failed surgical repair and the amount of muscle atrophy, fat infiltration, extent of retraction, and advanced age are some of the factors which demonstrate a direct correlation with high failure rates and poor clinical results after surgical repairs (Davies et al., 2017; Diebold et al., 2017; Kim et al., 2018; Rashid et al., 2017). Thus, in addition to the surgical procedure, postoperative treatment is essential to reduce the risk of re-rupture and ensure the success of the surgical intervention. This treatment consists of an approach that aims to minimize stress on repaired tissues and facilitate early tissue healing, and the treatment should be focused on restoring and balancing the scapular and glenohumeral

forces, as an improper intervention during this period can jeopardize the surgery (Goetti et al., 2020; Van der Meijden et al., 2012). This is particularly noticeable when considering variables such as load, as inadequate load management can have a negative impact on tissue healing. However, when properly applied, load can act as a positive stimulus for tissue healing, with different dosages tailored to different stages of recovery (Hyde et al., 2021). Furthermore, Kim & Lee (2022) demonstrated the effectiveness of physiotherapy interventions on pain control, increasing range of motion, and improving shoulder function after RCD repairs, showing that these interventions have a positive impact on patients' lives, promoting a faster and more successful recovery.

Additionally, evaluating physical function and muscle strength in the postoperative period is an alternative that enables investigation of important clinical considerations regarding poor surgical results, since variables such as torque are commonly evaluated to diagnose possible injuries or articular disorders, in order to measure the results of interventions and progression over time (Baltzopoulos & Brodie, 1989; Land & Gordon, 2011). This variable and others, such as peak torque normalized by body mass (PT/NM), total work, power, and the agonist/antagonist ratio (A/Ant R), can be quantified by an isokinetic dynamometer. This is a tool that records biomechanical function during an isolated joint movement, where the angular velocity remains constant, being able to detect function deficits and torque production in the tested articulation (Brown et al., 1995; Martinez-Garcia et al., 2020). Furthermore, as explored in the studies of Tudini (2020) and Bigoni et al. (2009) when used after RC (rotator cuff) repairs, the isokinetic dynamometer is believed to be an effective tool to guide and monitor the shoulder recovery process, as well as improve clinical results and quality of life (Coda et al., 2020; Kane et al., 2020).

Despite some studies showing that this training tool is useful for increasing muscle strength, total work, and range of motion in shoulder diseases, the utility of the isokinetic dynamometer as a postoperative treatment tool for certain surgical conditions remains largely unexplored (Thomas et al., 2001). Thus, the proposal of this study was to report the stages of functional status and muscle performance, as well as the effects of an isokinetic training program (5 weeks, 2/3x per week) in an individual who underwent an open RC repair and acromioplasty.

2. Case description

Subject Characteristics

A 60-year-old male patient with a body mass index of 22.9 kg/m², diagnosed with rupture of the supraspinatus tendon in the dominant limb (right-handed), was referred for evaluation at the Laboratory of Biomechanics and Clinical Epidemiology of the University Hospital/UEL. The condition was diagnosed through ultrasound as a 7 mm rupture of the supraspinatus tendon in the right limb. Following the diagnosis, the patient initiated the treatment (exercise sessions) that helped reduce his pain. However, he experienced discomfort after the conclusion of the sessions. Two years after the diagnosis, he reported experiencing a fall from a height of approximately one meter, which resulted in worsening of his condition. Approximately one year after the fall, he underwent an MRI of the injured shoulder, which showed superior subluxation of the humeral head, a complete full-thickness rupture, and an extension of the previously injured tendon (supraspinatus), with a laceration and tendinous retraction of approximately 2.4 cm (Figure 1). Additionally, he presented with tendinopathy in the infraspinatus, supraspinatus, and long head

of the biceps, with partial rupture of almost full thickness in the intracapsular portion, associated with medial subluxation. Two months after the MRI, the right RC repair was performed through an open approach, in addition to bursectomy and acromioplasty, involving four trans-osseous sutures, covering the entire humeral head failure. One month after surgery, the patient started exercise sessions, for six months, leading to a slight reported improvement in the condition, but still with restriction in the range of motion, pain, and impairment in function.

After reporting these complaints, the patient was assessed and trained in the isokinetic dynamometer for the management of dominant (right) supraspinatus tendon rupture (as well as tendinopathy of the infraspinatus and long head of the biceps plus medial subluxation). Signed informed consent was obtained from the participant prior to data collection and after the study protocol was reviewed by Ethics Committee for Research Involving Human Beings of the UEL and approved according to document IRB (#00768812.0.5231).

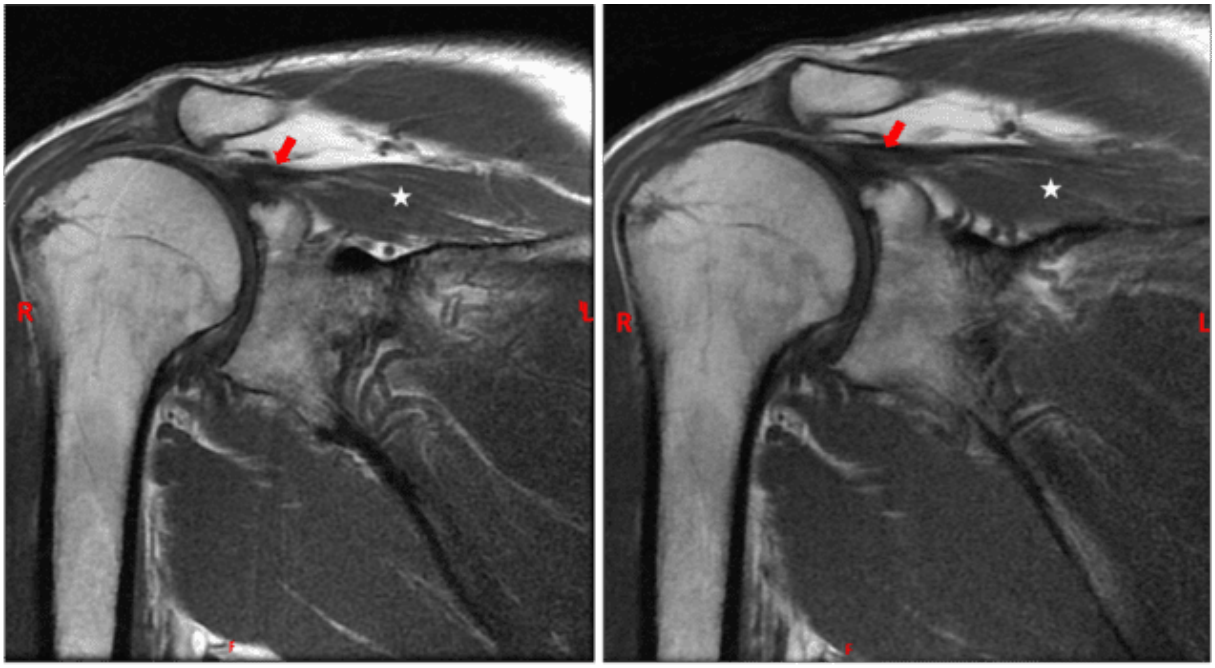

Figure 1. Right shoulder MRI Scan of the supraspinatus tear. Source: the authors.

3. Methods

Initial Examination/Clinical Measures

A comprehensive history taking was performed (personal data, history of injury, and main complaint) and underwent specific clinical tests to evaluate the stability of the glenohumeral joint and the integrity of the cuff muscles (test for supraspinatus tendonitis, Hawkins-Kennedy, Apley, Neer, sensitized Neer, and Jobe tests). (The data from this clinical study is available with this paper).

Physical Function

Functional status was evaluated using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, composed of 30 items, self-reported, able to measure physical disability and upper limb (UL) symptoms, designed to identify one or several musculoskeletal disorders of the UL (Orfale et al., 2005). The questionnaire was applied in the first evaluation, after six treatment sessions, and in the final evaluation. The DASH score varies from 0 to 100, with 0 being the lowest degree of disability and 100 being the highest; the result is calculated by applying established formulas (Orfale et al., 2005). The questionnaire minimum clinically important difference (MCID) was also calculated, this is defined as the smallest difference in the score that patients perceive as beneficial, this being able to detect small but important changes in health status over time (Deyo et al., 1991; Jaeschke et al., 1989; Sedaghat, 2019). The reported MCID for the DASH questionnaire ranges from 3.9 to 15 for unspecified shoulder disorders (Dabija & Jain, 2019; Green et al., 2022; Franchignoni et al., 2014; Schmitt & Di Fabio, 2004; Van Kampen et al., 2013).

Muscle Performance – Dynamometry

An isokinetic dynamometer - Biodex System 4® (Biodex Medical System Inc., Shirley, NY, USA) was used to analyze muscle performance. The evaluation was performed in the concentric isokinetic mode at angular velocities of 60, 180, and 300 °/s for flexion-extension and internal-external rotation movements with the arm at 90 ° abduction, in both the involved (right) and noninvolved limb. The trunk and pelvis were fixed with straps, the shoulder alignment and posture were confirmed with a goniometer, and palpation was performed of anatomical landmarks (acromion and greater tuberosity of the humerus) (Deyo et al., 1991). The dynamometer configuration for the flexion and extension movement was: orientation and dynamometer inclination at 0 °, seat orientation at 0 °, and backrest inclination at 85 °; for internal and external rotation at 90 ° abduction: dynamometer orientation at 0 °, dynamometer inclination at 5 °, seat orientation at 0 °, and backrest inclination at 85 ° (Figure 2A 2B). All calibration procedures and guidelines were according to the manufacturer's recommendations, with a 100 Hz sampling frequency.

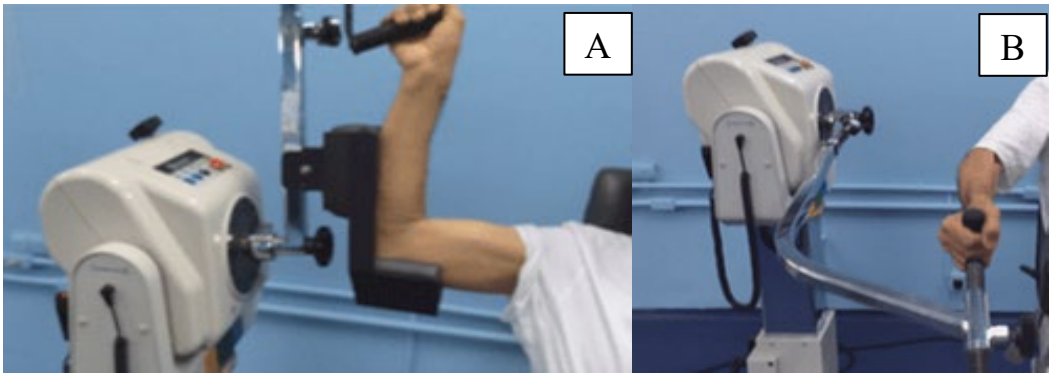

Figure 2A and 2B. 2A. Internal-external rotation movements with the arm at 90 ° abduction. 2B flexion-extension. Source: the authors.

The range of motion (ROM) was measured while the patient held the lever, performing the maximum active movement possible in the four movements (flexion-extension and internal-

external at 90 ° abduction). Prior to data collection, familiarization with the equipment and understanding of the movement were performed through submaximal efforts at each of the protocol velocities. The efforts were repeated until the individual indicated that he was comfortable with the movements of the equipment. After the familiarization (warm-up), the participant was instructed to perform maximum efforts throughout the repetitions, eight times for flexion-extension and for internal-external rotation, at velocities of 60, 180, and 300 º/s, while verbal encouragement and visual feedback were provided. A 90-second interval was granted between sets.

For reliability purposes, a coefficient of variation of less than 10 % for each set was considered acceptable (Malina et al., 2005). The raw data of peak torque (PT) parameters in Newton meters, peak torque normalized by mass (PT/NM) as a percentage, mean peak torque (MPT) in Newton meters, total range of motion (total ROM) in degrees, and the agonist/antagonist ratio (A/Ant R) as a percentage were extracted from the isokinetic dynamometer software itself (txt.).

Intervention

For the isokinetic resistance training program, specific intervention strategies were considered for the individual, after he had undergone rotator cuff repair, aiming for improvement in muscle performance and functional status after the training program. The positioning and adjustments were identical to the test, which was performed only for the limb involved (right shoulder). In all sessions, 10 minutes of warm-up were carried out with ballistic shoulder movements.

The isokinetic training program was conducted with 13 training sessions (totaling 5 weeks of training, 2/3x per week) and the pre and post evaluations were performed with 10 repetitions for each velocity/movement. The description of all sessions is presented in Table 1.

Table 1.
Evaluation, Special tests, DASH Questionnaire, Exercises, Sets, Reps, Resistance (velocity °/s), and Loads (% of peak concentric).

Week	**Session 1**	
1	Isokinetic evaluation: flexion/extension and internal/external rotation at 90 ° abduction at velocities of 60, 180 and 300 º/s. Special tests. DASH (Disabilities of the Arm, Shoulder and Hand) questionnaire.	
	Session 2	**Session 3**

2	FL/EX: 5 x 20 rep at 300 °/s, 50 % of peak. 3 x 12 rep at 180 °/s, 55 % of peak. IR/ER: 5 x 20 rep at 300 °/s, 50 % of peak. 3 x 12 rep at 180 °/s, 55 % of peak.	FL/EX: 5 x 20 rep at 300 °/s, 50 % of peak. 3 x 12 rep at 180 °/s, 55 % of peak. IR/ER: 5 x 20 rep at 300 °/s, 50 % of peak. 3 x 12 rep at 180 °/s, 55 % of peak.	
3	**Session 4** FL/EX: 5 x 20 rep at 300 °/s, 50 % of peak. 3 x 12 rep at 180 °/s, 55 % of peak. IR/ER: 5 x 20 rep at 300 °/s, 50 % of peak. 3 x 12 rep at 180 °/s, 55 % of peak.	**Session 5** FL/EX: 5 x 20 rep at 300 °/s, 50 % of peak. 3 x 12 rep at 180 °/s, 55 % of peak. IR/ER: 5 x 20 rep at 300 °/s, 50 % of peak. 3 x 12 rep at 180 °/s, 55 % of peak.	
4	**Session 6** FL/EX: 5 x 20 rep at 300 °/s, 55 % of peak. 3 x 12 rep at 180 °/s, 60 % of peak. IR/ER: 5 x 20 rep at 300 °/s, 55 % of peak. 3 x 12 rep at 180 °/s, 60 % of peak.	**Session 7** FL/EX: 5 x 20 rep at 300 °/s, 55 % of peak. 3 x 12 rep at 180 °/s, 60 % of peak. IR/ER: 5 x 20 rep at 300 °/s, 55 % of peak. 3 x 12 rep at 180 °/s, 60 % of peak. Physical function tests and re-assessment of the questionnaire DASH.	**Session 8** Diagonal bilateral isokinetic evaluation and adduction/abduction at a velocity of 60 °/s.
5	**Session 9** DIAG: 1 x 25 rep, 1 x 20 rep, 1 x 15 rep at 300 °/s, 50 % of peak. 1 x 25 rep, 1 x 20 rep, 1x 15 rep at 180 °/s, 50 % of peak. FL/EX: 2 x 20 rep at 300 °/s, 55 % of peak. 3 x 20 rep, 1 x 15 rep, 1 x 12 rep at 180 °/s, 60 % of peak.	**Session 10** DIAG: 1 x 25 rep, 1 x 20 rep, 1 x 15 rep at 300 °/s, 50 % of peak. 1 x 25 rep, 1 x 20 rep, 1x 15 rep at 180 °/s, 50 % of peak. FL/EX: 2 x 20 rep at 300 °/s, 55 % of peak. 3 x 20 rep, 1 x 15 rep, 1 x 12 rep at 180 °/s, 60 % of peak.	**Session 11** DIAG: 1 x 25 rep, 1 x 20 rep, 1 x 15 rep at 300 °/s, 50 % of peak. 1 x 25 rep, 1 x 20 rep, 1 x 15 rep at 180 °/s, 50 % of peak. ADD/ABD: 1 x 20 rep, 1 x 15 rep, 1 x 10 rep at 300 °/s, 50 % of peak. 1 x 20 rep, 1 x 15 rep, 1 x 10 rep at 180 °/s, 50 % of peak.

	1 x 12 rep, 1 x 10 rep, 1 x 8 rep at 60 °/s, 50 % of peak. IR/ER: 2 x 20 rep at 300 °/s, 55 % of peak. 3 x 20 rep, 1 x 15 rep, 1 x 12 rep at 180 °/s, 60 % of peak. 1 x 12 rep, 1 x 10 rep, 1 x 8 rep at 60 °/s, 50 % of peak.	1 x 12 rep, 1 x 10 rep, 1 x 8 rep at 60 °/s, 50 % of peak. IR/ER: 2 x 20 rep at 300 °/s, 55 % of peak. 3 x 20 rep, 1 x 15 rep, 1 x 12 rep at 180 °/s, 60 % of peak. 1 x 12 rep, 1 x 10 rep, 1 x 8 rep at 60 °/s, 50 % of peak.	
6	**Session 12** DIAG: 1 x 25 rep, 1 x 20 rep, 1 x 15 rep at 300 °/s, 50 % of peak. 1 x 25 rep, 1 x 20 rep, 1x 15 rep at 180 °/s, 50 % of peak. FL/EX: 2 x 20 rep at 300 °/s, 55 % of peak. 3 x 20 rep, 1 x 15 rep, 1 x 12 rep at 180 °/s, 60 % of peak. 1 x 12 rep, 1 x 10 rep, 1 x 8 rep at 60 °/s, 50 % of peak. IR/ER: 2 x 20 rep at 300 °/s, 55 % of peak. 3 x 20 rep, 1 x 15 rep, 1 x 12 rep at 180 °/s, 60 % of peak. 1 x 12 rep, 1 x 10 rep, 1 x 8 rep at 60 °/s, 50 % of peak.	**Session 13** DIAG: 1 x 25 rep, 1 x 20 rep, 1 x 15 rep at 300 °/s, 50 % of peak. 1 x 25 rep, 1 x 20 rep, 1x 15 rep at 180 °/s, 50 % of peak. FL/EX: 2 x 20 rep at 300 °/s, 55 % of peak. 3 x 20 rep, 1 x 15 rep, 1 x 12 rep at 180 °/s, 60 % of peak. 1 x 12 rep, 1 x 10 rep, 1 x 8 rep at 60 °/s, 50 % of peak. IR/ER: 2 x 20 rep at 300 °/s, 55 % of peak. 3 x 20 rep, 1 x 15 rep, 1 x 12 rep at 180 °/s, 60 % of peak. 1 x 12 rep, 1 x 10 rep, 1 x 8 rep at 60 °/s, 50 % of peak.	**Session 14** DIAG: 1 x 25 rep, 1 x 20 rep, 1 x 15 rep at 300 °/s, 50 % of peak. 1 x 25 rep, 1 x 20 rep, 1 x 15 rep at 180 °/s, 50 % of peak. ADD/ABD: 1 x 20 rep, 1 x 15 rep, 1 x 10 rep at 300 °/s, 50 % of peak. 1 x 20 rep, 1 x 15 rep, 1 x 10 rep at 180 °/s, 50 % of peak. FL/EX: 2 x 20 rep at 300 °/s, 55 % of peak. 3 x 20 rep, 1 x 15 rep, 1 x 12 rep at 180 °/s, 60 % of peak. 1 x 12 rep, 1 x 10 rep, 1 x 8 rep at 60 °/s, 50 % of peak. IR/ER: 2 x 20 rep at 300 °/s, 55 % of peak. 3 x 20 rep, 1 x 15 rep, 1 x 12 rep at 180 °/s, 60 % of peak. 1 x 12 rep, 1 x 10 rep, 1 x 8 rep at 60 °/s, 50 % of peak.
7	**Session 15** Isokinetic evaluation: flexion/extension and internal/external rotation at 90 ° abduction at velocities of 60, 180 and 300 °/s. Special tests. DASH (Disabilities of the Arm, Shoulder and Hand) questionnaire.		

Abbreviations: ADD/ABD = adduction/abduction, DIAG = diagonal, x = series, FL/EX = flexion/extension, IR/ER = Internal/ External Rotation (90 ° of abduction), rep = repetitions, °/s = degrees per second, % = percentage of peak of torque concentric. Special tests: test for supraspinatus tendonitis, Hawkins-Kennedy, Apley, Neer, sensitized Neer, and Jobe tests. Source: the authors.

4. Results

Functional status, according to the DASH questionnaire score, showed percentage improvement after six sessions in relation to the first evaluation in the categories of physical function, sport, work of 26.6 %, 45.5 %, and 33.2 % respectively. In the final evaluation, only the work function progressed to 44.4 % in relation to the first evaluation (Table 2) and in other categories the results were the same. Considering that the reported MCID for the DASH questionnaire ranges from ranges from 3.9 to 15 for unspecified shoulder disorders in the physical function domain, the participant demonstrated improvement in function values (Dabija & Jain, 2019; Green et al., 2022; Franchignoni et al., 2014; Schmitt & Di Fabio, 2004; Van Kampen et al., 2013).

Table 2.
Results of the DASH questionnaire (Disabilities of the Arm, Shoulder and Hand.

	1st Assessment	2nd Assessment (After 6 sessions)	% Improves compared to 1st Assessment	3rd Assessment (After 14 sessions)	% Improves compared to 1st Assessment
P. Function	34,1	25	26,6 %	25	26,6 %
Sport	68,7	37,5	45,5 %	37,5	45,5 %
Work	56,2	37,5	33,2 %	31,2	44,4 %

The DASH total score ranges from 0 (no dysfunction) to 100 (severe dysfunction).

Source: the authors.

The PT/NM and MPT are complementary variables, however the isokinetic values of PT can better contribute to the analysis of the biomechanical behavior of the joint; therefore, it will be described in detail. The PT improvement for the flexors ranged between 10.57, 10.57, and 3.78 %, respectively at 60, 180, and 300 º/s; for the extensors. An improvement was observed in the results only at 180 º/s, with a value of less than 7%. The external rotators showed improvement at 60 and 300 º/s of 5.68 and 2.97 % respectively and at 180 º/s a deficit of -6.02 % occurred. The internal rotators presented deficits at all velocities of -2.03, -26.17, -32.95 %, respectively at 60, 180, and 300 º/s (Table 3 and 4).

Total ROM for flexors and extensors in the involved limb showed a variation of less than 10 % between pre and post-treatment at all velocities. For the internal and external rotators, the values were below 9 % (Table 4). The values of the agonist/antagonist ratio of flexors-extensors at 60 º/s and at 300 º/s showed percentage improvements above 30 %, while at 180 º/s there seemed to be no difference. For internal-external rotators, the results ranged among 7.87, 27.30, and 52.70 % improvement, respectively at 60, 180, and 300 º/s (Table 3 and 4).

Table 3.

Results of the isokinetic parameters of flexion and extension at velocities of 60, 180 and 300 ˚/s.

		Pre	Post		Pre	Post	
		Involved		**% Improvement**	**Uninvolved**		**% Improvement**
Flexion 60 °/s	*PT (N.m)*	38.80	42.90	10.57	60.60	58.70	-3.14
	PT/NM (N.m/kg)	0.52	0.57	9.61	0.81	0.78	-3.70
	Mean PT (N.m)	36.80	40.70	10.60	55.00	52.70	-4.18
	ROM (°)	183.50	199.00	8.45	204.10	200.10	-1.96
	A/Ant Ratio	58.00	76.19	31.36	88.98	93.33	4.83
		Pre	**Post**		**Pre**	**Post**	
		Involved		**% Improvement**	**Uninvolved**		**% Improvement**
Extension 60 °/s	*PT (N.m)*	66.90	56.30	-15.84	68.10	62.90	-7.64
	PT/NM (N.m/kg)	0.89	0.75	-15.73	0.91	0.84	-7.69
	Mean PT (N.m)	58.10	52.40	-9.81	62.20	55.30	-11.09
	ROM (°)	183.50	199.00	8.45	204.10	200.10	-1.96
		Pre	**Post**		**Pre**	**Post**	
		Involved		**% Improvement**	**Uninvolved**		**% Improvement**
Flexion 180 °/s	*PT (N.m)*	38.80	42.90	10.57	47.00	56.90	21.06
	PT/NM (N.m/kg)	0.53	0.56	5.66	0.63	0.76	20.63
	Mean PT (N.m)	34.00	37.50	10.29	41.80	53.60	28.23
	ROM (°)	182.20	199.00	9.22	203.00	198.80	-2.06
	A/Ant Ratio	72.52	75.39	3.95	88.18	113.80	29.05
		Pre	**Post**		**Pre**	**Post**	
		Involved		**% Improvement**	**Uninvolved**		**% Improvement**
Extension 180 °/s	*PT (N.m)*	53.50	56.90	6.36	53.30	50.00	-6.19
	PT/NM (N.m/kg)	0.71	0.76	7,04	0.71	0.80	12.67
	Mean PT (N.m)	49.40	50.10	1.42	49.90	51.80	3.81
	ROM (°)	182.20	199.00	9.22	203.00	198.90	-2.02
		Pre	**Post**		**Pre**	**Post**	
		Involved		**% Improvement**	**Uninvolved**		**% Improvement**
Flexion 300 °/s	*PT (N.m)*	39.70	41.20	3.78	68.60	67.40	-1.75
	PT/NM (N.m/kg)	0.53	0.55	3.78	0.91	0.90	-1.09
	Mean PT (N.m)	36.10	38.90	7.76	52.00	38.90	-25.19
	ROM (°)	182.60	196.80	7,77	202.10	198.300	-1.88
	A/Ant Ratio	68.56	100.40	46.44	86.50	138.68	60.32
		Pre	**Post**		**Pre**	**Post**	
		Involved		**% Improvement**	**Uninvolved**		**% Improvement**
Extension 300 °/s	*PT (N.m)*	51.90	41.00	-21.00	79.30	48.60	-38.71
	PT/NM (N.m/kg)	0.69	0.55	-20.02	1.06	0.65	-38.67
	Mean PT (N.m)	40.80	38.70	-5.15	62.90	45.20	-28.14
	ROM (°)	180.60	196.80	8.97	202.10	198.30	-1.88

A/Ant Ratio: agonist/antagonist ratio, Mean PT: mean peak torque, N.m/kg: Newton meter/kilogram, PT: peak torque, PT/NM: peak torque normalized by body mass, ROM: range of motion, °: degrees, %: percentage. Source: the authors.

Table 4.
Results of the isokinetic parameters of internal and external rotation at velocities of 60, 180 and 300 ˚/s.

		Pre	Post		Pre	Post	
		Involved		**% Improvement**	**Uninvolved**		**% Improvement**
External rotation 60 °/s	*PT (N.m)*	17.60	18.60	5.68	32.20	28.70	-10.86
	PT/NM (N.m/kg)	0.23	0.25	8.69	0.40	0.38	-5.00
	Mean PT (N.m)	16.60	17.90	7.83	27.80	26.90	-3.24
	ROM (°)	70.70	65.70	-7.07	73.70	70.60	-4.21
	A/Ant Ratio	59.45	64.13	7.87	83.63	79.72	-4.67
		Pre	**Post**		**Pre**	**Post**	
		Involved		**% Improvement**	**Uninvolved**		**% Improvement**
Internal rotation 60 °/s	*PT (N.m)*	29.60	29.00	-2.03	38.50	36.00	-6.49
	PT/NM (N.m/kg)	0.39	0.39	0.00	0.51	0.48	-5.88
	Mean PT (N.m)	26.80	24.00	-10.45	30.90	32.00	3.56
	ROM (°)	70.70	65.70	-7.07	73.70	70.60	-4.07
		Pre	**Post**		**Pre**	**Post**	
		Involved		**% Improvement**	**Uninvolved**		**% Improvement**
External rotation 180 °/s	*PT (N.m)*	24.90	23.40	-6.02	32.60	31.90	-2.15
	PT/NM (N.m/kg)	0.33	0.31	-6.06	0.43	0.43	0.00
	Mean PT (N.m)	23.30	22.10	-5.15	31.20	30.70	-1.60
	ROM (°)	69.80	64.70	-7.31	72.70	69.90	-3.85
	A/Ant Ratio	83.55	106.36	27.30	87.63	100.94	15.18
		Pre	**Post**		**Pre**	**Post**	
		Involved		**% Improvement**	**Uninvolved**		**% Improvement**
Internal rotation 180 °/s	*PT (N.m)*	29.80	22.00	-26.17	37.20	31.60	-15.05
	PT/NM (N.m/kg)	0.40	0.29	-27.50	0.50	0.42	-16.00
	Mean PT (N.m)	27.50	16.40	-40.36	33.20	27.60	-16.87
	ROM (°)	69.80	64.70	-7.31	72.70	69.90	-3.85
		Pre	**Post**		**Pre**	**Post**	
		Involved		**% Improvement**	**Uninvolved**		**% Improvement**
External rotation 300 °/s	*PT (N.m)*	23.60	24.30	2.97	39.00	36.60	-6.15
	PT/NM (N.m/kg)	0.31	0.32	3.22	0.52	0.49	-5.76
	Mean PT (N.m)	22.30	22.50	0.90	25.50	34.00	33.33
	ROM (°)	67.90	62.40	-8.10	71.70	68.60	-4.32
	A/Ant Ratio	67.45	103.00	52.70	95.35	99.72	4.58
		Pre	**Post**		**Pre**	**Post**	
		Involved		**% Improvement**	**Uninvolved**		**% Improvement**
Internal rotation 300 °/s	*PT (N.m)*	35.20	23.60	-32.95	40.90	36.70	-10.27
	PT/NM (N.m/kg)	0.47	0.31	-34.04	0.55	0.49	-10.90
	Mean PT (N.m)	34.20	20.00	-41.52	39.40	34.80	-11.68
	ROM (°)	67.90	62.40	-8.10	71.70	68.60	-4.32

A/Ant Ratio: agonist/antagonist ratio, Mean PT: mean peak torque, N.m/kg: Newton meter/kilogram, PT: peak torque, PT/NM: peak torque normalized by body mass, ROM: range of motion, °: degrees, %: percentage. Source: the authors.

5. Discussion

The current study evaluated the functional status and muscle performance of an individual who underwent an open RC repair in addition to acromioplasty, after the patient had undergone 13 training sessions of isokinetic exercises with three velocities (60, 180, and 300 º/s). The functional outcomes were evaluated using the DASH questionnaire, the results were positive and the smallest difference in the score that patients perceive as beneficial, that is, the minimum

clinically important difference, was reached, revealing that isokinetic training in the shoulder after RC repair can bring positive subjective and functional results to this joint (Table 2).

Postoperative recovery is described in the literature as essential for the return of physical function and quality of life, however the patient's age, functional activity, physical conditioning, type of surgery, and/or severity or size of the lesion are determinant in the return of optimal capacity of the injured limb. A randomized controlled trial described that 40 % of RCD repairs performed in the United Kingdom fail in 12 months, regardless of the surgical technique used, emphasizing that a failed repair adversely affects patient quality of life (Carr et al., 2015). However, these results were obtained from individuals who underwent only surgical procedure, without any type of intervention or treatment in the postoperative period.

Thus, successful treatment of rotator cuff repair may be dependent on the sum of the surgical procedure and postoperative recovery training (Sgroi, & Cilenti, 2018). This is because even with success in the surgical intervention, after altering the tendon and/or muscle structure during the open surgical approach, impairment in physical function is observed, especially the reduction in RC strength (Cho et al., 2015; Parada et al., 2015).

Tudini (2020) described in a recent integrative review, that isokinetic dynamometers have been used extensively to measure strength in individuals with shoulder injuries. The dynamometer quantifies this strength as torque, which is a variable defined as a force applied over a distance, causing a rotational movement. Therefore, peak torque is the maximum amount of torque that a muscle can generate in a moment arm that demonstrates muscle strength in a given joint (Ackland & Pandy, 2011; Dougherty et al., 2018; Sherman et al., 2013; Hik & Ackland, 2019). In the current study, a difference between the values of PT of the external and internal rotators, was found after the intervention at 60 º/s, which is a velocity that has better accuracy in torque measurement (Janicijevic et al., 2020). This result corroborates with that reported by Mullaney & Mchugh (2006), who also found higher values of this isokinetic variable (PT) in internal rotators, as expected, since this muscle group contains a greater transverse section area and the greater this area of the muscle, the greater the force it can generate (Mullaney & McHugh, 2006; Terry & Chopp, 2000).

There are still uncertainties in the literature about the ideal load for the rotator cuff muscles after a surgical repair. While some studies indicate that excessive load can have a negative impact on tissue recovery, others highlight that an optimal load can enhance the healing process (Hyde et al., 2021; Killian et al., 2012). However, limited information is available regarding how isokinetic resistance can influence tissue regeneration after surgical repair of the rotator cuff. Despite this, the findings demonstrate improvement in PT after postoperative training for the flexors at 60 and 180 °/s. For the extensors, the increase was only at 180 º/s, but with a value of 6.36 %. This value does not appear to be very expressive, but when looking at the uninvolved member, it is possible to observe that it had a PT decrease of -6.19 %. In addition, the same decrease in torque values was observed for both limbs at other velocities. Thus, the PT was maintained and even increased for the extension movement at this velocity, contrary to the other results for the same movement. For the external rotators, the improvement was at 60 and 300 º/s, also with values below 6 %. However, the same concept reported for the extensors can be applied to this movement, since PT values decreased for the untrained member at all velocities and for the trained member at 180 °/s.

These results were obtained without any aggravation of symptoms and demonstrate that, for certain shoulder movements, isokinetic training can increase or maintain muscle strength,

without greater risks of injury in the postoperative period. This can occur because isokinetic movement is performed at a constant velocity of movement and as the muscle force input changes, the resistance changes. Thus, the patient's own muscular resistance is met with a proportional amount of resistance provided for the machine throughout a range of motion to maintain the velocity of contraction (Andrews et al., 2012; Downey et al., 1994). Therefore, the risk of applying excessive load to the tissue is reduced in isokinetic movement, as in the concentric mode the machine does not impose more resistance than the muscle capacity to generate strength and if the patient experiences any pain in the arch of movement the muscle strength input decline and resistance decrease simultaneously, being a safe option for muscle training and possibly reducing the chances of a re-tear in the postoperative period.

In clinical practice, it is also useful to evaluate the relative balance of the agonist and antagonist muscles around a joint, since groups of opposing muscles provide dynamic joint stability and the imbalance between them can predispose a joint to injury (Drigny et al., 2020; Hadjisavvas et al., 2022; Kamalden et al., 2021; Maryam et al., 2022; Sapega, 1990). External rotators have a smaller cross-sectional area, so internal rotators are considered to be 1.5 times stronger than these, with a strength ratio of 2/3 (66 %) respectively (Ellenbecker & Davies, 2000; Ellenbecker & Roetert, 2003; Janicijevic et al., 2020; Mullaney & McHugh, 2006). The results of the internal/external rotators ratio in the current study were close to this and showed values of 59 % in the pre and 64 % in the post at 60 °/s. These findings may suggest that there was a strength deficit of external rotators, confirmed by the PT values, and these values approached the expected normative ratio with the training. Some authors state that the values of the normative ratio of shoulder rotators for injury prevention are between 66 and 76 %, so values below 66 % are associated with external rotator weakness, severe strength imbalances, and muscle instability (Ellenbecker & Davies, 2000; Ellenbecker & Roetert, 2003). The highest velocities presented percentage increases of 27.1 and 52.8 %, respectively, at 180 and 300 º/s (Table 4) and were out of the normative ratio for this joint. However, the faster angular velocities could have interfered in these values, as these do not provide accurate peak torque values as the 60 °/s velocity (Janicijevic et al., 2020).

For the movement of flexion and extension, this principle of muscular balance and dynamic joint stability is also applied. The flexor group also has a smaller cross-sectional area, and some authors consider the strength of the extensors to be 1.25 times greater than their opposite muscle group, with a strength ratio of 4/5 (80 %) respectively (Ivey et al., 1985; Mullaney & McHugh, 2006). Therefore, for the ratio between extension and flexion, the results showed greater differences at 60 °/s, with values of 58 % in the pre and 76 % in the post, corresponding to a 31.3 % increase after the exercise sessions (Table 3). These findings demonstrate that PT enhancement or maintenance, as a result of isokinetic training, can improve the patient A/Ant ratio and shoulder muscular balance, therefore reducing the risk of injury to that joint.

Strength deficits were found for the internal rotators at all velocities, with values of -2.03, -26.17, and -32.95 %, at 60, 180 and 300 º/s, respectively. This also happened in each of the four movements across nearly all velocities in the uninvolved limb (Table 3 and 4). These results may be a consequence of sarcopenia, a condition associated with the aging process, which causes a decrease in muscle mass and strength that mainly affects individuals over 50 years of age (McKendry et al., 2021; Papadopoulou, 2020). However, these deficits may have been influenced not only by the patient's age, which was 60 years old, but also by his absence from his profession, which consisted of daily manual work, in which there was a great mechanical

overload and demand for strength. Muscle tissue responds to demands placed on it and the mechanical overload leads to a series of intracellular processes that enhance protein synthesis, increasing the area of transverse section which is associated with enhancement of muscle strength (Jones et al., 2008; Krzysztofik et al., 2019; Plotkin et al., 2022). After the injury and the surgical procedure, the individual stopped performing such occupational activities, and spent time resting, or performing only light efforts. This new routine, associated with lack of muscle stimulation and sarcopenia could have contributed to this generalized loss of muscle strength. Furthermore, the isokinetic load for the internal rotators was apparently lower than the mechanical demand that these muscles were used to performing in occupational activities. Some authors reported that disuse or unloading leads to muscle mass loss, while others show that after just 3 to 10 days of muscle unloading, a negative change in the neuromuscular junction (NMJ) can be observed (Chalmers et al., 2016; McKendry et al., 2021; Nunes et al., 2022). Therefore, this reduction in overload imposed on shoulder muscles possibly contributes to the muscle strength reduction and the alteration in NMJ could explain the elevated deficits in higher velocities, that demands greater neuromuscular control.

Despite the positive results presented above, this study had some limitations, among which can be mentioned: the test position and training of internal and external rotators at 90 º abduction may have been a limiting factor for data inconsistency at some velocities, due to the fact that the modified neutral position brings a neutral glenohumeral position, enhanced by bony congruity and, theoretical length-tension enhancement of the posterior rotator cuff (Ellenbecker, & Davies, 2000; Mayer et al., 2001). The study lacked a control subject to determine what could be expected for the isokinetic variables at different velocities; and the load range analysis for data extraction and interpretation were not used.

6. Conclusion

The results demonstrate that isokinetic exercises prescribed in the postoperative period of rotator cuff repair, after an open approach, in addition to a bursectomy and acromioplasty, of an individual complaining of ROM, muscle function, and performance limitations, promoted recovery of the cited outcomes and a reduction in the associated symptoms, proving it to be a useful treatment proposal. Furthermore, this case report confirms the use of isokinetic equipment as an appropriate and valid tool to evaluate performance recovery after rotator cuff repair.

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