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Bridging the Gap between Physiotherapy, Osteopathy, and Exercise Rehabilitation

Internship Report

Diogo Filipe Chaves Neves

Porto, 2025

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Supervisor: Andreia Isabel Nogueira Pizarro

Tutor: Paulo Alexandre Brandão Oliveira Gomes

Diogo Filipe Chaves Neves

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ABSTRACT

This internship report explores the integration of physiotherapy, osteopathy, and exercise rehabilitation through the implementation of a unified assessment protocol based on Passive Range of Motion (PROM). Conducted at the FOR+ Clinic, the internship focused on developing a systematized approach to identify joint restrictions and asymmetries, particularly in the shoulder and hip complexes.

By analyzing scapulohumeral and pelvifemoral rhythms and interpreting PROM data within a biomechanical framework, the protocol aimed to bridge the gap between disciplines and enhance individualized intervention strategies. Two case studies were conducted to illustrate how PROM findings can inform exercise prescription, track progress, and improve communication among healthcare professionals.

The results support a holistic, system-based view of the human movement, advocating for integrated assessment practices to optimize patient outcomes.

KEY WORDS: BIOMECHANICS; EXERCISE REHABILITATION; OSTEOPATHY; PASSIVE RANGE OF MOTION; PHYSIOTHERAPY

Abbreviations

AROM – Active Range of Motion

BFR – Blood Flow Restriction

COM – Center of Mass

ER – External Rotation

FAI – Femoroacetabular Impingement

HA – Hyaluronic Acid

IR – Internal Rotation

KPI – Key Performance Indicator

NAS – Numerical Rating Scale

OA – Osteoarthritis

PROM – Passive Range of Motion

PSIS – Posterior Superior Iliac Spine

ROM – Range of Motion

RPE – Rate of Perceived Exertion

SLR – Straight Leg Raise

VAS – Visual Analog Scale

Introduction

The current musculoskeletal healthcare environment needs the integration of a holistic approach to rehabilitation as a necessary advancement. Despite clear interconnections among disciplines such as physiotherapy, osteopathy, and exercise rehabilitation, clinical practice remains fragmented, with professionals often working in isolation. This lack of interdisciplinary integration creates communication gaps; inconsistent treatment plans and reduces understanding of body system interactions. An ongoing challenge stems from the lack of standardized assessment protocols that healthcare professionals can use seamlessly. The study of biomechanics and functional anatomy throughout the years has demonstrated that the human body functions as a coordinated system of interdependent segments.

Research findings demonstrate that joint dysfunctions and limitations and altered positions in one joint create effects on adjacent or distant regions (Lobbos et al., 2024; Moreside & McGill, 2012; Neumann, 2017). Clinical assessments currently lack effective methods to translate this knowledge into practical structured assessments.

Within this context, this internship, undertaken at the FOR+ Clinic, a multidisciplinary center specializing in physiotherapy, osteopathy, and exercise rehabilitation, was designed with the intention of bridging the gap between these approaches and bringing to the public the best they can offer. The main aim was to develop and trial a functional assessment protocol primarily based on Passive Range of Motion (PROM) testing. This protocol focused on the shoulder and pelvic girdles as pivotal hubs of movement, with the aim of identifying mobility restrictions influencing global functional patterns. PROM assessments were selected due to their ability to isolate joint relative movement from neuromuscular influences, providing a clearer picture of structural limitations and asymmetries.

The hypothesis underlying this work is that PROM testing, when interpreted with a biomechanical systems-thinking lens, can provide key performance indicators (KPIs) for both diagnosis and exercise prescription. Moreover, correlating PROM values with observed movement patterns, such as

in performance or rehabilitation contexts, offers a pathway to personalized, evidence-based interventions.

This report is structured as follows:

- **Chapter 1** introduces the FOR+ Clinic by detailing its structure, clinical team, day-to-day operations and internship responsibilities.
- **Chapter 2** presents a review of the current literature on physiotherapy, osteopathy, and exercise rehabilitation, identifying gaps in interdisciplinary integration and provides a brief literature review of important biomechanical aspects for contextualizing the rationale behind a unified PROM-based assessment model.
- **Chapter 3** details the internship journey, observations, and some key points encountered in implementing collaborative practices in a multidisciplinary environment and more successful outcomes when working in the rehabilitation context.
- **Chapter 4** outlines the methodology of the proposed assessment protocol, including its design, testing procedures, and criteria for interpreting PROM values. It presents two case studies that illustrate the application of the protocol, correlating PROM findings with functional outcomes and exercise adaptation. It discusses some key findings, highlighting the clinical relevance and practical value of the protocol, followed by considerations of limitations and future directions.
- **Chapter 5 and 6**, the discussion and conclusion, synthesizes the outcomes and proposes how the PROM-based assessment protocol may contribute to a broader shift toward integrated care models in musculoskeletal health.

By merging biomechanical insight with interdisciplinary cooperation, this internship report aims to support a more connected, patient-centered model of care, one that respects both the individuality of the human body and the collective expertise of healthcare professionals.

1. Characterization Of the Internship Clinic

FOR+ (Physical Therapy, Osteopathy and Rehabilitation) is a multidisciplinary clinic specialized in integrative healthcare, combining traditional physiotherapy with osteopathic practices and tailored exercise rehabilitation programs. The clinic emphasizes a comprehensive approach to patient care, focusing on optimizing functional outcomes through evidence-based methods. I chose to intern at FOR+ due to its innovative treatment methodologies and its commitment to fostering collaboration among experienced healthcare professionals. I aimed to enhance my understanding of how different therapeutic disciplines can coexist and complement each other, ultimately improving patient outcomes.

Although the clinic has been open since 2017, its founders began planning it long before, with a mission to deliver the best primary healthcare to those in need. They aim for realistic and lasting solutions. Their goal is not only to recover their customers as quickly as possible, but also to provide long-lasting solutions. They support their patients throughout the recovery process, working with them to develop strategies that can prevent future injuries. In addition to their competent clinical staff, they collaborate with excellent health professionals from different fields, ensuring referrals to specialists when necessary.

The clinic has collaborative partnerships with:

1. Companies across various industries, one of them being Cartonagem Trindade where the clinic started its partnership in 2013, assigning one or more healthcare professionals to deliver services. These services include promoting active breaks through stretching, mobility and low-intensity exercises for employees who spend long hours in static postures, as well as offering manual therapy and some circuit-based exercises group classes. The company has seen value in implementing these services over the years, having also invested in some exercise equipment. In doing so, companies invest in and foster a healthier work environment for their staff, making them happier and more productive (Coulson et al., 2008).

2. Sports clubs' institutions, where athletes, if in need, can be evaluated and trained either in a functional and performance standpoint as well as an injury rehabilitation context at lower prices.
3. Other rehabilitation clinics nationwide for patients that sometimes come from longer distances and don´t have the means or time to continue the work in the clinic.
4. Higher and secondary education institutions, with internship programs.
5. Professional training institutions, to forward patients to other exercise professionals that want to continue training outside of the clinic

The physical space of the clinic is organized efficiently to accommodate its diverse range of services. It consists of several key areas: A waiting area, two bathrooms, four treatment rooms, and both an indoor and outdoor gym designed for therapeutic and strength exercises. The bathrooms are clean, well-maintained, and equipped to meet the needs of patients, especially those with mobility issues.

The treatment rooms are the core of the clinic, each carefully designed to cater to various treatment modalities. The rooms are equipped with a variety of tools, such as physiotherapy tables, desks, chairs, hot/cold therapy units, dry needling equipment, gloves, electro muscle stimulation (EMS) machines, different tapes, equipment used for manual therapy treatments, goniometers, sphygmomanometers, skeleton models for patient education. These rooms are

equipped to meet the demands of different specialists, ensuring that each professional has what they need to deliver effective care.

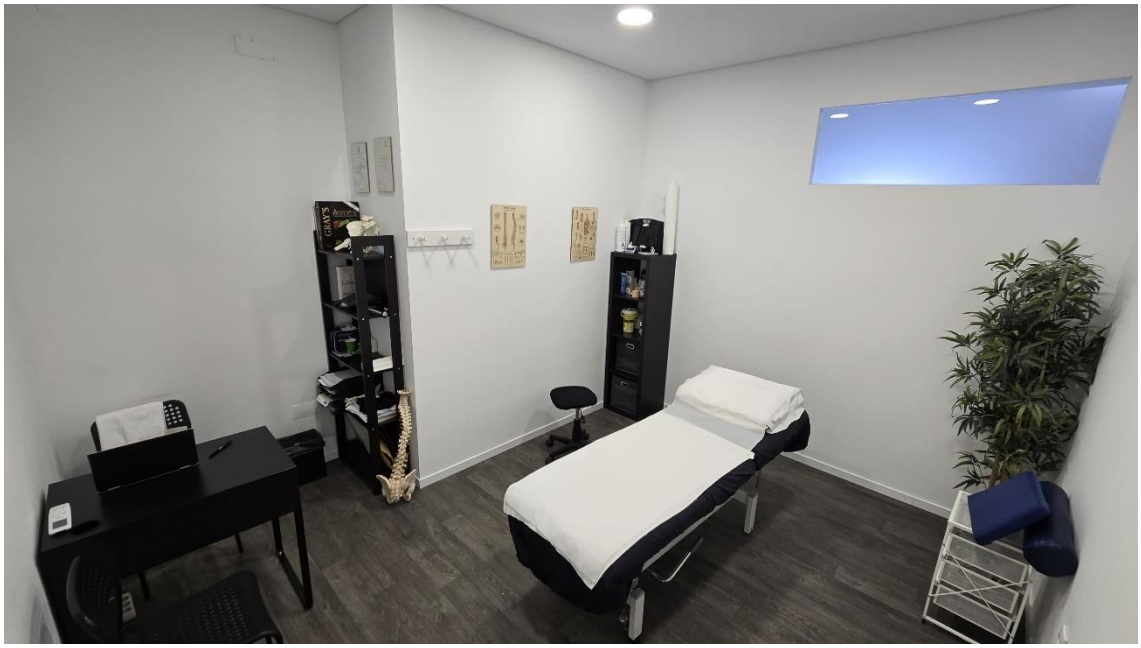


Figure 1 – Treatment Room

The gym area, both indoors and outdoors, is one of the clinic's standout features. The indoor gym is equipped with isoinertial or flywheel machines from NeuroExcellence mainly their squat, leg extension, leg curl and groin machines which are all equipped with dynamometers, except for the cable machines like their conical pulley device and two EpteO adjustable cable machines which are also isoinertial. Adjustable weights, a plyo box, chairs, bumper plates, resistance bands, yoga balls, allow for a variety of physical exercises suited for rehabilitation, strengthening, and conditioning.



Figure 2 – Gym equipment

The presence of force plates and the dynamometers of the flywheel devices provide the team with valuable insight of asymmetries, compensatory strategies as well as force and speed production capabilities, helping to guide treatments and track progress. Additionally, a pull-up bar, sport balls, instability surfaces like different Bosus, foam pads and trampolines, yoga blocks, vibrating and non-vibrating myofascial release tools are also available to enhance treatment effectiveness. The outdoor gym, which is used more during the warmer days and occasionally for more sport specific activities like sprinting and changes of direction, is spacious and versatile, allowing for dynamic and varied exercise programs, including those in natural settings for patients who benefit from the open air. The clinic also provides towels and gym clothing in case of unprepared patients that need to go to the gym to complete their treatment session.

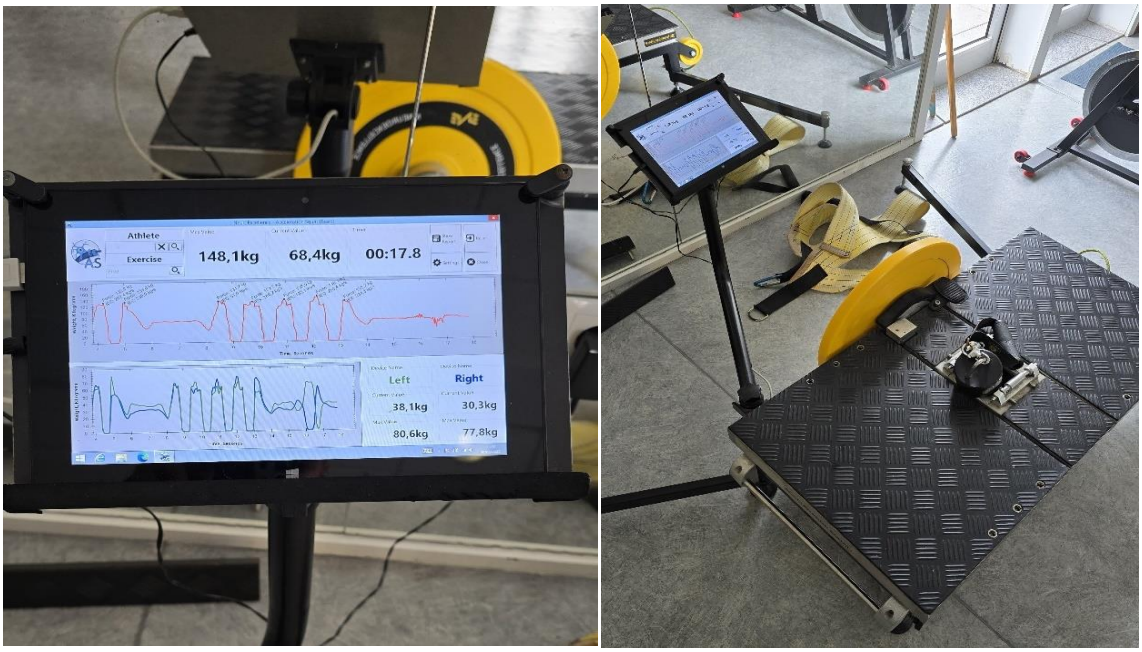


Figure 4 – NeuroExcellence Squat Machine and it´s force plate real time analysis software



Figure 3 – NeuroExcellence Leg Curl and Leg Extension Machine

1.1. FOR+ Team

The clinic is composed of a dedicated and highly skilled team of professionals, each contributing their expertise to deliver comprehensive care to patients. The team consists of three osteopaths, two physiotherapists, one massage therapist, two strength and conditioning coaches with exercise

rehabilitation specialization, and one physician specialized in sports medicine, working collaboratively to ensure the best outcomes for each patient.

Among the osteopaths, two have completed their master's degrees in Osteopathy in England, bringing with them evidence-based knowledge and practices from their studies. One of these osteopaths specializes in pediatric and geriatric care, offering tailored treatment approaches to these unique patient populations, they also teach in higher education degrees. Being one of them, Paulo Gomes, my internship tutor, I must thank for the opportunity. Together, the team plays a vital role in performing thorough assessments and developing personalized treatment protocols.

Following the initial assessment and treatment in the osteopathy and physiotherapy rooms, patients are often referred to the exercise professionals. The assessment is individualized and made by either one of the physiotherapists or osteopaths, followed by a functional assessment by the exercise professionals depending on the presentation of the patient. If needed there's a referral and discussion of the assessment among the other therapists. The exercise specialists also focus on improving patients' strength, mobility, and functional movements. In addition, when needed, they address other factors such as gait patterns and posture with exercises on which they try to educate the patient to be autonomous and continue the work outside the clinic, ensuring a holistic approach to recovery. The close collaboration between the clinicians ensures a seamless continuum of care, optimizing patient recovery and well-being.

Throughout my internship, I have had the opportunity to learn from and work alongside this multidisciplinary team, gaining invaluable insights into patient-centered care and rehabilitation practices.

1.1. Responsibilities as an intern

The primary objective of this internship was to explore ways to make the assessment protocol more efficient and effective, especially in facilitating information exchange among physiotherapists, osteopaths, and exercise rehab professionals. The internship began at the 1st of October 2024 and ended at the

2nd of February 2025 as it is described alongside the different phases at the attachments XIII.

To achieve this, I was actively involved in the daily operations of the clinic, observing and collaborating with the physiotherapists, osteopaths, and exercise rehabilitation specialists. As an osteopath myself, I offered but also attended patient consultations, participated in multidisciplinary team meetings, and reviewed various assessments and treatment protocols used in the clinic.

The internship is a crucial stage in the development and learning process, both professional and personal, it allows the exchange of experiences and knowledge among a company's employees, as well as strategies, plans and concepts. Thus, during this internship, I had the following objectives:

- Deepen knowledge: Consolidate and expand theoretical and practical knowledge of training, especially in rehabilitation, with a focus on the areas of functional assessment, treatment and exercise prescription.
- Skills development: Develop and improve clinical, communicational and decision-making skills, applying the knowledge acquired in daily practice.
- Integration of knowledge: Integrate osteopathy knowledge with physiotherapy and rehabilitation approaches, aiming at a more complete and effective clinical practice.
- Innovation: Propose and implement a new evaluation system that optimizes the rehabilitation process, contributing to the improvement of the quality of care provided to patients.
- Continuous training: Develop the capacity for continuous learning and the search for scientific evidence to support clinical practice.

Functional assessment:

- Master the understanding of human movement and its biomechanics, to better understand the different assessment techniques used in practice.
- Understand the reason for the limitations of the patients' quality of movement and what information we can extrapolate from the evaluations.

- Develop a personalized functional assessment protocol, integrating knowledge from physiotherapy and osteopathy.

Exercise Prescription:

- Learn to prescribe individualized exercises, considering the needs and limitations of each patient.
- Relate the results of the prescribed exercises and their efficacy based on a test, re-test method.

Patient monitoring:

- Monitor the evolution of patients throughout the rehabilitation process, adjusting the treatment plan as necessary.
- Establish a good therapeutic relationship with patients, promoting empathy and a therapeutic alliance.
- Prepare reports and clinical documentation in a clear and concise manner.

Development of the new assessment system:

- To conduct a literature review on physiological normative values of range of motion, assessment systems used in physiotherapy and rehabilitation.
- Identify the main limitations of existing systems and the needs of patients.
- Propose a new assessment system that is more practical, efficient and capable of providing more accurate information about the limitations of movement and the needs of each patient.
- Implement and evaluate the new system in a group of patients, collecting data on its effectiveness and ease of use.

1.1.1. Challenges and Observations

One of the key challenges identified during the internship was the lack of a standardized approach to information sharing among the different professionals within the clinic. Each professional had their own assessment, line of thought and documentation methods, which could lead to inconsistencies and communication

gaps. Furthermore, the internship also highlighted the importance of integrating clinical experience with academic coursework, as students often struggled to comprehend theoretical concepts without the context provided by practical training. These obstacles were defined as a goal to improve upon as the internship went on.

1.1.2. Recommendations and Strategies for Improvement

To address these challenges, several strategies were developed during the internship:

- Develop a comprehensive, interdisciplinary assessment protocol that incorporates the unique perspectives of physiotherapy, osteopathy, and exercise rehabilitation.
- Promote regular interdisciplinary team meetings to discuss patient cases and coordinate care plans, ensuring seamless communication and a holistic approach to rehabilitation.

This internship experience has been invaluable, providing me with a deeper appreciation for the interconnectedness of these allied health disciplines and the importance of fostering collaboration and communication to deliver the most effective and comprehensive rehabilitation services to patients.

2. State of art

2.1. Introduction to Physiotherapy, Osteopathy, and Exercise Rehabilitation

Osteopathy and physical therapy are two distinct yet overlapping fields within healthcare, particularly in the treatment of musculoskeletal disorders. The two fields share a common belief in treating patients as whole, yet they have distinct philosophical foundations and therapeutic methods. The following synthesis examines the distinct features and shared mindsets between osteopathy and physical therapy.

The fundamental principle of osteopathy states that the body operates as a whole with all its systems connected to each other. This holistic perspective is encapsulated in the four osteopathic principles: the body is a unit, it is capable of self-regulation and healing, structure and function are interrelated, and treatment should be based on these principles (Fahlgren et al., 2015). Osteopaths utilize a range of manual techniques, including osteopathic manipulative treatment, to address dysfunctions in the body's structure and promote healing (Bohlen et al., 2021). The treatment approach focuses on musculoskeletal system analysis, but nowadays it is also considered the psychological and emotional health factors through a biopsychosocial treatment model (Saracutu et al., 2018).

Physical therapy works to restore and improve physical function and mobility through exercise and manual therapy and additional modalities including ultrasound and electrical stimulation (Camarinos & Marinko, 2009; Ordem dos Fisioterapeutas, 2023). Physical therapists have training to evaluate and treat various physical disabilities and functional limitations and impairments. Physical therapists use evidence-based practices and standardized protocols to guide their interventions which focus on measurable outcomes such as pain reduction and range of motion improvement, all of which are correlated with quality of life (Ordem dos Fisioterapeutas, 2023). While physical therapy may incorporate manual techniques, it is generally less focused on the holistic aspects of care compared to osteopathy.

The two disciplines share important similarities despite their distinct approaches. Both osteopathy and physical therapy work to reduce pain while

improving function and life quality for patients who have musculoskeletal conditions. For example, research has shown that both approaches can be effective in treating various disorders, such as temporomandibular disorders and chronic pain conditions (Priebe et al., 2015; Cuccia et al., 2010). Furthermore, both fields emphasize the importance of patient education and active participation in the rehabilitation process, encouraging patients to engage in exercises and lifestyle modifications that support their recovery (Edwards & Toutt, 2018; Orrock & Myers, 2013).

The role of exercise professionals during rehabilitation protocols is multifaceted and integral to the recovery process for patients across various health conditions. Exercise professionals, including exercise physiologists, trainers, and rehabilitation specialists, contribute significantly to the rehabilitation team by providing tailored exercise programs, promoting adherence to rehabilitation protocols, and enhancing overall patient outcomes.

One of the primary responsibilities of exercise professionals in rehabilitation is to design and implement individualized exercise programs that align with the specific needs and capabilities of each patient. This involves conducting thorough assessments to evaluate the patient's physical condition, limitations, and goals. For instance, in cardiac rehabilitation, exercise professionals create exercise prescriptions that consider the patient's cardiovascular health, ensuring that the intensity and type of exercise are appropriate for their condition (Yang et al., 2023). This personalized approach is crucial, as it has been shown that adherence to exercise regimens can significantly impact recovery outcomes (Chen et al., 2018).

Exercise professionals also contribute to the rehabilitation process by monitoring patient progress and adjusting the exercises prescriptions as needed. This ongoing assessment allows for modifications to be made in response to the patient's evolving condition and capabilities. For example, in pulmonary rehabilitation, exercise professionals are involved in evaluating the effectiveness of exercise interventions and making necessary adjustments to optimize outcomes (Ennis et al., 2023). This approach ensures that patients receive the

most effective rehabilitation strategies tailored to their individual needs. Moreover, exercise professionals are increasingly recognition for their role in community-based rehabilitation programs. As patients transition from clinical settings to home or community environments, exercise professionals can provide the necessary support and guidance to help facilitate this, by bridging the gap between rehabilitation and community exercise, exercise professionals help patients maintain the gains achieved during formal rehabilitation and promote a sustainable, active lifestyle.

As the healthcare landscape continues to evolve, the integration of exercise professionals into rehabilitation teams will be crucial for addressing the diverse needs of patients and promoting long-term health and well-being.

The therapeutic relationship is another area where osteopathy and physical therapy as well as exercise professionals share similarities. These areas prioritize building empathy with patients and understanding their individual needs and preferences. This patient-centered approach is essential for fostering trust and compliance, which are critical for successful treatment outcomes (Bradbury et al., 2012; Thomson et al., 2014). Additionally, these professions are increasingly recognizing the value of interdisciplinary collaboration, often working alongside other healthcare providers to deliver comprehensive care (AlKuait, 2024).

However, the training and educational pathways for osteopaths and physical therapists differ significantly. Osteopathic education typically involves a more extensive focus on manual therapy techniques and the philosophical underpinnings of osteopathy, often requiring a degree in osteopathic medicine (Vaughan & Grace, 2016). In contrast, physical therapy programs have generally been grounded in a science-based curriculum that emphasizes anatomy, physiology, and rehabilitation techniques, culminating in a academic degree (Ordem dos Fisioterapeutas, 2023) (Camarinos & Marinko, 2009). This difference in training reflects the distinct approaches each profession takes toward patient care. However, the current state of osteopathy is changing and getting more recognized with more literature and science-based evidence, especially in the

neuromusculoskeletal area. Osteopaths require a professional license to be able to exert, however it's starting to get into the higher education and academic degrees in some countries including in Portugal since 2016.

Another key difference lies in the regulatory frameworks of each profession. In many countries, osteopathy is recognized as a distinct healthcare profession with its own regulatory bodies, while physical therapy is often integrated into broader healthcare systems with standardized licensing and practice guidelines (Engel et al., 2016). This regulatory landscape can influence the scope of practice for each profession, including the types of treatments they are authorized to provide and the settings in which they can operate.

The perception of each profession among healthcare providers and patients also varies. Studies have indicated that general practitioners may hold differing views on the effectiveness and safety of osteopathy compared to physical therapy, which can impact referral patterns and patient access to care (Schmid et al., 2021). Patients often report varying levels of satisfaction with their experiences in osteopathy and physical therapy, influenced by factors such as treatment outcomes, practitioner communication, and the perceived value of the therapies received (Bradbury et al., 2012; Edwards & Toutt, 2018).

In terms of treatment, osteopathy often employs a broader range of manual techniques, including soft tissue manipulation, joint mobilization, visceral and cranial osteopathy, which are less commonly utilized in physical therapy (Oliveira et al., 2020). Physical therapists, on the other hand, may incorporate more technologically advanced modalities, such as electrical stimulation and biofeedback, into their treatment regimens (Camarinos & Marinko, 2009). This distinction highlights the different therapeutic tools and techniques each profession emphasizes in practice.

Despite these differences, both osteopathy and physical therapy are increasingly integrating evidence-based practices into their treatment approaches. Research continues to support the efficacy of both disciplines in managing various musculoskeletal conditions, leading to a growing body of literature that informs clinical practice (Orrock & Myers, 2013; Jiang, 2024). This

emphasis on evidence-based care reflects a broader trend within healthcare toward accountability and the need for practitioners to demonstrate the effectiveness of their interventions.

Many physiotherapists also pursue additional training in osteopathic approaches into their curriculum and practice. Similarly, some osteopaths integrate physiotherapy methods such as therapeutic exercise and rehabilitation protocols into their care. Therefore, it's inaccurate to claim that one profession or modality is “better” than the other. The clinician’s competence, critical thinking, patient communication, and ability to integrate various approaches are what truly determine treatment success.

In conclusion, while osteopathy and physical therapy share common goals of improving patient outcomes and enhancing quality of life, they differ significantly in their philosophies, techniques, training, and regulatory frameworks. Both professions contribute valuable perspectives and skills to the management of musculoskeletal disorders, and their collaborative efforts can lead to more comprehensive and effective patient care. As the healthcare landscape continues to evolve, ongoing research and dialogue between these disciplines will be essential for optimizing treatment strategies and improving patient outcomes.

As an osteopath pursuing a master's degree in clinical exercise, I had the opportunity to complete an internship at a physiotherapy, osteopathy, and exercise rehabilitation clinic. One main goal of this internship was to explore ways to streamline the assessment protocol and facilitate the transfer of information between these allied health disciplines.

2.2. Exploring the Clinical Landscape

The internship experience allowed me to witness firsthand the collaborative nature of physiotherapy, osteopathy, and exercise rehabilitation.

Physiotherapists, with their expertise in physical assessment and movement analysis, often work closely with osteopaths to address musculoskeletal dysfunctions and imbalances. Osteopaths, in turn, provide manual therapy techniques to address structural and functional impairments,

which can then be complemented by the exercise-based interventions implemented by exercise rehabilitation specialists. This ensure that the patient receives a comprehensive, holistic approach to their rehabilitation and recovery while allowing the practitioners to leverage each other's unique skillsets and also to save time so they can not only see more patients but to ensure the care received is more efficient and tailored (Mina & Fischer, 2017). Other advantages include the avoidance of potential overlaps or gaps in care, which can happen when each discipline works in isolation.

The interdisciplinary nature of this clinical setting underscores the need for effective communication and information sharing to ensure the best possible outcomes for patients.

Since different professionals with different backgrounds work together there should be a clear process to guide the transition of care between them (Mina & Fischer, 2017).

In physiotherapy and osteopathy, the assessment protocol typically involves a comprehensive evaluation of the patient's physical function, including range of motion, muscle strength, and postural analysis. These findings are then communicated to the exercise rehabilitation specialist, who can then design an appropriate exercise program to address the identified impairments and functional limitations. However, the key performance indicators (KPI's) used in the assessment are sometimes not directly translatable into the exercise context.

This highlights the need for a more streamlined assessment process that can effectively bridge the gap between the various disciplines (Mina & Fischer, 2017).

2.3. Integrating Diverse Modalities

The internship experience highlighted the importance of integrating diverse methods, such as team-based learning and simulation-based exercises, into the academic curriculum.

One significant barrier is the lack of a standardized assessment protocol between professionals for ROM testing. The work by Irving et al., (2022)

demonstrated discrepancies in assessment practices among professionals assessing recurrent patellar dislocation. It was found that physiotherapists recognized the importance of established protocols but also expressed that these protocols sometimes limit their professional autonomy. This suggests a significant push towards tailored, person-centered approaches rather than a uniform, one-size-fits-all method (Volkmer et al., 2021). This dichotomy indicates that variations in assessment practices may not solely depend on the evidence but also reflect the clinician's clinical reasoning, professional identity, and contextual factors.

This assessment inconsistency can lead to:

- **Miscommunication and confusion:** Different therapists may use varying terminology, assessment methods, and grading scales, making it difficult to understand and continue previous interventions effectively.
- **Delayed progress:** Inconsistent assessments can hinder accurate tracking of patient progress, leading to delayed or inappropriate treatment adjustments.
- **Increased risk of error:** Variations in assessment can increase the risk of overlooking critical issues or misinterpreting patients´ limitations.

To address these challenges found in the context of the internship, I proposed the implementation of regular team meetings to:

1. **Develop a standardized assessment protocol:**
    - **Consensus building:** Team members will collaboratively define and agree upon a standardized set of terms, assessment methods (e.g., goniometry, visual estimation, functional tests), and grading scales for ROM and movement capabilities.
    - **Pilot testing and refinement:** The proposed protocol will be pilot tested on a small group of patients, followed by a critical evaluation and refinement process.

2. **Enhance communication and knowledge sharing:**
    - **Regular meetings:** Scheduled team meetings will provide a platform for regular discussions on patient cases, sharing of assessment findings, and collaborative decision-making regarding treatment plans.
    - **Case presentations:** Individual therapists will present challenging cases, allowing for peer review and discussion of assessment findings and treatment strategies.
3. **Improve patient care:**
    - **Consistent and accurate assessments:** A standardized protocol will ensure consistent and accurate assessments across all professionals, facilitating better tracking of patient progress and more effective treatment planning.
    - **Improved patient transitions:** Clear and concise documentation of assessments and treatment plans will facilitate smoother transitions between professionals, minimizing disruptions to patient care.
    - **Enhanced patient outcomes:** By improving communication and consistency in assessment and treatment, we can ultimately enhance patient outcomes and improve the overall quality of care provided at the clinic.

By implementing these team meetings and developing a standardized assessment protocol, we can create a more efficient and effective system for patient care, ensuring that all therapists are working towards common goals and providing the best possible outcomes for our patients.

2.4. The Role of Fluid Mechanics

The assessment and treatment of musculoskeletal conditions often require an understanding of fluid mechanics, as the principles of fluid dynamics can be applied to the human body. The human body's water content ranges from 44.6%

to 75.7%, water content within your body decreases with age and other factor like disease, physical activity and diet, hence the range (White et al., 1992; Edelman & Leibman, 1959). The flow of blood, lymph, and synovial fluid plays a crucial role in the health and function of the musculoskeletal system.

Synovial fluid plays a crucial role in facilitating movement within synovial joints. According to Tamer, the principal function of synovial fluid is to reduce friction between the articular cartilages during joint movement (Tamer, 2013). The high molar mass of hyaluronan present in synovial fluid gives it the required viscosity to act as a lubricating solution (Tamer, 2013). Aging can lead to structural changes in synovial joints, which in turn impact an individual's mobility and overall well-being (Gul et al., 2024). As Gul explains, the musculoskeletal system undergoes a sequence of modifications during the aging process, and these changes in the structure of synovial joints are pivotal in shaping an individual's mobility (Gul et al., 2024).

Synovial fluid not only serves as a lubricant but also plays a role in nourishing the articular and hyaline cartilage. As Levick explains, the synovial microcirculation generates intra-articular fluid (synovial fluid) that transports glucose by convection during joint movement, which is essential for supplying central chondrocytes with nutrients (Levick, 1995).

The fact that the human body’s composed of water and we've got synovial fluid in our joints, means that we don't have fulcrums, if we had a fulcrum there would be a lot of pressure and heat that would be released every time we moved and we would destroy our joints, this representation is often misunderstood, especially in students, when learning biomechanics and functional anatomy (Abdullah, 2019; Cajori, 1926; Hui et al., 2011; Levick, 1995). So instead of having a fulcrum, we have this thin film of synovial fluid that allows the surfaces to glide smoothly over each other, instead of the traditional “dead guy anatomy” model that led to this idea, not to mention all the other visco-elastic tissues that abound in the musculoskeletal system. The visco-elastic tissues and synovial fluid are crucial in dissipating compression forces, allowing for shock absorption and minimizing joint wear and tear over a lifetime of movement and physical

activity, and they will behave differently depending on the forces exerted (Cajori, 1926; Abdullah, 2019; Levick, 1995; Hui et al., 2011).

The hyalin cartilage cover at both ends of the joint has no blood vessels, it is nourished through the diffusion of nutrients from the subchondral bone and synovial fluid (Wang et al., 2012). Synovial fluid has glycoproteins in its content, and cartilage is a highly hydrated tissue, comprised of 70% to 80% water per wet weight (Elder & Athanasiou, 2009). The high-water content is a result of water being attracted to the negatively charged proteoglycan molecules within the tissue (Elder & Athanasiou, 2009; Xu et al., 2013; Cederlund & Aspden, 2022). Due to the hydrophilic properties of the hyaline cartilage, this means that when the water from the synovium is right next to it, it promotes the separation of the water into positively and negatively charged water. The negative charged water stays right along the hyaline cartilage on both sides of the joint, as the positive charged water stays mostly in between. In this middle articular region, there´s significantly higher proteoglycan molecules in the synovium and the positive charged water gets more attracted (Torzilli & Allen, 2022; Elder & Athanasiou, 2009; Xu et al., 2013; Cederlund & Aspden, 2022), thus further facilitating a electromagnetic force that helps create a repulsion mechanism to keep the bones away from each other, almost like trying to join 2 magnets that are repelling.

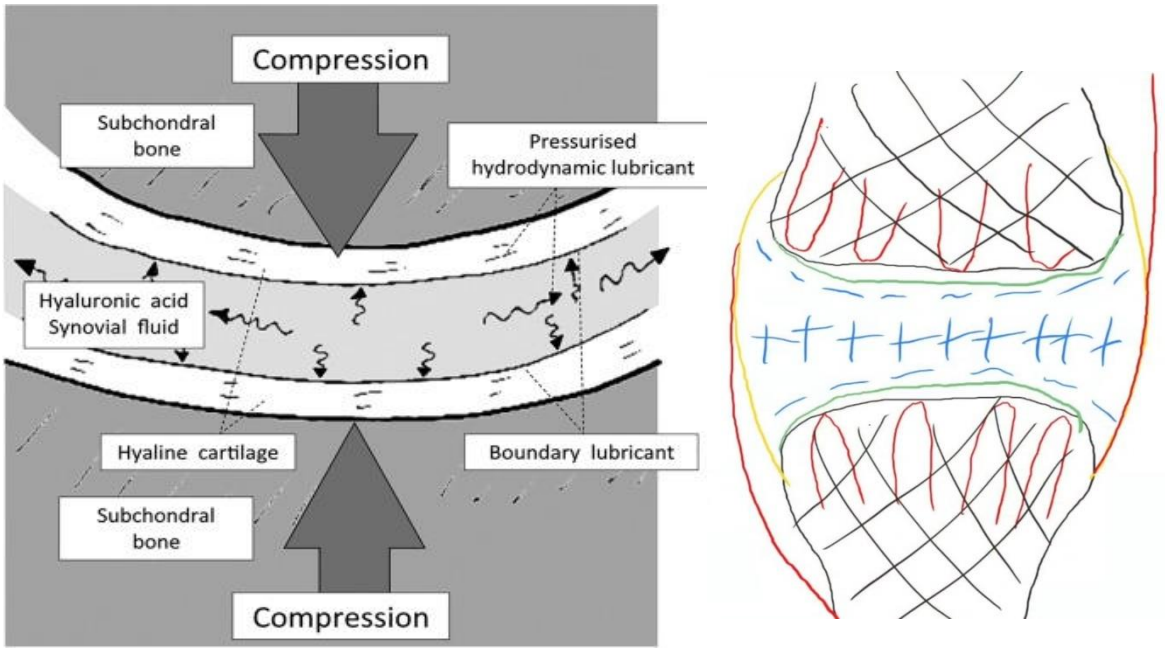


Figure 5 – Illustration of the repulsion mechanism

In fact, a study conducted by Terayama (1980), used fresh cadavers' knees with intact synovial joints where they applied compressive forces up to around 1100 Newtons and the bones still didn´t touch. On the same study, compressive forces on arthritic hip joints were also applied, since the electromagnetic force was compromised due to the degeneration of the cartilage, they found that the bones would come in contact with each other on the degenerative areas. If we take the magnet example, it's similar to when the north and south end of 2 magnets snap together, this pushes the synovial fluid away from the contact area creating a compressive and expanded representation at the joint.

Prolonged pressure on the bone and articular cartilage can lead to significant detrimental effects (Karsdal et al., 2008; Lories & Luyten, 2010; Goldring & Goldring, 2010; Zhen & Cao, 2014; Yokota et al., 2011).

The articular cartilage plays a crucial role in load transfer across the joint. Conditions that produce increased or altered patterns of load distribution can accelerate the development of osteoarthritis (OA) (Goldring & Goldring, 2010). Prolonged pressure can cause softening and thinning of the articular cartilage, as well as microfractures through the calcified cartilage and subchondral bone (Nakamae et al., 2006). The blood supply from the bone is what's responsible for

the nutrition of the hyalin cartilage on the bony attachment and with enough pressure and tension the trabecula bone compresses and the blood flow to that area becomes restricted. This can disrupt the normal biomechanical function of the cartilage and lead to further degeneration (Nakamae et al., 2006; Lories & Luyten, 2010). At the bone level, prolonged pressure can induce bone sclerosis, which deforms the articular surfaces and alters local stress distribution, further exacerbating cartilage damage (Karsdal et al., 2008; Goldring & Goldring, 2010). The increased bone turnover and remodeling in response to abnormal mechanical loading can also contribute to OA progression (Karsdal et al., 2008; Zhen & Cao, 2014). This degeneration occurs due to the lack of diffusion of nutrients often in the area where the most pressure and lack of relative movement occurs.

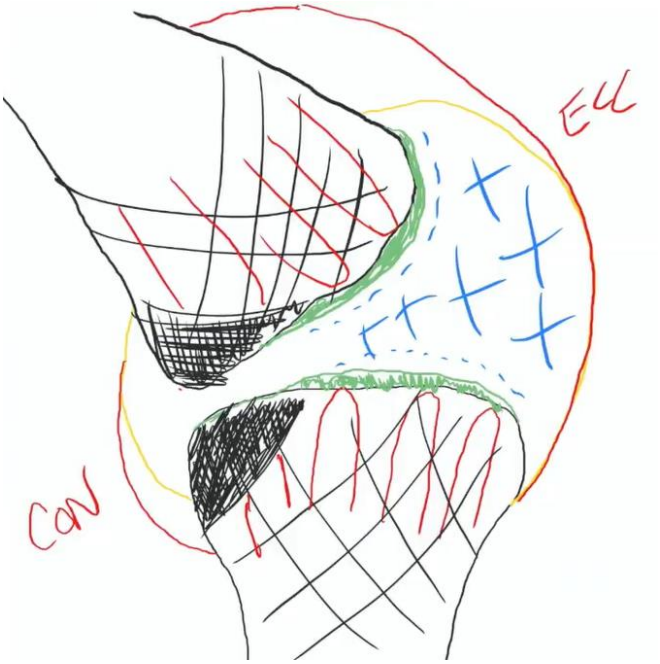


Figure 6 – Illustration of the altered pressure gradient due to concentric and eccentric orientations and its relationship with the joint nutrition

Additionally, prolonged disuse and unloading, such as from immobilization or bed rest, can cause rapid bone loss and muscle wasting, further compromising the musculoskeletal system (Reilly & Franklin, 2016; Bloomfield, 2010). This disuse-induced osteopenia and osteoporosis increase the risk of fractures (Bloomfield, 2010).

OA is a disease affecting the whole joint, however, the articular cartilage (a subset of hyaline cartilage) within the joint is the most affected tissue. OA is known as a "wear and tear" phenomenon because it mainly affects joints under higher amounts of stress (He et al., 2020). It results in articular cartilage being thinned and wearing away (Chang et al., 2022). Based on the disruption and altered mechanisms affecting the articular cartilage from continuous compression there will be more stiffness and a lack of relative motion that prevents the synovium to lubricate and nourish the connective tissues of the joint. In an experimental study by Salter & Field, (1960), investigating the effects of continuous compression on living articular cartilage, the researchers found that the compressed areas developed lesions which varied from superficial necrosis to loss of the full cartilage thickness, depending on the duration of compression. Additionally, they observed that simple immobilization of a joint in a forced position had similar lesions in nature to those produced by clamp compression.

Hyaluronic acid (HA), or Synvisc injections have glycosaminoglycan that has the ability of several proteins to bind (Campo et al., 2003). These injections are often utilized in the treatment of OA. This not only helps to maintain the viscosity and lubrication, but also to reestablish the repulsion mechanism. The therapeutic use in conditions like OA is based on its ability to restore the viscoelasticity of synovial fluid, which often diminishes with the progression of OA (Altman et al., 2015; Rodríguez-Merchán, 2013). Research indicates that HA injections can provide significant pain relief and improve joint function in patients with knee OA. A systematic review highlighted that hyaluronic acid promotes cartilage repair and delays OA progression (Zheng et al., 2020). Furthermore, a meta-analysis demonstrated that HA injections could lead to improved pain relief and physical function, particularly in the short to medium term following treatment (Shen et al., 2018). However, its efficacy is not universally accepted. Some studies suggest that while HA can provide symptomatic relief, its long-term benefits are less clear, and the overall improvement may be modest. For example, a review noted that the effectiveness is most pronounced between 5 and 13 weeks post-injection, after which the benefits may diminish (Hameed & Ihm, 2012). Additionally, the variability in patient responses and the lack of

consensus on the optimal treatment regimen contribute to the ongoing debate regarding its effectiveness (Chareancholvanich et al., 2013).

All this is extremely important not only to be able to manage and help clients and patients that are dealing with discomfort, pain or conditions like OA, but it also allows us to recognize that a healthy joint is able to lubricate and get the adequate nutrition as a whole, in order to avoid prolonged pressure, potentially causing the “wear and tear” phenomenon that can be caused by the lack of movement capabilities, immobilizations or overuse of the same tissues.

All movement is based on gradients. By exploring this line of thought, we need to be mindful that this doesn´t translate to a model where physical activity, sports and exercise are bad by nature due to the loads which one gets exposed to. Physical activity and exercise interventions have mainly positive outcomes on cartilage structure (Petrigna et al., 2022). Clinicians, coaches, trainers and researchers must be aware when prescribing exercise programs to select the most appropriate intervention based on the patient’s needs.

2.5. Bridging the Gap through Comprehensive Assessment

During the internship I found that each professional had its own unique approach to assessments and documentation, which sometimes led to inconsistencies and challenges in information sharing. To address this, I proposed the development of a comprehensive, interdisciplinary assessment protocol that would incorporate the key elements from physiotherapy, osteopathy, and exercise rehabilitation.

This proposed assessment protocol would include an analysis on simple KPI’s, mainly on passive ROM assessments that would be easy to communicate and understand, allowing for a more seamless transition of care and a better understanding of the patient's overall movement capabilities.

For that to happen we first need to ensure there is a harmonized language and understand what constitutes "good" ROM for the relevant body segments that would be considered in the assessment protocol. However, because of the high complexity of the human body, the focus will mainly be on the hip and

shoulder complex and what those joints ROM's can tell us about the more proximal and distal areas.

The normal ROM for the shoulder and hip joints is a critical aspect of musculoskeletal health, influencing both functional capabilities and overall quality of life. Systematic reviews highlight that modalities such as yoga and physiotherapy not only improve flexibility but also lead to significant improvements in health-related quality of life measures (Sivaramakrishnan et al., 2019). The evidence suggests that maintaining or improving flexibility through targeted interventions is crucial for enhancing overall quality of life, particularly in older adults and those recovering from musculoskeletal injuries (Zhang et al., 2015; Burk et al., 2020). Understanding the normative values for these joints is essential for clinicians, physical therapists, and researchers alike.

The shoulder joint is characterized by a wide range of motion due to its ball-and-socket structure. According to the American Academy of Orthopedic Surgeons, the normal active range of motion for shoulder flexion and abduction is approximately 180 degrees, while external rotation at 90 degrees of abduction is typically around 90 degrees (Gill et al., 2020). A systematic review found that for daily tasks, around 130 degrees of shoulder flexion and abduction were necessary (Oosterwijk et al., 2018). Magermans et al., (2005) has shown that in daily tasks shoulder flexion can go for at least 150 degrees, however, they also mention that restriction in elbow motion will lead to a considerable increase in range of motion in the shoulder during activities of daily living has a compensatory strategy. One way this could potentially occur, for example, is when someone tries to write on a keyboard but due to insufficient pronation, humeral elevation and internal rotation may occur to facilitate the hand positioning, thus allocating tension and stress from one structure to another.

Generally, the normative range for shoulder internal rotation from 90 degrees of abduction is approximately 70 degrees to 90 degrees when measured with the shoulder in a neutral position (Shirai et al., 2022). This range is essential for various functional activities, including reaching behind the back and performing overhead motions, has Gates et al., (2015) highlighted that during

activities of daily living we would require a peak average of 79 degrees of internal rotation, specifically when reaching for the back pockets.

Research has shown that the internal rotation range can be influenced by specific activities and sports. For instance, athletes, particularly those involved in overhead sports such as tennis and baseball, often exhibit variations in shoulder internal rotation due to the demands of their sports (Chiang et al., 2016). In a study involving junior female tennis players, it was found that those with higher performance rankings had greater internal rotation flexibility, suggesting a correlation between shoulder mobility and athletic performance (Chiang et al., 2016).

Glenohumeral internal rotation deficit refers to a condition where there is a significant difference in internal rotation between the dominant and non-dominant shoulders, often observed in overhead athletes (Yoshida et al., 2022). This deficit can lead to compensatory mechanisms that may increase the risk of shoulder injuries, particularly in athletes who rely heavily on their throwing or swinging motions. A study indicated that baseball pitchers frequently exhibit decreased internal rotation in their dominant shoulder, which can contribute to shoulder pain and dysfunction (Yoshida et al., 2022), however we must have into account that baseball players also tend to develop an increase in humeral retroversion from the repetitive and stressful act of throwing which allows for more shoulder external rotation to be represented (Thomas et al., 2019) but potentially decreasing internal rotation capabilities. This highlights the importance of maintaining adequate internal rotation for not only optimal performance in sports requiring significant shoulder use but for daily living as well.

However, these values can vary based on demographic factors such as age and gender. A community-based cohort study by Gill et al., (2020) highlighted that normative data for shoulder ROM should be stratified by age and gender, as variations exist within different populations. This underscores the importance of context when assessing shoulder mobility. Moreover, the impact of physical activity on shoulder ROM cannot be overlooked. Regular exercise has been shown to maintain or even improve shoulder ROM, particularly in older adults. A

study indicated that women aged 50 to 71 who engaged in regular exercise demonstrated significant improvements in shoulder abduction and external rotation (Xiao, 2020). This suggests that lifestyle factors, like exercise and physical activity play a crucial role in maintaining shoulder mobility, emphasizing the need for targeted interventions in populations at risk of reduced ROM.

Additionally, the benefits of being more physically active are notorious. People who are more physically active and have less sedentary behaviors appear to have lower cardiovascular risk, higher quality of life (Santos et al., 2024), more mental health (Teno, Silva and Júdice, 2024), lower risk of developing diabetes type 2 (Aune et al., 2015). Adapted physical activity in individuals with OA can reduce pain and activity limitations in the short, mid and long terms, especially of the lower limbs, which has been demonstrated in high-level clinical trials and meta-analyses (Daste et al., 2021).

In addition to demographic and lifestyle factors, pathological conditions can significantly affect shoulder ROM. Conditions such as myofascial pain syndrome and rotator cuff tendinopathy can lead to restricted movement and pain (Silva et al., 2016). For example, individuals with rotator cuff injuries often exhibit limitations in shoulder flexion and abduction, which can severely impact daily activities (Silva et al., 2016). Thus, understanding the normative ROM values is essential for identifying deviations that may indicate underlying pathology.

The hip joint also plays a vital role in overall mobility, with normative values for hip ROM being essential for assessing functional capabilities. In the sagittal plane the normal hip can move to 120 degrees of flexion and 10 to 15 degrees of extension (Neumann et al., 2017). For hip internal rotation in a flexed position, normal values range from 30 to 45 degrees, while external rotation typically ranges from 40 to 60 degrees (Sadeghisani et al., 2015). These values are crucial for activities such as walking, running, and climbing stairs, as they facilitate the transfer of energy between the lower and upper extremities. A reduction in hip internal rotation has been associated with low back pain and other musculoskeletal disorders like hip impingement, anterior cruciate ligament tears and abdominal strains, emphasizing the importance of maintaining adequate

ROM in this joint (Avman et al., 2019; Bedi et al., 2014; Sadeghisani et al., 2015; VandenBerg et al., 2016; Kapron et al., 2012). Furthermore, asymmetries in hip rotation ROM can lead to compensatory movement patterns that may result in injury over time (Sadeghisani et al., 2015).

A study on professional baseball players also found that limitations in hip internal and external rotation were associated with a higher incidence of hip and groin injuries (Li et al., 2015). This highlights the importance of maintaining adequate hip mobility not only for performance but also for injury prevention. Furthermore, the relationship between hip morphology and ROM has been explored in the context of femoroacetabular impingement (FAI), a condition that can lead to pain and decreased mobility. Abnormalities in hip joint morphology can restrict movement and contribute to the development of FAI, which is particularly prevalent in young adults (Pollard et al., 2010). Understanding these relationships is crucial for developing effective rehabilitation strategies and preventive measures.

To fully understand how the shoulder and hip work we should also see how the rest of the body influences it. For instance, end-range shoulder flexion is a complex movement that requires not only the mobility of the shoulder joint itself but also the coordinated movement of the spine and ribcage. Research indicates that both spinal extension and rotation play significant roles in achieving optimal shoulder flexion.

Spinal extension is crucial for facilitating shoulder flexion. When the thoracic spine is extended, it allows for greater upward rotation of the scapula, which is essential for full shoulder flexion. A study by Yabata and Fukui, (2022) demonstrated that shoulder flexion is significantly affected by the position of the thoracic spine, with more external rotation of the scapula observed in thoracic flexion compared to thoracic extension. This suggests that maintaining an extended thoracic spine during shoulder flexion can enhance scapular mechanics, thereby promoting a greater range of motion at the shoulder. Theodoridis and Ruston, (2002) also demonstrated a repeatable upper thoracic movement pattern with rotation and lateral flexion of the thoracic spine during

shoulder flexion independently of it being in the scapular or sagittal plane. A systematic review from Heneghan et al., (2019) also demonstrated that at end range shoulder flexion there's unequivocal evidence of thoracic spine movement but mainly extension. Understanding how the spine influences the shoulder is important, especially when one of the complex shoulder joints is the scapulothoracic that every professional learns about it but seems to neglect in their practice, probably because of the lack of practical application.

Underlaying the thoracic spine and having a direct attachment is the ribcage which is often forgotten in most strength and conditioning and mobility programs. The ribcage serves as a foundation for the scapula to be able to move freely, thus the importance of having a mobile ribcage, one that can expand and compress 360º during the phases of inhalation and exhalation, allowing proper shoulder mechanics. Alterations in the positions of the spine and the ribcage can directly affect shoulder joint function, for example, studies have shown that asymmetries in scapula and shoulder ROM and position are often observed in individuals with shoulder impingement, suggesting that the relationship between the scapula and ribcage is critical for optimal shoulder function (Samakoush & Norasteh, 2022).

Research indicates that rib movement can influence shoulder mobility, particularly in individuals who have undergone chest wall procedures, which are often associated with postoperative shoulder dysfunction (Tachihara & Hamada, 2019). Furthermore, Tachihara and Hamada (2019) findings suggest that when we elevate the upper limb most movement is found in the fifth, fourth and third ribs, decreasing toward the lower ribs and manipulative therapies targeting the thoracic spine and upper ribs have been shown to improve shoulder pain and enhance joint mobility, underscoring the importance of ribcage positioning in shoulder function. Studies have also demonstrated that individuals with shoulder pathologies often exhibit reduced thoracic mobility, which correlates with limited shoulder range of motion (Theisen et al., 2010). The relationship between spinal posture and shoulder mobility is further emphasized in studies examining the effects of postural alignment on shoulder function. For instance, forward head posture has been linked to changes in scapular positioning, which can impair

upward rotation and, consequently, shoulder mechanics (Lynch et al., 2010). The positioning of the spine, including its curvature, can affect the joints' ability to function optimally, limited mobility in the shoulder and hips can impact spinal curvatures and vice versa (Olszewska et al., 2018).

Breathing patterns also play a role in shoulder mobility, particularly thoracic dominant breathing, which can lead to increased activation of shoulder elevation muscles such as the upper trapezius (Smyth et al., 2022). This activation may happen to ensure a opening of the airway, guaranteeing adequate oxygen intake, this strategy to use secondary breathing musculature, can contribute to shoulder dysfunction if the ribcage is not positioned correctly, as improper ribcage mechanics can limit diaphragm mobility and lead to compensatory movements in the shoulder complex (Albarrati et al., 2018).

The relationship between hip mobility and shoulder range of motion (ROM) is also an area of growing interest in the fields of physical therapy and sports medicine. Research indicates that there is a biomechanical and functional connection between the hip and shoulder joints, particularly in activities that require coordinated movement patterns, such as throwing and overhead sports. This connection is often referred to as the "kinetic chain," where the movement of one joint can influence the function and mobility of another.

Studies have shown that limitations in hip mobility can lead to compensatory movements in the shoulder, potentially resulting in decreased shoulder ROM. For instance, Moreside & McGill (2012) demonstrated that improvements in hip ROM through specific interventions can enhance overall functional movement patterns, suggesting that hip mobility is crucial for optimal shoulder function. However, the specific findings regarding the direct impact of hip mobility on shoulder ROM were not the primary focus of their study. Therefore, while hip mobility is important, the direct link to shoulder function needs further clarification. The concept of "hip-shoulder separation" is particularly relevant in sports like baseball and tennis, where the ability to rotate the hips independently from the shoulders is critical for performance and injury prevention. Research by Chalmers et al. (2017) highlighted that pitchers with better hip and

shoulder separation exhibited improved pitching mechanics and reduced injury risk. This suggests that restricted hip mobility could lead to compensatory shoulder mechanics, potentially increasing the risk of shoulder injuries.

Furthermore, the role of the trunk and pelvis in facilitating shoulder mobility cannot be overlooked. The spine-pelvis relationship is essential for maintaining proper alignment and movement patterns during dynamic activities (Lee et al., 2019). However, this study focused primarily on the relationship between the spine and pelvis in the context of hip arthroplasty, rather than directly addressing the influence of this relationship on shoulder mechanics. Therefore, while their findings underscore the importance of pelvic alignment, they do not directly support the claim regarding shoulder mobility. While there is evidence to suggest that hip mobility can affect shoulder ROM, the direct connections and mechanisms require further investigation. Limitations in hip mobility may lead to compensatory patterns that restrict shoulder movement, while improvements in hip ROM could enhance shoulder function. This relationship underscores the importance of addressing hip mobility in rehabilitation and training programs for active individuals, recreational exercisers and patients with shoulder dysfunction.

These are important considerations to acknowledge, shoulder and hip range of motion isn´t all about the joint itself but require a holistic view to fully understand its capabilities.

In clinical practice, assessing ROM in both the shoulder and hip is vital for diagnosing conditions, planning rehabilitation and monitoring progress. For instance, clinicians often utilize goniometric measurements to evaluate shoulder and hip ROM, comparing individual results against established normative values to identify limitations (Missmann et al., 2022). This practice is particularly important in populations with a high risk of mobility impairments, such as the elderly or individuals recovering from surgery (Stubblefield, 2017).

It is to note that the body moves as a whole, hip and shoulder mobility are interdependent. A recent study from (Lobbos et al., 2024) demonstrated that limitations in pelvic position can contribute to compensatory changes in shoulder movement patterns. These findings highlight the importance of assessing and

addressing mobility limitations in a holistic manner rather than focusing solely on individual joints.

Biomechanical analyses by Steele et al. (2013) elucidate the relationship between Center of Mass (COM) positioning and muscle activation. Their findings indicate that the quadriceps and gluteus maximus muscles exhibit different activity patterns depending on the position of the COM, with these muscles becoming more active when the COM is positioned further forward or backward than typical (Steele et al., 2013). Such adaptations highlight that muscle function is modulated not only by anatomical relationships but also by the biomechanical challenges presented by COM positioning.

For instance, the influence of trunk orientation on muscle activity has been explored by Lee and An, (2023) who show that forward trunk lean alters hamstring activation dynamics during a single-leg deadlift. When the trunk leans forward, the dynamics shift, necessitating alterations in muscle tension to stabilize the body against gravity and momentum generated during the movement (Lee & An, 2023). This underscores the interplay between COM position and trunk orientation in regulating force generation across the muscular system.

A robust relationship exists between the position of the COM and muscle tension generation. Understanding these dynamics not only informs concepts in biomechanics but also enhances approaches in sports science, rehabilitation, and injury prevention.

Having all this in mind we can start to develop an assessment protocol to try to make a more comprehensive approach, not only for making the interdisciplinary work easier, but to also be able to select more effective exercises based on findings from before and after the intervention assessments. Otherwise, despite having the best intention we end up guessing that the exercise was effective, since everyone responds differently, sometimes the best exercise or intervention for someone might not be the best for someone else, hence the expression, if you're not assessing you're just guessing.

Before defining the normative values for our KPIs we need to understand the concept and difference of relative movement and orientations.

Relative movement in biomechanics and human movement refers to the motion of one body segment in relation to another segment or a reference point. This concept is crucial in understanding how different parts of the body interact during various activities, such as walking, running, or performing sports. The analysis of relative movement allows researchers and practitioners to assess the dynamics of human motion, identify potential dysfunctions, and develop effective rehabilitation strategies.

The analysis of relative movement is particularly relevant in the context of human gait. Studies have shown that understanding the kinematics of joints, such as the knee and ankle, during walking can provide insights into the forces and moments acting on these joints (Wu et al., 2010). For example, the anterior cruciate ligament experiences varying loads during different phases of gait. Analyzing these loads in relation to joint angles can help in understanding injury mechanisms and developing preventive strategies (Wu et al., 2010). This relationship between joint kinematics and relative movement is essential for optimizing performance and minimizing injury risk in athletes. As Bedi et al. (2014) demonstrated, a decrease in hip internal rotation ROM is associated with more compensatory movements in other to be able to internally rotate the femur, this can be represented for example, as a knee valgus strategy which is usually a orientation strategy, where multiple segments move to try to compensate for the lack of movement available, the same mechanism occurs with neck strains, where the lack of cervical ROM is compensated by the whole thorax. Tokuyasu et al., (2024) demonstrated that people with relatively low hip mobility showed greater lumbar spine and pelvic movement, while those with relatively high hip mobility showed less lumbar spine and pelvic movement.

2.6. Pelvifemoral Rhythm

Pelvifemoral rhythm is how the pelvis moves in relationship to sacrum and femurs.

A primary understanding of sacral nutation is that it affects the orientation and stability of the pelvic girdle, which influences the hip's kinematic behavior. During nutation, the sacrum tilts anteriorly, which can lead to changes in the position of the ilium and femur. This geometric adjustment may promote a bias towards internal rotation of the hip joint (Vleeming & Schuenke, 2019). The anterior movement of the sacrum allows the iliac bones to stabilize in a manner that can change the angular relationship with the femur, potentially leading to increased internal rotation torque during movements.

Research by Hammer et al. (2018) emphasizes that during nutation, the motion within the sacroiliac joint (SIJ) involves both flexion-extension and anterior-inferior translations, which are essential for understanding how the position of the sacrum influences adjacent structures, including the hips. As the sacrum undergoes nutation, biomechanical alterations occur, where the orientation of ligaments and muscle attachments around the pelvic region can contribute to altered hip joint mechanics. Thus, with a forward rotation of the sacrum, the hip may be predisposed to internal rotation due to the shift in joint congruency and the resultant action of the surrounding musculature (Vleeming & Schuenke, 2019). Vleeming and Schuenke, (2019) have elaborated on the mechanics of force closure in the SIJ during various movements, explaining that sacral nutation is crucial for adapting the pelvis to the loading forces encountered during physical activities. This might also contribute to alterations in the pelvic floor muscle activity.

With relative motion, moving the leg in front of the body requires the ventral cavity to move relatively backwards. This biases different eccentric and concentric mechanisms occurring depending on the hip flexion angle, and it turns out that hip flexion isn’t so sagittal. In fact, hip flexion has various rotational elements and biases throughout each of its phases (Neumann, (2017); Swinton et al., (2012); Neumann, 2010; Li et al, (2004); Nakagawa et al, (2000)) and we´re going to divide it into 3 phases.

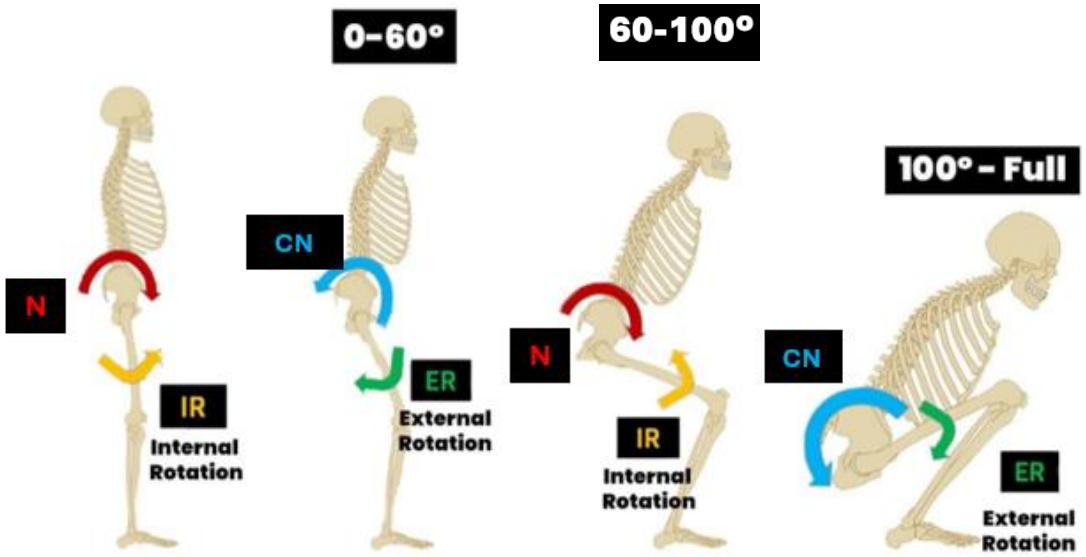


Figure 7 - Pelvifemoral Rhythm Illustrating the hip relative motion regarding the pelvis and sacrum. N refers to Nutation of the sacrum while CN refers to counternutation of the sacrum

- **Standing**: Biases sacral nutation and hip internal rotation
- **0-60º**: Biases sacral counternutation and relative hip external rotation.
- **60-100º**: Biases sacral nutation and relative hip internal rotation. Relative nutation in a counternutated position (relative IR within ER)
- **100/110º+**: This range has a bias towards counternutation and relative hip external rotation.

These ranges represent a positional bias happening during hip flexion of the femur in relation with the sacrum which is also correlated with the internal and external rotators moment arms demonstrated by Neumann, (2017).

Data indicates that the piriformis, posterior fibers of the gluteus minimus, and the anterior fibers of the gluteus maximus reverse their rotary action and become internal hip rotators as the hip is significantly flexed (Neumann, 2010).

According to Neumann, (2017) as the hip flexes (when the thigh moves forward and upward), the pelvis moves in a compensatory motion to maintain balance and alignment. The anterior tilt occurs because the iliac crests (top parts of the pelvis) rotate forward. This anterior pelvic tilt allows the hip joint to have enough room to flex fully while maintaining the functional alignment of the spine and pelvis.

Applying this to a squat, if a person begins with an anterior pelvic tilt, the pelvis is already tilted forward, which biases the femur into more hip flexion relative to the pelvis at the starting conditions. As they descend deeper into the squat, the hip joint experiences more flexion, and there's less available space in the front part of the hip joint. This is because the femoral head (the ball of the hip joint) starts to run out of space in the antero-superior part of acetabulum. Bagwell et al., (2016) also demonstrated that on average, for every 5° of anterior pelvic tilt there was 1.2-1.6° of internal femur rotation and the converse was true for posterior pelvic tilt and external femur rotation. This internal rotation helps the storage of potential energy and the application of force into the ground in order maintain control and not fall during the eccentric phase, which may be magnified on the concentric phase of the squat to release the kinetic energy and apply more force to ascend and pick up leverage to move back into external rotation. This magnification may present itself as a compensatory strategy by a knee valgus moment, overpronation and even spine extension to try to keep up with the demands of the internal rotation and downward force necessary to complete the movement.

Based on Swinton et al., (2012) findings, at the bottom of the squat where internal rotation and hip flexion is maximized, untrained individuals and those with restricted movement capabilities may be unable to maintain hip abduction and external rotation, which may lead to those individuals descending into an adducted and internally rotated posture which could create larger stresses at the knee. Shortened or concentrically oriented hip external rotators appear to limit internal rotation. Over time, repetitive and intense contractions of the external rotators, such as the piriformis and obturator internus, can lead to a concentric orientation, restricting the internal rotation capacity of the hip joint due to the buildup of tension and neural adaptation (Tanabe et al., 2023).

To go deeper into the squat, the body may compensate by performing a posterior pelvic tilt, which is often referred to as a "butt-wink." This happens when the pelvis rotates backward, moving the center of mass backwards to allow more depth. Essentially, the anterior tilt (forward rotation of the pelvis) transitions into posterior tilt (backward rotation), in order to control the center of mass

(Hoogenboom et al., 2023), this motion has external rotation positional bias, this action can sometimes be magnified by a flexion orientation of the pelvis and lumbar spine, often seen at the bottom of the squat, where the pelvis and lumbar spine move as a unit.

A side note regarding the mechanics of the lower limb, but also an important consideration, is how the knee extension represents an internal rotation of the femur relative to a externally rotated tibia due to the screw home mechanism (Neumann, (2017); Li et al, (2004); Nakagawa et al, (2000)) which might explain some limitations of the straight leg raise if hip internal rotation presents limited.

Based on these principles we can presume that to be able to demonstrate true relative movement we first need to create space where we can move into otherwise the likelihood of compensatory strategies or limited range of motion to occur will be greater. For instance, if the goal is to move from point A to point B but I'm already in point B then there won't be movement demonstrated, just like when someone's performing a squat with exacerbated anterior pelvic tilt from the start, making the squat range of motion to be either limited or compensated in some other way.

Understanding these mechanics allows us to better identify why limitations in the different parts of a squat happen, as well as troubleshoot those limitations with a more effective exercise selection. For example, if I want to try to work on someone's ability to internally rotate, we can select exercises where I work closer to the middle range of hip flexion or work with hinge like movements where the thorax and pelvis move relative to the femurs creating the same hip flexion, if someone has limited hip flexion, for example, being able to only reach 80 degrees without compensations/orientations occurring like flexing the lumbar spine, it might mean that their internal rotation is limited. If someone is limited in both measures, meaning limited in external and internal rotations, the first option would probably be to restore external rotations measures, to be able to superimpose the internal rotation element, allowing the transition from point A to point B as mentioned in the previous example.

2.7. Scapulohumeral Rhythm

The scapulohumeral rhythm is the relationship of the humerus to the scapular movement. In the healthy shoulder, a natural kinematic rhythm or timing exists between glenohumeral abduction and scapulothoracic rotation. This rhythm is one of the more dominant and observable kinematic relationships.

Neumann (2017), reported that after about 30 degrees of (frontal plane) abduction this rhythm remained remarkably constant, occurring at a ratio of 2:1, meaning for every 3 degrees of shoulder abduction, 2 degrees occur by glenohumeral joint abduction, and 1 degree occurs by scapulothoracic joint upward rotation. This principle of shoulder abduction states that based on a generalized 2:1 scapulohumeral rhythm, a full arc of nearly 180 degrees of abduction is the result of a simultaneous 120 degrees of glenohumeral joint abduction and 60 degrees of scapulothoracic upward rotation. Published scapulohumeral rhythms vary across studies, ranging from 1.25:1 to 2.9:1, which are relatively close to the reported 2:1 ratio (Neumann, 2017).

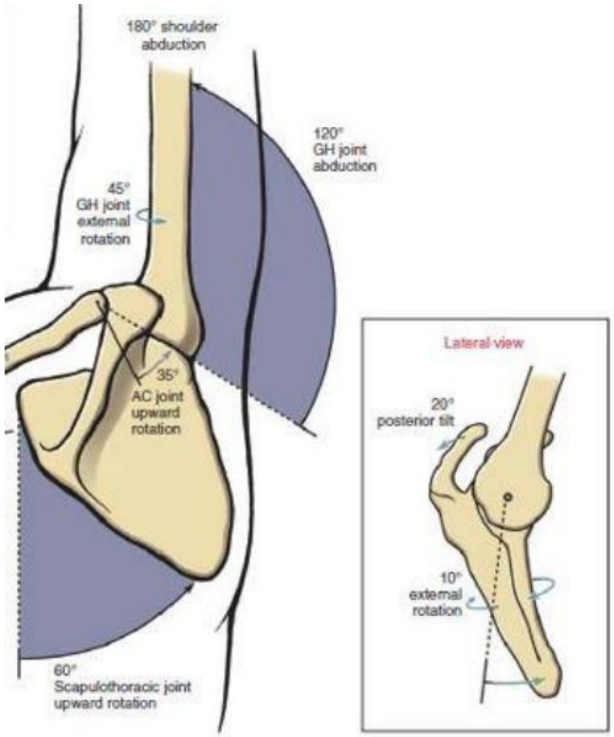


Figure 8 – Scapulohumeral rhythm. Representation of the scapula and humeral movement capabilities during full shoulder flexion.

Variations in the reported scapulohumeral rhythms reflect differences in measurement technique, subjects' structure and position, speed and plane of motion, and external loading. As we transition from the frontal plane shoulder abduction, into the sagittal plane shoulder flexion, the demands of internal rotation increase, thus making the scapula more internally rotated, and the humerus initially also less externally rotated than in abduction (Ludewig et al., 2009).

Regardless of the differing ratios reported in the literature, the classic 2:1 ratio remains a valuable reference for evaluating shoulder abduction.

At rest the position of the scapula is anteriorly tilted by around 10 degrees and internally rotated approximately 30 to 40 degrees, making the humerus relatively external rotated to the scapula (Neumann, 2017).

The first 30 degrees of shoulder flexion are mainly by the glenohumeral, sternoclavicular and acromioclavicular joints, meaning there´s not a lot of contribution of the scapula itself, afterwards the glenohumeral and scapulothoracic joints move simultaneously (Neumann, (2017), Ludewig et al., (2009) and Kapandji et al. (2018)). Conversely, the infraspinatus is least active when the shoulder is flexed beyond 60 degrees, particularly in positions beyond 90 degrees (Yu et al., 2019).

This means that in the 0-60-degree range most of the humeral action is biased towards external rotation. If the humerus externally rotates, then the scapula will relatively be in an internally rotated position, which can be better understood by the posterior cuff muscle's proximal line of pull. If we concentrically orient the infraspinatus, not only will the humerus externally rotate but it will also make the medial border lift away from the ribcage making the scapula relatively internally rotated.

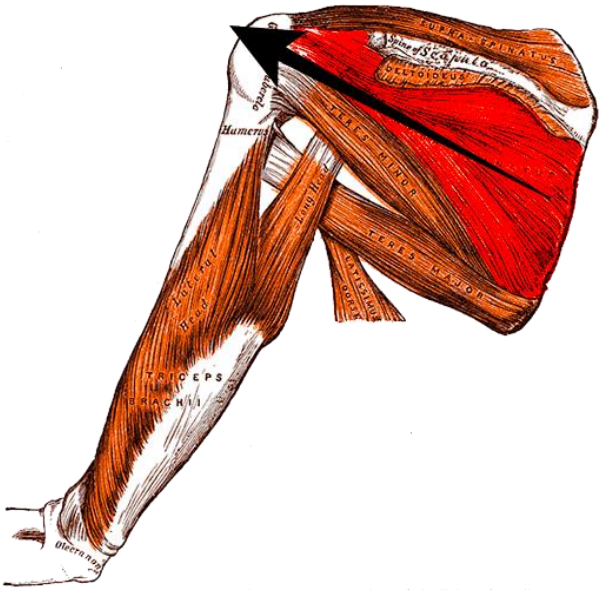


Figure 9 – Representation of the Infraspinatus scapular Internal rotation moment

From 60-120 degrees, the combined actions of posterior tipping, upward and external rotation of the scapula, allow the congruency of the scapula up against the ribcage, enhancing stability and distributing load on the rotator cuff muscles (Seth et al., 2019; Cho et al., 2014; Gooding et al., 2014). A winged scapula might be an inability of this phase to properly occur due to an altered scapulothoracic position, either by the thorax / ribcage position or by the scapula itself which changes the line of pull of different muscles. Neumann, (2017) states that in these ranges the serratus anterior, lower and middle trapezius act in a force-couple to posteriorly tilt and externally rotate the scapula relative to the acromioclavicular joint. Although the middle trapezius decreases its leverage in upward rotation, it still contributes with a needed retraction force along with the rhomboid muscles, mainly the upper fibers, to neutralize the strong protraction effect of the serratus anterior (Neumann, 2017), this helps the scapula to maintain its congruency with the thorax, otherwise a winged scapula could potentially occur and thus altering the shoulder mechanics. This action creates a bias towards an externally rotated scapula relative to an internally rotated humerus.

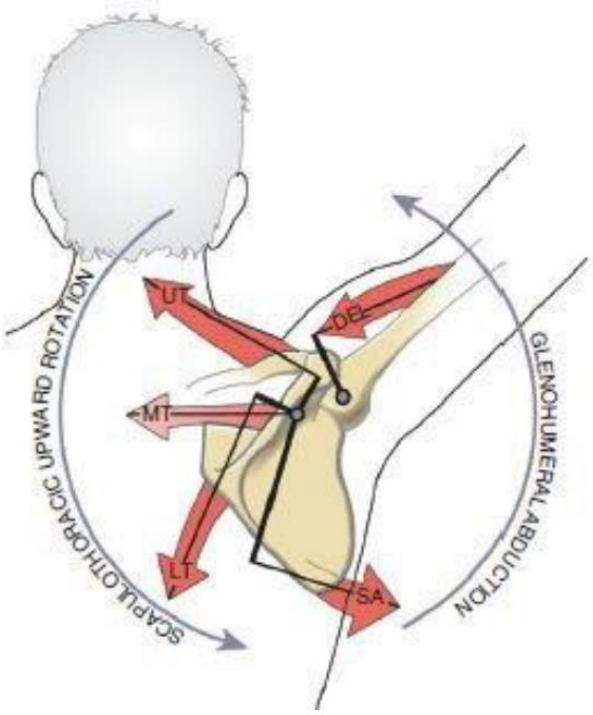


Figure 10 – Representation of the interscapular muscles during mid-range shoulder flexion, mainly the upper, mid and lower trapezius, as well as the serratus anterior and deltoid

From 120-180 degrees the humerus maximally externally rotates and the scapula orients into the scapular plane (30-45 degrees anterior of the frontal plane), which positions the scapular in a more internal rotated position relative to the humerus despite still being externally rotating (Neumann, (2017), Ludewig et al., (2009) and Kapandji et al. (2018))

To sum up we´ve divided the shoulder flexion arch into 3 phases as we did per the hip flexion arch:

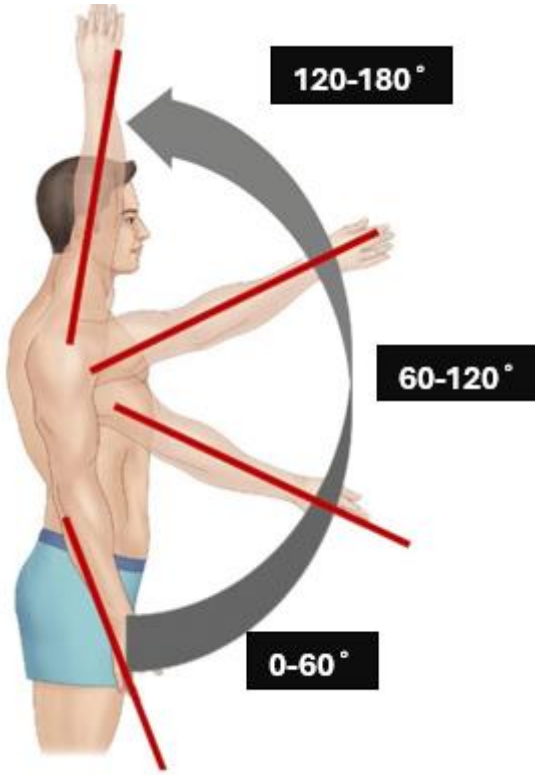


Figure 11 – Three phases of shoulder flexion

- **0-60º**: This range has a bias towards scapula IR relative to humerus ER.
- **60-120º**: This range has a bias towards scapula ER relative to humerus IR.
- **120º+**: This range has a bias towards scapula IR relative to humerus ER.

The mechanics of breathing indicate that the entry of air follows a gravitational gradient. During breathing, air movement within the respiratory system can sometimes be modeled as laminar or turbulent flow, similar to how liquids move through channels. The physical properties of air, including density and viscosity, contribute to pressure differences across various compartments of the thoracic cavity, which guide the mechanics of breathing (Avilés-Rojas & Hurtado, 2022). The flow of air during inhalation creates a negative pressure in the thoracic cavity, which facilitates lung expansion and allows air to flow from the atmosphere into the lungs and thus influencing the ribcage movement.

According to Takashima (2017), a supine position biases a decrease in the ribcage anteroposterior and increases the mediolateral diameter, conversely a

sidelying or lateral recumbent position increases the anteroposterior and decreases the mediolateral diameter. This demonstrates that we can influence expansion at different areas of the ribcage depending on how we're positioned.

Due to the scapula being connected at the ribcage through muscles like the serratus anterior, rhomboid, and levator scapulae, it's important to understand how one contributes to the other, especially on how it influences the pressure gradient dynamics at the ribcage during breathing.

Tachihara and Hamada (2019), found that when we elevate the upper limb most movement is found in the fifth, fourth and third ribs, decreasing toward the lower ribs when the thoracic extension angle remains the same. This illustrates the influence of how shoulder elevation influences different areas of ribcage expansion.

We can then presume that increased muscle tension between the scapulae, magnified scapular ER for example, may correlate with the anterior ribs pump handle mechanism, therefore representing a directional air flow bias due to the shoulder positioning. This means that we can better select exercises based on positioning of the body, like supine, prone, side lying and standing, as well as shoulder positioning to influence the expansion capabilities of the different areas of the ribcage.

2.8. Passive ROM Assessment

Various methodologies and assessment protocols exist in the literature for this purpose, spanning from functional movement screenings to specific clinical tests designed to quantify joint ROM. However, no literature was found regarding an understanding of how passive range of motion of the upper and lower limb can influence an individual presentation and its movement capabilities.

One comprehensive approach to assess hip and shoulder mobility involves the Functional Movement Screening (FMS), a tool developed to evaluate movement patterns and identify limitations in functional mobility. Wang et al. detailed that the FMS includes various specific tasks such as the deep squat, hurdle step, in-line lunge, and shoulder mobility tests (Wang et al., 2016). These tasks collectively assess the integrity of the hips, knees, and shoulders, providing

insight into the functional mobility of these joints through structured protocols that engage multiple movement patterns. The shoulder mobility assessment combines internal rotation with adduction and external rotation with abduction to evaluate bilateral range of motion.

The problem with the FMS and most active assessment protocols is that they only take into account some compensatory strategies, usually the most common ones, of how the movement is demonstrated and sometimes it can be left out some missing pieces of the whole picture, for instance, it may let us know that there can be a restriction to access a given position but it doesn´t tell us where the limitation comes from. To better control abnormal and compensatory behaviors and isolate the joints motion without the contractile variables passive ROM might be a better option.

In this internship, a passive range of motion (PROM) protocol was used to try to better identify relative movements, ROM limitations, select more adequate exercises, evaluate improvements throughout the implemented protocols and see if it is a reliable assessment method to better guide exercise prescription.

In general, ROM assessments depict either the active ROM (AROM) or the PROM. AROM refers to the internal muscular effort required to move the joint through its range, when testing, the person to be tested moves the assessed joint without assistance using the agonistic musculature. This method not only assesses the joint's capability, but it can also provide insight into the functional ROM of the muscles involved in the movement, however, there exists a notable absence of a standardized method demonstrating good accuracy, and inter- and intra-rater reliability for assessing especially the shoulder (van den Hoorn et al., 2025). Furthermore, there can also be significant psychological factors, fatigue levels, or pain thresholds, making it less reliable in some contexts.

In PROM, the practitioner, the investigator, or another external force, moves the body part of the person to be tested through the ROM. However, changes in positioning, stretch tolerance and compensatory movements influence the ROM value. PROM is associated with less engagement of the

nervous system because it does not rely on voluntary muscle contraction, while active ROM tests engage the central nervous system more significantly.

PROM assessments for the shoulder and hip are fundamental components of physical therapy. These assessments help clinicians evaluate flexibility, mobility, and the presence of restrictions in joint movement. The following outlines specific tests and protocols utilized in most clinical settings for assessing PROM in both the shoulder and hips, being some specifically designed to assess various pathologies, such as rotator cuff injuries, impingement syndromes, and shoulder instability.

One widely discussed test is the Hawkins-Kennedy Test, which evaluates shoulder impingement by placing the shoulder in 90 degrees of flexion and then internally rotating the arm. Positive results typically manifest as pain during the movement, indicating potential subacromial impingement (Hegedus et al., 2007; Tennent et al., 2003). Furthermore, the Neer Test involves elevating the arm while stabilizing the scapula, also aiming to provoke pain related to impingement, demonstrating the utility of such tests in diagnosing rotator cuff pathology (Hegedus et al., 2007; Tennent et al., 2003). Another significant examination for shoulder pathologies includes the Apprehension Test, which checks for anterior instability by placing the shoulder in a 90-degree abducted position and externally rotating it. A positive response to apprehension signifies joint instability and potential labral tears (Bahk et al., 2007).

Moreover, it has been established that while some tests demonstrate high sensitivity, their specificity can vary widely, necessitating careful interpretation during a thorough clinical assessment (Sciascia et al., 2012; Hegedus et al., 2012).

When assessing the hip, clinical evaluation incorporates a variety of tests aimed at detecting issues such as hip OA and FAI. Faber's Test (Flexion, Abduction, and External Rotation) aids in identifying hip joint pathology by positioning the patient’s leg in a figure-four position. Pain during this maneuver suggests intra-articular hip issues (Grassi et al., 2019). The FADIR test (Flexion, Adduction, Internal Rotation test) is a clinical examination maneuver used to

assess hip pathology, particularly to diagnose hip impingement, labral tears, or FAI. It is commonly performed in individuals who present with hip pain or groin discomfort, especially when there is suspicion of structural abnormalities in the hip joint (Shanmugaraj et al., 2018). The Thomas Test is also a common test in assessing hip flexor tightness, especially in conditions like hip OA, where range of motion may be significantly reduced (Grassi et al., 2019), however Vigotsky et al., (2016) has shown that it can be a unreliable test if pelvic tilt isn´t controlled.

While passive ROM provides valuable data regarding flexibility, it has limitations. Notably, increased passive ROM does not necessarily translate into functional improvements in active movements but it can give us valuable information of the movement capabilities of given joint if performed correctly. Additionally, there can be concerns about over-reliance on passive ROM testing, as it may overlook crucial dynamic stability and neuromuscular control that are better assessed through active tests. In addition, some people may find it hard to stay relaxed while the assessment is taking place, making it harder to test.

It is important to also consider changes that may occur structurally that can influence movement. For example, arthritis and inflammatory processes that affect joint structures, including synovium and cartilage. Studies indicate that conditions such as rheumatoid arthritis are associated with substantial reductions in joint flexibility due to pain, swelling stemming from synovitis and the inflammation of the synovial membrane (Patterson et al., 2023; Deniz et al., 2021). This inflammation results in stiffness, which constrains active movement and reduces passive articulation, as patients may instinctively avoid movements that exacerbate pain. Additionally, persistent inflammatory states can lead to bony changes, joint deformities and damage, complicating motion capabilities and reinforcing a cycle of discomfort and immobility (Putra et al., 2021; Häkkinen, 2005).

2.8.1. Shoulder Passive Range of Motion Assessments

- **Glenohumeral Passive Motion Assessment**: This includes evaluating motions such as flexion, extension, abduction, adduction, internal rotation,

and external rotation. Each movement is assessed while the patient is lying supine, allowing the therapist to manipulate the shoulder joint gently.

- **Passive External and Internal Rotation Test**: The therapist holds the patient's arm at the elbow while the shoulder is abducted to assess the external and internal rotation capacity. Limitations specially in external rotation may indicate capsular stiffness or rotator cuff pathology (Yeo et al., 2021).

Protocol Example: Yeo et al. (2021) conducted a study highlighting the importance of passive range of motion assessments in patients with adhesive capsulitis, which involved assessments of shoulder joint ROM over a 12-week period to track improvements post-therapy. Their findings underscored that PROM assessments are essential in determining the functional status of the shoulder throughout treatment.

Reliability and Validity: The reliability of these PROM measurements is crucial. Schick et al., (2023) reported variability in physical therapy protocols following shoulder surgeries, indicating the need for standardized methods for assessing passive shoulder ROM to ensure consistent outcomes across clinical practices. This illustrates the importance of consistency when performing a assessment.

2.8.2. Hip Passive Range of Motion Assessments

Hip PROM Tests:

- **Hip Flexion Test**: Performed with the patient supine, the therapist passively brings the knee towards the chest to assess the motion at the hip joint while stabilizing the pelvis to prevent lumbar compensation.
- **Thomas Test**: An assessment to evaluate hip flexor tightness. The patient lies supine at the edge of an examination table while one leg is held to the chest, allowing the other leg to hang off the table to assess hip extension.
- **Internal and External Rotation**: The patient's knee is flexed to 90°, and then the therapist rotates the hip joint laterally (external rotation) and medially (internal rotation) to assess the available ROM.

Protocol Example: A study from Elham Karaminia et al., (2021), showed that hip PROM could be used to identify soccer players at higher risk of lower limb injuries. Hip rotational ROM and abduction limitation were significantly associated with incidence of several common soccer injuries, including groin pain, muscle strain, and ACL/knee injuries. Their findings demonstrate the utility of PROM protocols in enhancing patient outcomes.

2.8.3. General Considerations for PROM Assessments

When conducting PROM assessments, the following should be noted:

- **Patient Positioning**: Proper positioning is essential to isolate movements effectively. Supine or seated positions are often used for the shoulder, while supine and side-lying positions are common for the hip.
- **Use of Goniometers**: Measurements should be recorded using goniometers to document the precise angles of motion achieved during passive assessments.
- **Pain and Discomfort Monitoring**: Clinicians must evaluate the patient's response to movements. Any discomfort or pain reported during PROM should be noted as it can indicate underlying pathology.
- **Acute Effect:** In static and dynamic stretching, an acute effect occurs within the first five stretches for ROM, stretch tolerance, passive torque and energy, which then return to baseline after around one hour. The acute effect of stretching on ROM shows the greatest improvement in the first repetitions, whereas the ROM gain is reduced with increasing repetitions. Consequently, four to five repetitions are recommended for practical implementation.

2.8.4. Documentation and Reporting

In clinical practice, thorough documentation of PROM assessments is crucial for tracking progress, justifying treatment interventions, and facilitating interdisciplinary communication. Each assessment should include:

- Baseline measurements,

- Follow-up evaluations,
- Adjustments in the intervention based on outcomes,
- Patient subjective reports on discomfort or pain levels during movement.

In conclusion, the assessment of passive range of motion for the shoulder and hip joints is a cornerstone of physical therapy as it should be for personal trainers and coaches. Employing well-structured tests and protocols allows for comprehensive evaluations that inform treatment strategies and contribute to enhanced recovery outcomes.

For the purpose of simplicity and based on what we know about the physiological ROM of the upper and lower limb, the tests and normative values considered for the proposed assessment protocol are as mentioned in the following table:

Table 1 – Assessment table with the different tests and normative values defined as "Goal"

TESTS	Left	Right	Goal
Sh. Flexion			150-180º
Sh. ER			90º
Sh. IR			70-90º
Hip Flexion			120º
Hip ER			40-60º
Hip IR			30-45º
SLR			70-90º
Hip Extension			10-15º

3. Navigating the Internship Experience

During my internship at the clinic, I had the privilege of observing firsthand how healthcare professionals in the fields of exercise rehabilitation, osteopathy and physical therapy work together to provide holistic care for patients dealing with a range of issues, from postoperative recovery to more routine conditions such as muscle strains, ankle sprains, back pain, overuse injuries and so on.

The internship began with an observational period during which I spent a substantial amount of time watching clinicians, including physical therapists, osteopaths, and exercise specialists, interact with one another and conduct exercise interventions tailored to each patient's unique needs.

3.1. Flywheel training

During the observation phase, I tried to use the gym when it was free. This allowed me to become more familiar with the machines and equipment, so that I would be able to guide patients through their use in the future.

At first when utilizing the isoinertial machines with integrated force plates and dynamometers of the flywheel devices it was interesting to see how it made it easier to evaluate the maximum strength and velocity produced in real time. In addition, the NeuroExcellence Acceleration Squat machine, having 2 force plates, allows to analyze the differences in each leg in real time during the squat and other exercises performed. This is useful for monitoring strength and asymmetries as well as for managing progression during rehabilitation situations such as anterior cruciate ligament (ACL) ruptures. In these situations, quadriceps strength and its relationship with the unaffected side are key components (Palmieri-Smith and Lepley, 2015).

Flywheel training has been shown to enhance muscle activation more effectively than traditional weight training, particularly during the eccentric phase of movements. A systematic review indicated that exercises performed on flywheel devices provoke higher electromyographic activity compared to conventional weight stack devices, such as the leg press and barbell front squat (Martín-Fuentes et al., 2020). This heightened muscle activation can lead to greater strength gains and muscle hypertrophy, making flywheel training

particularly appealing for athletes seeking to maximize their performance (Núñez & Villarreal, 2017). Furthermore, flywheel training's unique resistance mechanism allows for continuous tension throughout the range of motion, which can be advantageous for developing strength and power (Núñez & Villarreal, 2017).

In contrast, traditional weight training has long been the standard for building strength and muscle mass. Research has consistently demonstrated its efficacy in improving one-repetition maximum (1RM) strength across various populations, including older adults (Thiebaud et al., 2014). Traditional resistance training typically involves fixed weights, which can limit the ability to train eccentrically at high intensities safely, a critical component for muscle growth and injury prevention (Vatovec et al., 2019). However, traditional methods are well-established, with numerous studies validating their effectiveness in enhancing muscular fitness and overall athletic performance (Cox et al., 2019).

The efficacy of flywheel training extends beyond mere muscle activation; it has also been linked to injury prevention. For instance, eccentric training using flywheel devices has been shown to reduce the risk of hamstring injuries in athletes, particularly in sports that require rapid acceleration and deceleration, such as soccer (Vatovec et al., 2019). This is particularly relevant given the high incidence of hamstring injuries in competitive sports, where traditional training methods may not adequately prepare athletes for the demands of their sport (Lauersen et al., 2018). The ability of flywheel training to emphasize eccentric loading is crucial, as eccentric contractions are known to be effective in strengthening muscles and tendons, thereby reducing injury risk (Vatovec et al., 2019).

In a systematic review by Hu et al., (2024), indicated that isoinertial flywheel training is an effective tool for enhancing performance aspects closely tied to muscle power, such as countermovement jump and peak power output, in both healthy untrained and well-trained individual. This meta-analysis found that inertial flywheel resistance training is superior to weight stack resistance training in enhancing muscle power, while no significant differences were found when compared to barbell free weights training like developing maximal strength.

Moreover, the adaptability of flywheel training makes it suitable for a wide range of populations, including those with varying fitness levels and rehabilitation needs. Studies have indicated that flywheel training can be effectively integrated into rehabilitation protocols for individuals recovering from injuries, as it allows for controlled loading and can be tailored to the specific needs of the patient (Núñez & Villarreal, 2017). This adaptability is a significant advantage over traditional weight training, which may not be as easily modified for individuals with specific rehabilitation requirements (Thiebaud et al., 2014).

Despite the advantages of flywheel training, traditional weight training remains a cornerstone of strength and conditioning programs. The familiarity and accessibility of traditional methods make them a practical choice for many athletes and fitness enthusiasts. Additionally, traditional weight training has a robust body of evidence supporting its effectiveness in improving muscular strength, endurance, and overall fitness (Cox et al., 2019). The ability to utilize free weights and machines allows for a diverse range of exercises that can target specific muscle groups effectively.

In terms of training outcomes, both flywheel and traditional weight training can lead to significant improvements in muscle strength and hypertrophy. However, the mechanisms by which these adaptations occur may differ. Flywheel training's emphasis on eccentric loading may result in different muscle fiber recruitment patterns compared to traditional concentric-focused training (Núñez & Villarreal, 2017). This distinction is critical for athletes looking to optimize their training regimes based on their specific performance goals.

The psychological aspects of training should not be overlooked. The novelty of flywheel training may enhance motivation and engagement among athletes, particularly those who may find traditional weight training monotonous (Núñez & Villarreal, 2017). This psychological benefit can lead to improved adherence to training programs, which is essential for long-term success in any fitness regimen.

Flywheel training also allows for true eccentric overload to be demonstrated with more safety. When discussing eccentric training, avoid using

the term “eccentric overload“. This broader term could permit super-slow movements, for example, spending 10-12 seconds in the eccentric phase. Eccentric overload training provides a greater load during the eccentric phase of contraction than traditional methods, which use concentric-limited loading (Kowalchuk & Butcher, 2019). Using isoinertial machines makes it easy to modify exercises increase the challenge during the eccentric phase. One effective method that can be applied to traditional weight training is the 2-1 technique (i.e., “using both legs to lift the weight and 1 leg to lower it”). This approach performed with submaximal to maximum effort increases the emphasis on the eccentric phase of the movement. However, for it to qualify as true eccentric overload training. The load during the eccentric phase must exceed the concentric one-repetition maximum of the working leg. Another way to achieve this is by utilizing assistance from another person, preferably a qualified professional, trainer or coach who has knowledge and experience with this equipment. The assistant can help with the concentric phase of the movement, making it harder to resist on the way down and creating a true eccentric overload. An alternative scenario would be to combine an exercise that allows for greater force production during the concentric phase with a harder (less force producing) variation during the eccentric phase. For example, doing a thruster (a squat combined with a shoulder press) on the concentric phase and then an eccentric shoulder press, thus also creating eccentric overload.

Regarding safety, we tend to see advantages that allow for a more controlled environment, the resistance can be adjusted based on the individual's unique strength and capabilities. This adaptability is particularly beneficial for those in rehabilitation settings, where the risk of exacerbating injuries is a significant concern (Cox et al., 2019). When using a flywheel device, exercise intensity can be maximum in every repetition. Furthermore, the magnitude of resistance is adjusted to the level of fatigue, which is not possible with traditional resistance training. For example, if someone performs repetitions with a barbell loaded with 50 kg. Failure is reached when the force applied cannot be at least equal to 50 kg, in which case they may be in danger and need assistance. In contrast when training with a flywheel device the participant will continue

performing repetitions until complete fatigue is reached. This is because the system is energy-based and not gravity-based. If the exercise is the squat, the participant will apply lower and lower force to the flywheel, continuing to perform repetitions, since he will store in the flywheel less and less kinetic energy in each repetition due to fatigue, until he reaches the point of applying the necessary force just enough to lift his weight.

However, there are concerns that need to be addressed when using these machines, especially the squat variations. Since the eccentric phase of the movement requires a controlled and synchronized timing with the pulling phase of the machine, the first times using flywheels require an adaptation phase, otherwise people will have the tendency to fight the resistance of the machine, for example, in a squat, they will try to stop the eccentric at the top of the squat which makes them have to absorb the produced force in less amount of time, magnifying the force output and thus, if not controlled, exceeding the load tolerance of the person.

Flywheel training provides a practical method of achieving eccentric overload, increasing strength and power, combating age-related adaptations, and overall improving quality of life in older adults (Kowalchuk & Butcher, 2019).

3.2. Patient Assessment Protocols

One of the key observations I made during my internship was how the initial assessments were carried out and how exercise interventions were planned based on the clinicians' evaluations. For example, when a patient with a recent knee replacement came into the clinic, the clinician would conduct a thorough assessment, asking questions about his age, occupation, daily activities, hobbies, main complaint, pain pattern, pain levels, possible causes, when it started, limitations felt, medical and family history, past injuries, sleep, diet, medication, possible addictions like smoking and drinking and what’re his expectations regarding the rehabilitation process. This would be followed by a physical examination beginning with a postural assessment, followed by a series of tests to assess range of motion limitations, gait pattern, swelling, joint stiffness,

both provocative and non-provocative tests, and any other signs of complications or additional tests deemed appropriate by the clinician for the patient presented.

Once the assessment was complete, the clinician would communicate directly with the exercise professional to develop a treatment plan. This would include specifics on which exercises should be incorporated into the rehabilitation program and what intensity or volume would be appropriate for the patient at each stage of recovery. For example, in postoperative patients, the clinician would usually emphasize low-impact exercises initially, focusing on gentle range-of-motion exercises and gradually progressing to more dynamic and force production movements as the patient's condition improved.

Once the treatment plan was established, the exercise professionals would take over the implementation of the interventions. They would work directly with patients, guiding them through a variety of exercises aimed at improving strength, flexibility, balance, and overall function. I observed the ways in which they adjusted each exercise to suit the patient's capabilities and limitations, offering modifications and progressions depending on how the patient was responding.

For instance, in the case of a patient recovering from an ankle sprain, the exercise professional began with simple range-of-motion exercises, ensuring the patient could move the ankle without pain or discomfort. Gradually, the exercises progressed to more weight baring, balance and stability work, with the patient performing exercises like standing on one leg, using an unstable platform and more force production exercises to stimulate the entire ankle complex. The exercise professional carefully observed the patient's form and asked for feedback, adjusting the intensity and difficulty level based on how well the patient was managing the exercises.

The importance of proper technique in these interventions was something I observed frequently. The exercise professionals were not only responsible for ensuring that the patients completed the exercises correctly, but they were also charged with educating them about the importance of good form. This education was essential for ensuring that the patient did not exacerbate their condition or

introduced new unwanted compensations or injuries during the rehabilitation process.

On the other side of the spectrum, there were some athletes that seeked help not only dealing with an injury but also to improve their sports performance. This would involve a similar assessment process but with more focus on other parameters, like the utilization of force and speed tests like, the Countermovement Jump, Leg Curl, Squat, Horizontal Jump, Leg Curl, Leg Extension and Adductors Isometric strength assessment which were assessed by utilizing the force plates and dynamometers of either NeuroExcellence or ChronoJump devices. Based on the athlete´s assessment a training program would be elaborated to improve his weakest points.

3.3. Promoting Movement and Function

A key focus of the clinic was not only to treat existing impairments but to promote long-term health through an active lifestyle. It encouraged patients to see movement not as a temporary task, but as a lifelong habit.

During consultations, the different professionals often discussed the benefits of regular physical activity for cardiovascular health, weight management, mental well-being, and overall longevity. Patients were also advised on how to incorporate simple but effective changes into their routine, such as:

- Walking or cycling instead of driving short distances
- Taking short movement breaks during sedentary work
- Doing stretches in the morning or before bed
- Participating in community exercise groups, swimming, or yoga classes

Importantly, they helped patients identify physical activities that were enjoyable and suitable for their age, health condition, and preferences. The idea was to make activity sustainable and enjoyable rather than burdensome (World Health Organization, 2020).

To support behavior change, sometimes some professionals worked with patients to establish weekly activity goals, which were tracked and discussed during follow-up sessions. Visual aids such as calendars or mobile apps were sometimes recommended to help patients stay consistent and motivated. This helped patients integrate movement into their agenda not just as a part of therapy, but as a regular part of daily life as is suggested by Michie et al. (2009), Kwasnicka et al. (2016), and the World Health Organization (2020) to better implement behavior changes.

For patients with chronic conditions or older adults, therapists emphasized the importance of safe and moderate-intensity activity, tailored to each person's capabilities. Gentle but regular movement helped these individuals maintain independence and reduce the risk of falls, cardiovascular disease, or depression.

3.4. Empowering Patients through Education

There were two cases, one of them that I had the pleasure of following and contributing to the rehab plan, that highlighted how promoting a healthy and active lifestyle goes beyond therapy and exercise sessions. By making physical activity accessible, sustainable, and personalized, the professionals at the clinic were able to support real, lasting changes in their patients' lives.

Case 1: Sedentary Office Worker with Chronic Lower Back Pain

Background:

A 52-year-old accountant, came to the clinic with chronic lower back pain, worsened by years of prolonged sitting at work. He was overweight, sedentary, and had not engaged in regular exercise for many years.

Therapeutic Approach:

In addition to manual therapy which was implemented before the strengthening program, performed twice per week with a third day of autonomous work with given exercises, focused on core stability and weight loss, it was recognized the need to promote long-term behavioral changes to prevent future recurrences. Kendall et al. (2020) have highlighted that many patients with painful musculoskeletal conditions might benefit from initial management through

passive manual therapies to alleviate pain, which can make transitioning to active exercise therapy more feasible.

Lifestyle Intervention:

- The therapist introduced the concept of “movement snacks” — short bouts of physical activity during the workday (Islam et al., 2021).
- It was advised to stand and stretch for 2–3 minutes every 60 minutes spent sitting and eventually progressing to every 30 minutes.
- A 20-minute daily walk after lunch was incorporated into his schedule as a starting point for cardiovascular exercise.
- A simple standing desk modification was suggested to alternate between sitting and standing during work hours.

Support Tools:

- A calendar was used to track his daily movement breaks and walks.
- He was introduced to a mobile app that reminded him to move every hour and allowed him to log his activity.

Outcome:

Over the course of several weeks, this individual reported a noticeable reduction in back pain and increased energy levels. He became more conscious of his posture and was motivated to continue walking regularly, eventually increasing his walks to 40 minutes on most days.

Case 2: Retired Woman with Early-Stage Osteoarthritis

Background:

A 68-year-old female retired teacher was referred to the clinic after being diagnosed with early-stage OA in both knees. She had become increasingly inactive due to joint discomfort and fear of falling.

Therapeutic Approach:

In addition to physical therapy twice per week to improve joint mobility and muscle strength, the therapist focused on helping her build confidence and reintegrate movement into her routine safely.

Lifestyle Intervention:

- It was encouraged to participate in local senior aqua fitness classes twice a week to promote joint-friendly movement and eventually try strength training supervised. Due to the decreased demands of gravity in water, it's effective for unloading the joints and to reduce pain, joint dysfunction and improving quality of life (Song and Oh, 2022).
- A daily walking goal of 15 minutes (with a cane for support, if needed) was set, with the possibility of gradual progression.
- She was taught warm-up and cool-down stretches to manage stiffness and reduce post-activity discomfort (Sands et al., 2013) which according to the guidelines of ACSM (2018) and the American Heart Association (2020) is an important component.

Warm Up sequence given to prepare the neuromuscular system, increase joint mobility, and elevate body temperature:

Table 2 - Warm Up dynamic stretching sequence

Exercise	Sets	Duration	Notes
Arm circles (small → large)	2 sets	15–20 sec each	Forward and backward directions
Leg swings (front-back & side-to-side)	2 sets	10–15 reps	Hold onto stable surface
Hip openers (standing or walking)	2 sets	10 reps/leg	Mobilizes hips and groin
Torso rotations	2 sets	10–15 reps	Controlled, increase range progressively

Supported by ACSM (2018) and Sands et al. (2013) to enhance readiness and reduce injury risk.

Cool-down sequence given to reduce post-exercise muscle tension, promote circulation, and support recovery:

Table 3 - Cool-down static stretching sequence

Muscle Group	Stretch Example	Sets	Hold Time	Notes
Hamstrings	Seated or standing toe reach	2-3	20–30 sec	Avoid bouncing
Quadriceps	Standing quad stretch	2–3	20–30 sec	Keep knees close, pelvis neutral
Calves	Wall calf stretch	2–3	20–30 sec	Ensure heel stays down
Hip Flexors	Half-kneeling hip stretch	2–3	20–30 sec	Engage glutes to deepen stretch
Shoulders	Cross-body shoulder stretch	2–3	20–30 sec	Keep shoulders relaxed

As per Sands et al. (2013), static stretching in the cool-down can support parasympathetic activation and facilitate muscle recovery.

Support Tools:

- A weekly physical activity log was created for her to complete at home and bring to each session.
- Her daughter initially provided encouragement and accompanied her on walks, helping to establish a routine and ensure safety.

Outcome:

After one month, she was walking independently for 30 minutes most days and attending aqua classes regularly. She reported feeling more independent, with improved knee function and reduced fear of movement. The therapist emphasized how these consistent habits were key to managing OA in the long term.

3.4. Adapting to Individual Needs

Another valuable aspect of my internship experience was observing how the exercise professionals and physical therapists tailored exercise programs to meet each patient's specific limitations, goals, and progress. Rather than applying a "one-size-fits-all" approach, they continuously assessed and modified exercises to ensure safety, effectiveness, and comfort. This adaptability was crucial in promoting functional recovery and patient engagement.

Trainers or clinicians can use progressions or regressions, modify range of motion, or incorporate assistive tools to match each individual's current capacity. Key indicators for when to apply these changes include visible technique errors, signs of compensation (such as shifting weight or altered movement patterns), reports of pain or discomfort, excessive fatigue, or failure to complete the intended repetitions or range. Monitoring these cues helps guide timely and individualized modifications, ensuring continued progress without compromising safety (Halson, 2014; Zhao et al., 2024).

1. Ongoing Assessment and Real-Time Feedback

Before, during, and after each session, every professional carefully observed patients' movements, posture, facial expressions, and feedback. If a patient experienced discomfort, fatigue, or difficulty performing an exercise correctly, adjustments were made immediately. These could include changes in range of motion, intensity, duration, or even the type of exercise selected.

2. Practical Cases of Exercise Adaptation

Knee Pain

A common issue observed in the clinic was patients experiencing anterior knee pain during squats and knee flexion, often due to patellofemoral dysfunction or early OA.

Intervention Adaptation based on literature:

- The professional reduced the squat depth, allowing the patient to squat only to a pain-free range while improving the ROM as tolerated over time. In some cases, the squat was replaced temporarily with a sit-to-stand exercise from a higher chair, promoting the same functional movement pattern with less strain and other exercises were used (e.g., partial and box squats, split squats, knee extensions) (Androulakis-Korakakis et al., 2023.
- Electrical muscle stimulation (EMS) was often utilized in conjunction with exercise as it shown to increase strength parameters (Filipovic et al., 2011; Micke et al., 2022; Mukherjee et al., 2022). Although this method is demonstrated to be effective, sometimes it also limited the selection of exercises due to the physical cable constraints of the device.
- A stability ball was placed behind the patient against the wall to support the back, encourage a more vertical squat and more vertical shin angle. Adding a constraint helps ensure that the exercise effectively targets specific muscle groups (e.g., quadriceps and hip musculature) (Androulakis-Korakakis et al., 2023).
- The patient was instructed to keep the knees aligned with the toes and when failed to do so, for example with a knee valgus moment, a band was used between the knees to promote a resistive force against the band to promote the desired limb alignment outcome.
- Resistance was removed, reduced or assistance was applied (e.g., band assisted squats, bodyweight and using weights).

The following table shows a few strategies that can be implemented to unload stress of the anterior knee, more specifically the patellofemoral joint, within different planes of motion.

Table 4- Ways to unload the patellofemoral joint in different planes of motion

	Hip/Trunk	Knee	Ankle/Foot
Sagittal	Forward trunk lean	Minimize anterior translation of knee	Weight through heel
Frontal	Hip neutral (no lateral trunk lean)	Knee in line with middle of foot (avoid dynamic valgus)	Neutral arch
Transverse	Hip neutral against a wall (no trunk rotation)	Knee in line with the midfoot (avoid a valgus and varus moment)	ER of foot to compensate for excessive femoral and tibial internal rotation. IR of foot to compensate for excessive femoral and tibial external rotation.

Limited Shoulder Range of Motion

Patients recovering from rotator cuff repair or shoulder impingement often struggled with overhead movements.

Intervention Adaptation based on literature:

- Exercises were initiated in a supine position to minimize gravity's effect on the shoulder joint, thus reducing the demand (Gaunt et al., 2010) and progressing over time (e.g., wand-assisted shoulder flexion lying down).

- Range of motion gradually increased as tolerated, starting below shoulder height and when tolerated, above shoulder height. Depending on the individual limitation either in a more abducted or adducted position of the humerus.
- Elastic bands or pulleys were introduced with very low resistance to facilitate pain-free motion, as well as the use of short-lever positions (e.g., elbows bent) to reduce torque on the shoulder. Enhancing the strength of the rotator cuff and scapular stabilizers, progressing the difficulty as tolerated with resistance training is one key aspect of the rehabilitation process (Singh et al., 2022).
- The use of kinesiology tape Elastic KT and Myofascial Trigger Point Release has been shown to be effective in the treatment of shoulder pain (Singh et al., 2022), which combined with resistance training can improve clinical effectiveness.
- Functional movements like reaching or dressing were simulated with support to gradually reintegrate daily tasks.

Balance Issues in Older Adults

Patients with poor balance, particularly older adults and elderly people, needed close supervision and modifications during weight-bearing exercises.

Intervention Adaptation:

- Exercises such as single-leg stands or step-ups were performed with support from canes, sticks, walls or a stable chair.
- Seated versions of exercises were introduced first (e.g., seated leg extensions, seated marches).
- When standing exercises were added, a professional remained nearby for support, and the surface was kept non-slippery and obstacle-free.
- Simple balance tools like foam pads or BOSU balls were only introduced once the patient demonstrated improved postural control as well as more dynamic balance exercises.

- Resistance training was also implemented. A comprehensive meta-analysis found that combining resistance training with balance exercises significantly improves dynamic balance and lower-limb strength (Jiang et al., 2024).

Progression Based on Patient Readiness

Progression was always based on patient tolerance, not just on fixed timelines. Exercise professionals followed a principle of "challenge without overload," ensuring that exercises were advanced only when the patient demonstrated adequate control, confidence, and symptom-free performance. This helped prevent setbacks while still encouraging continuous improvement.

In summary, exercise adaptation was a dynamic and integral part of patient care at the clinic. The ability of the professionals to adjust each exercise to fit the patient's unique condition not only enhanced physical recovery but also made patients feel heard, supported, and safe. Observing this personalized approach gave me a deeper understanding of the clinical reasoning behind therapeutic exercise and the importance of flexibility in rehabilitation practice.

3.5. Incorporating Evidence-Based Strategies

I also witnessed how the clinical team consistently integrated evidence-based strategies into their assessment, treatment planning, and therapeutic interventions. This approach ensured that patients received care rooted in the latest research, clinical expertise, and individual needs—resulting in more effective and efficient outcomes.

Evidence-based practice (EBP) in the clinic was not limited to choosing exercises supported by research; it also involved critical thinking, patient education, and outcome measurement. Below are some practical examples of how these strategies were applied in real patient scenarios:

Example 1: Low Back Pain – Avoiding Passive Treatments Alone

According to current clinical guidelines, such as those from the American Physical Therapy Association, active treatments are more effective than passive modalities for managing non-specific low back pain.

How the clinic applied this:

- While modalities like manual therapy, Transcutaneous Electrical Nerve Stimulation (TENS) or heat were occasionally used to reduce pain, the primary focus was on strengthening and mobility exercises (Qaseem et al., 2017).
- Patients were educated about the importance of staying active and avoiding prolonged bed rest.

Example 2: Knee Osteoarthritis – Strengthening and Weight Management

Lower limb strengthening and weight loss are among the most effective conservative interventions for knee OA (Fransen et al., 2015).

How the clinic applied this:

- Patients with knee OA followed a program including strength exercises (e.g., wall sits, step-ups) to improve function not only at the lower limbs, including the hip musculature like the glutes, hamstrings and adductor muscles but at the axial spine, by implementing axial mobility and strengthening (e.g., core stability, mobility and strength by using planks and rotational movements).
- When appropriate, patients were referred to a nutritionist or encouraged to track daily activity to support long-term joint health.
- The use of pain scales and functional outcome measures also helped to monitor progress. It was frequently used the following scales:
    - **Visual Analog Scale (VAS)**: The VAS is a simple and widely used instrument that requires patients to mark their pain intensity on a continuous line, typically 10 cm long, ranging from "no pain" to "worst imaginable pain." This scale is favored for its sensitivity in detecting changes in pain levels over time.
    - **Numerical Rating Scale (NRS)**: The NRS is another common pain assessment tool where patients rate their pain on a scale from 0 to

10. This method is straightforward and easy to implement, allowing for quick assessments during clinical visits.

Evidence supporting the VAS and NRS highlights its effectiveness and demonstrated efficacy in tracking changes in pain levels, serving as a practical tool for both clinical and research settings (Karcioglu, O., et al., 2018).

Other methods could also complement the efficacy of the clinic interventions, like blood flow restriction (BFR) training, which has received attention as a method to enhance muscle strength and hypertrophy, especially when combined with low-load exercise. This approach involves the application of a restrictive cuff or band around a limb to partially occlude blood flow which is thought to trigger anabolic responses during resistance training, allowing individuals to achieve beneficial outcomes typically associated with high-intensity exercise with significantly lighter loads (Clarkson et al., 2020), although close monitoring when using these methods should be used to ensure safety.

Example 3: Fall Prevention in Older Adults – Multicomponent Programs

Evidence supports that the most effective fall prevention programs for elderly patients include balance training, strength exercises, and environmental modification (Gillespie et al., 2012; Jiang et al., 2024; Sherrington et al., 2019).

How the clinic applied this:

- Older patients engaged in progressive balance exercises (e.g., tandem walking, foam surface exercises), combined with resistance training (e.g., box squats, leg curl, leg extensions).
- Home safety checklists were discussed during sessions to help patients reduce trip hazards (e.g., loose rugs, poor lighting).
- Education on medication side effects and footwear was also part of the fall prevention strategy.

Kim & Hegazy (2024), conducted a comprehensive footwear review on balance and fall prevention in older adults, showing that the use of shoes should be

tailored to individual balance deficits and introduced with guidance and training due to potential initial instability.

Example 4: Rotator Cuff Tendinopathy – Eccentric Loading

Current evidence supports eccentric exercises and progressive loading for managing tendinopathies, including those affecting the rotator cuff.

How the clinic applied this:

- Patients performed eccentric shoulder exercises (controlled lowering of resistance and by using the flywheel devices) (Jarin et al., 2021; Sussmilch-Leitch et al., 2012).
- Therapists and exercise professionals monitored load tolerance and used pain-monitoring models to guide progression (e.g., keeping pain within an acceptable threshold, such as 3/10 on a pain scale). There is evidence that allowing pain during the rehab process might have benefits over pain-free exercises in the short term. (Birgitte Hougs Kjær et al., 2024; Smith et al., 2017)

3.6. Team Meetings and Ongoing Learning

As part of my internship at the physical therapy clinic, I had the opportunity to participate in the clinic's monthly team meetings, which were an integral part of the staff's continuous professional development and collaborative practice.

The meetings typically ranged from two to three hours and included physiotherapists, osteopaths, and exercise professionals. However, certain meetings focused exclusively on physiotherapists and osteopaths, particularly when the agenda involved passive and table-based treatments that fall outside the scope of practice for exercise professionals.

Each meeting had a specific focus, alternating between detailed discussions of individual body regions—such as the knee, shoulder, hip, or spine—and broader rehabilitation-related topics. When focusing on a body part, the team reviewed its anatomy, biomechanics, common pathologies, and the most effective evidence-based interventions. For example, one meeting was

dedicated to the shoulder, where we discussed rotator cuff injuries, scapular dyskinesis, and treatment approaches like strengthening protocols and neuromuscular control exercises. Other sessions were centered around rehabilitation modalities and therapeutic techniques. Topics included the application and clinical reasoning behind modalities such as EMS, transcutaneous electrical nerve stimulation (TENS), spinal manipulation, dry needling, and a variety of exercise-based interventions. The goal was to evaluate when and how to use each modality, based on the patient's condition, goals, and stage of recovery.

These meetings encouraged critical discussion and idea exchange among the team, creating a collaborative environment where everyone could contribute, ask questions, and share clinical experiences. I found these sessions especially valuable for deepening my understanding of how theoretical knowledge is applied in real clinical decision-making.

Overall, the monthly meetings played a significant role in enriching my internship experience, reinforcing key clinical concepts, and exposing me to a wide range of perspectives within the field of rehabilitation.

4. Case Studies Methodology

These case studies describe the application of the proposed assessment protocol to help guide the exercise selection based on the lower and upper limb ROMs. The assessment had considered the relative motions and compensatory strategies that we might see when taking these measures.

4.1. Research Design

A case experimental design (A-B-A) was used, where the baseline phase (A) involved initial assessment of ROM, followed by an intervention phase (B) that included exercises aimed at improving ROM and strength, and finally, a second assessment phase (A) for re-testing.

Phase 1 (Baseline Assessment): Prior to the intervention, a comprehensive range of motion assessment was conducted. Measurements for both the lower and upper limbs were taken to identify movement restrictions, specifically focusing on the following tests straight leg raise, hip and shoulder flexion and rotation, both internal and external.

This focused set of PROM tests is not arbitrary but grounded in the concept that the body functions as an integrated kinetic chain. By selecting tests that assess the appendicular system (shoulder, hip and leg) movement, it ensured that we could:

- Identify systemic patterns of limitation (e.g., understanding the asymmetries in IR and ER can provide insights into the rotational bias to one side and the overall capabilities of global axial rotation).
- Understand how joint restrictions relate to compensatory movement strategies (e.g., lack of hip IR and tendency to let the knees cave in).
- Make more informed decisions about exercise prescription that consider both local deficits and global interaction (e.g., if only 90 degrees of hip flexion are present then a deep squat would probably require a compensatory strategy).
- Practicality: Implement an assessment protocol that can be efficiently applied without significantly extending the session duration, thus making it

more practical for clinicians and exercise professionals to implement during their practices.

Phase 2 (Intervention): The patient underwent a series of targeted exercises designed to enhance flexibility, strength, and joint mobility, with a focus on improving range of motion and function.

Phase 3 (Retest Assessment): After the completion of each selected exercise, the patient was retested by the same examiner, using the same ROM protocol to assess improvements or lack thereof.

4.2. Assessment Protocol

Supported by the previous literature review, the primary aim was to measure ROM in both the upper and lower limbs, with special attention to joint movements at the hip and shoulders. The assessment followed the protocols implemented by Clarkson (2013) and Norkin & D Joyce White (2016), aside from the shoulder flexion and the hip ER and IR which were performed in a supine position. The hip rotation has been shown to be a reliable testing method although potentially presenting different results when compared to a sitting position (Gradoz et al., 2018; Kouyoumdjian et al., 2012). The shoulder flexion test was based on Clarkson (2013) and Norkin & D Joyce White (2016) protocols but it was modified in order to take into account the elbow deviation and humerus rotation.

4.2.1. Test Protocol for Lower Limb (Hip ROM):

4.2.1.1. Straight Leg Raise

Measured with patient supine, it was asked to maintain the non-measured limb with the feet pointing up in a dorsiflexed position, while the operator flexed the patient hip with a straight knee in the sagittal plane. Since to hold and measure the leg straight usually requires 2 people, one to hold the leg while the other one measures, for purposes of simplicity, a smartphone app named Angle Meter was used, and the smartphone was placed at the front of the shin with the bottom of the phone in contact with the anterior tibial tuberosity. Rupali Soeters et al., (2023), demonstrated that smartphone apps provide measurements

comparable with manual measurements taken by physical therapists using a goniometer.



Figure 12 – Straight Leg Raise Assessment

The test was stopped based on the following points:

- Initial resistance, pain or discomfort is felt
- The leg deviates from the sagittal plane
- The extended leg moves
- Orientation of the pelvis, spine and/or abdominal wall.

4.2.1.2. Hip Flexion

Measured with patient supine, it was asked to maintain the non-measured limb with the feet pointing up in a dorsiflexed position, while the operator flexed the patient hip in the sagittal plane. While holding the knee, a goniometer was used with the greater trochanter and lateral femoral epicondyle as reference points.



Figure 13 – Hip Flexion Assessment

The test was stopped based on the following points:

- Initial resistance, pain or discomfort is felt
- The leg deviates from the sagittal plane
- The extended leg moves
- Orientation of the pelvis, spine and/or abdominal wall.

4.2.1.3. Hip Internal and External Rotation

Measured with the patient supine and the hip flexed at 90 degrees. A goniometer was used to assess the range of hip rotation. When 90 degrees of hip flexion weren´t attainable on at least one limb, these tests were performed by having into account possible compensatory strategies at the starting conditions when measuring.



Figure 14 – Hip external rotation assessment on the left and hip internal rotation assessment on the right

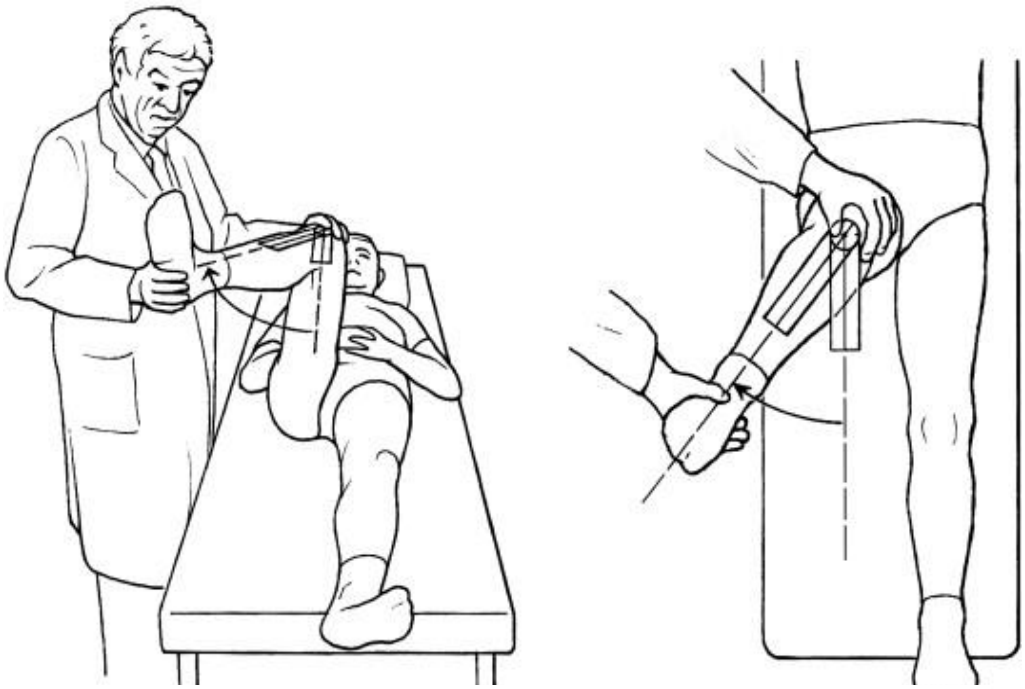


Figure 15 – Representation of the utilization of the goniometer during hip internal rotation

The test was stopped based on the following points:

- Initial resistance, pain or discomfort is felt
- The leg deviates from the sagittal plane
- The spine rotates or side bends
- Orientation of the pelvis, like a pelvic hike or turn.

4.2.2. Test Protocol for Upper Limb (Shoulder ROM):

4.2.2.1. Shoulder Flexion

Measured with a digital goniometer app to assess the relative motion at the in shoulder joint movement.

In the supine position, one hand is placed on the lower ribcage to prevent it from rising, while the opposite hand grasps the elbow joint with the thumb placed on the olecranon. The next step involves flexing the elbow at around 90 degrees, so that tension in the long head of the triceps muscle does not limit the motion, and supinating the hand, followed by a slight external rotation of the humerus to align the elbow with shoulder in the sagittal plane. Finally, raising the

arm into flexion while avoiding lateralization of the elbow or IR of the shoulder to occur.



Figure 16- Shoulder flexion assessment

The test was stopped based on the following points:

- The arm cannot reach the side or lateral curves of the chest;
- The arm abducts and comes out of the midline;
- Humerus rotates internally (forearm comes to the center);
- Forearm pronation;
- Back arches or rib cage elevates;
- The humerus cannot reach the height of the ear (around 140 degrees).

4.2.2.2. Shoulder Internal and External Rotation:

Using a goniometer with the patient in supine position, the shoulder is placed in 90 degrees of abduction, 90 degrees of elbow flexion and in a slight supinated position, representing the starting point. The shoulder is then rotated externally or internally depending on the assessment.



Figure 17 – Shoulder external rotation assessment on the left and internal rotation represented on the right

The external rotation test was stopped based on the following points:

- External rotation is greater than 90° (most likely an orientation of the spine due to the starting position at the table);
- Arching of the back/rib cage;
- Forearm pronation;
- Elbow moves up;
- The trunk rotates.

The internal rotation test was stopped based on the following points:

- Arm descends or performs a horizontal adduction;
- Humeral head slides anteriorly;
- Protraction of the shoulder blade.

4.3. Ethical Considerations

The present study was established according to Helsinki declaration.

Informed Consent: The patient was provided with information regarding the nature of the study, risks and benefits, and gave written informed consent to participate (Attachments XIV-XV).

Confidentiality: All data collected was anonymized, and confidentiality was ensured throughout the study.

4.4. Case Studies

4.4.1. Case Study 1

The reported case was a patient with ongoing bilateral arthritic chronic knee pain lasting for almost a year, with a greater incidence of discomfort in the right knee. Imaging showed OA ranging from grade 1 to grade 3 depending on both knees and recently started with mild left shoulder pain which was diagnosed with calcific supraspinatus tendinopathy and acromioclavicular arthritis.

Patient Information: A 58-year-old sedentary female patient. The patient also reports reduced mobility and pain during activities of daily living, particularly when walking and using stairs. She had some physical activity and gym training background until her thirties which had to stop due not being able to find enough time because of her work.

Presenting Complaints: Persistent knee stiffness, pain with long walks, getting up and down the stairs, limited knee flexion, and difficulty performing rotational movements at the hip and ankle.

The patient presented to the clinic following medical advice from an orthopedist to initiate physical therapy as a result of a diagnosis of bilateral knee OA.

For monitoring the exercise intensity and effort it was utilized a modified Borg scale. The Modified Borg Scale is a widely used subjective tool for assessing the rate of perceived exertion (RPE) during physical activity. The scale provides an intuitive 0 to 10 rating system, where 0 indicates “no exertion at all” and 10 represents “maximal exertion” (Borg, 1998). The scale is typically employed in both clinical and sports settings to monitor and guide training intensity. In the context of the present internship, the Modified Borg Scale was used to monitor the intensity of therapeutic exercise, particularly in early-stage rehabilitation where maintaining proper technique was prioritized. Its simplicity, low cost, and ease of use make it highly suitable for real-time decision-making.

4.4.1.1. Intervention

4.4.1.1.1. Week 1

The exercise intervention consisted of selected exercises based on the assessment protocol and it ranged from mobility to strength exercises.

Mobility exercises: Focused on improving general movement capabilities, especially the most restricted measures.

Strengthening exercises: Focused on improving strength around the foot, knee and hip muscles to support better joint stability, which would influence knee ROM (e.g., squats, calf raises, knee extension and hinge like movements)

Each session lasted between 1 to 2 hours, depending on the patient's availability, and was conducted once a week.

At the first session due to the knee being swollen, the patient started with some manual therapy work which only consisted of helping to drain the swelling. After, the assessment protocol was performed showing the following measures:

Table 5 – Case Study 1. Initial assessment

TESTS	Left	Right	Goal
Sh. Flexion	60	65	150-180º
Sh. ER	63	74	90º
Sh. IR	32	22	70-90º
Hip Flexion	85	80	120º
Hip ER	50	36	40-60º
Hip IR	3	5	30-45º
SLR	44	59	70-90º

Additional tests were also considered, especially knee flexion which was performed in a supine position with the goal of reaching the ankle towards the posterior hip/ glute region. Pain was presented during the knee flexion ROM test. However, since the test board didn´t account for the knee joint ROM, for simplicity purposes, it was only considered her subjective pain sensitivity by using a 0 to 10 scale, where 0 was no pain and 10 being the worst pain she has ever felt. It was

also asked to perform a standing toe touch and a squat to assess her movement quality. The toe touch was limited, being only able to reach just below the knees. Her squat had good form until around 60 or 70º degrees of hip flexion parallel, after which the knees caved in, the lower back extended, and the feet collapsed inward or over-pronating which could be indicative of lack of hip IR.

Assessment Interpretation

The most noticeable restrictions were the IR measures, both at the shoulders and hips but more so at the hips. This indicates an anterior orientation of the pelvis in order to compress and produce force into the ground therefore acquiring more IR but as compensatory strategy. Due to the magnification of hip ER on the left and better SLR on the right, it is possible that she has a longitudinal right turn at the pelvis, meaning a left innominate more pushed forward than the right one, thus creating these limitations. It is to note that although the anterior orientation of the pelvis is a way to leverage more hip IR, as the testing is performed in a supine position, there may be a rolling back of pelvis on the table thus presenting with better hip ER than IR. Due to her squat presentation we can also associate the knees and feet caving in as compensatory strategy to try to find more IR in order to be able to push the ground and stay upright.

The anterior orientation of the pelvis accentuates the lumbar curvature and forward center of mass, which to try to stay upright and not fall she tilts her posterior ribcage backwards which make her shoulder ER to present better compared to her shoulder IR, similar to a thoracic extension mechanism. Since her shoulder ER is better on the right compared to left and the opposite is also true for her IR, it probably means that she has an axial rotation towards the right which promotes scapular IR on the right which may allow for more ER.

Based on the assessment, the first goal would be to try to get a stacked position, meaning a pelvis and ribcage that can stack on top of each other to try to improve her ribcage dynamics, then try to give her more ER so that IR can be imposed on top of the ER space.

At the first session due to a loss of ER and IR measures, the goal was then to improve the ER first before imposing IR.

1) Hooklying Breathing Isometric Push with Low Reach

This exercise intended to be a low force demanding activity. The hooklying position requires less tension overall compared to a standing position since we don´t require to fight against gravity to keep an upright position.

Legs were kept at about 45 degrees of hip flexion with a band around the distal femurs, subsequently the knees would also be at around 45 degrees of flexion. It was cued to keep and push through the foot contacts, more specifically the first metatarsal head or “ball of the big toe” and inner heel without dumping the foot inward, meaning without losing the outside of the foot. This position would bias the femurs into ER especially with the band around the knees which was reinforcing the ER demands, it is to note that it was instructed to keep the hips aligned with the knees and feet to avoid compensatory strategies. By pushing with the instructed foot contacts we would bias more IR at the foot and tibia as well as a more neutral hip position since the posterior superior iliac spine (PSIS) would be more supported on the floor, this combined with the hip position would create the opposite mechanism of the screw-home mechanism, which is the required mechanism to optimally bend the knee, a tibia that can IR relative to the distal femur.

At the shoulder we kept the arms pointing at the ceiling at around 45 degrees of flexion to also emphasize shoulder ER relative to a IR’ed scapula. By utilizing breathing in this position we would promote not only a ribcage that could expand posteriorly, mainly between the scapulas, but a subsequent pelvic floor activity that would be able to work efficiently with the diaphragm to create a upward and downward pressure that allows better expansion of the ribcage (Eswaramoorthi et al. 2021).

It was performed 3 sets of 10 deep breaths with 30 seconds in between sets at a RPE of 3-4/10.

Table 6 – Week 1. Assessment table of the before and after the first exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	60	66	65	74	150-180º
Sh. ER	63	68	74	80	90º
Sh. IR	32	34	22	23	70-90º
Hip Flexion	85	91	80	87	120º
Hip ER	50	58	36	43	40-60º
Hip IR	3	8	5	16	30-45º
SLR	44	56	59	64	70-90º

Overall, we've managed to improve in overall mobility quite significantly as well as the reported knee bending discomfort. As a result, it was decided that this would be an exercise to keep in her daily routine.

Since the ER measures still presented limited but increased motion it was determined that a ground-based rolling activity would be implemented. This activity was designed to not only enhance rotational capabilities but also to emphasize ER biased ranges.

It is to note that after this exercise her toe touch improved quite significantly, which might also be correlated with the SLR and hip IR improvements.

The rest periods in between sets and exercises were based on the patient state of readiness and fatigue levels.

2) Side Lying 45/45 Rolls

This exercise required a side lying position, a foam roller between the legs which would decrease the IR demand and a yoga block just to support the head position. The goal was to start the motion with the top knee by pushing the leg forwards with as little tension as possible and consequently letting the body segmentally roll until the movement reached the cervical spine. On that point, the motion was reversed with the upper leading the movement. It was asked to take

a deep inhale at both end ranges and to perform the exhale while the turning was taking place. The hip was kept at around 45 degrees of flexion just like the shoulders and it was placed a small, rolled towel below the iliac crest of the bottom hip to create some lateral compression of the pelvis and some additional comfort.

It was performed 2 sets of 2 minutes per side, at a RPE of 2-3/10, but the second set was performed only 90 seconds at the left side lying to try to address the hip IR asymmetry.

Table 7 – Week 1. Assessment table of the before and after the second exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	66	75	74	83	150-180º
Sh. ER	68	84	80	90	90º
Sh. IR	34	38	23	31	70-90º
Hip Flexion	91	95	87	92	120º
Hip ER	58	58	43	47	40-60º
Hip IR	8	10	16	16	30-45º
SLR	56	59	64	63	70-90º

Good changes were made across the board, so it was then decided to aim for some specific strength work after these changes.

3) Unilateral Seated Cable Leg Curl with tibial IR (Isoinertial)

The patient was seated with the ischium in contact with the seat and an ankle strap was used with a cable resisting knee flexion. It was then performed a leg curl with the big pointing inward but while trying to keep the foot, knee and hip aligned. The foot pointing inward would promote tibial IR which is associated with the bending mechanism of the knee. It was performed the exercise utilizing the isoinertial machine with a rate of perceived effort (RPE) of 6-7/10 to avoid overloading and discomfort at the knees.

It was asked to perform this exercise at home by using a band secured behind the ankle.

4 sets of 20 repetitions on both legs were performed with 30 seconds after in between sets, at a RPE of 6/10 which gave the non-working leg, around 90 seconds in between sets.

Table 8 – Week 1. Assessment table of the before and after the third exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	75	74	83	81	150-180º
Sh. ER	84	83	90	90	90º
Sh. IR	38	38	31	33	70-90º
Hip Flexion	95	91	92	88	120º
Hip ER	58	54	47	47	40-60º
Hip IR	10	13	16	17	30-45º
SLR	59	63	63	66	70-90º

Due to the nature of the more locally dominant knee exercise, it wasn´t expected for changes to occur at the table tests. However, some changes occurred, mainly improving the internal rotation measures while a minor drop occurred at the flexion and external rotation measures.

4) 90/90 Wall Calf Raises

We ended the session with some hamstring and soleus co-contraction work with the lower limbs elevated to help promote more lymphatic drainage and venous return. The patient in supine position placed both feet on the wall at around 90 degrees of knee flexion and close to 90 degrees of hip flexion. It was asked to try to drag the feet down without them moving which would engage the hamstrings, keeping the back relaxed it would promote a slight posterior pelvic tilt by using the hamstrings, instead of the rectus abdominis. Maintaining the downward pressure it was then performed calf raises, by elevating the heels relative to the wall and maintaining the metatarsal heads on the wall which would require the soleus and calf muscles to work.

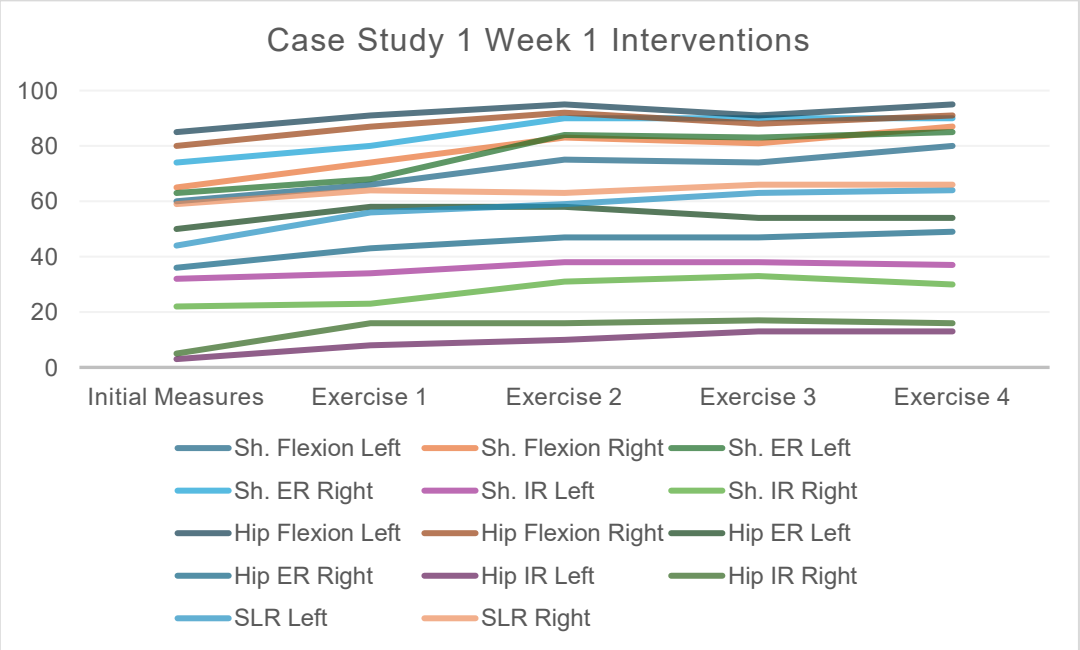
3 sets of 15 reps, at a RPE of 8, with 60 seconds in between sets.

Table 9 – Week 1. Assessment table of the before and after the fourth exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	74	80	81	87	150-180º
Sh. ER	83	85	90	90	90º
Sh. IR	38	37	33	30	70-90º
Hip Flexion	91	95	88	91	120º
Hip ER	54	54	47	49	40-60º
Hip IR	13	13	17	16	30-45º
SLR	63	64	66	66	70-90º

Overall, at the end of the session, we were able to work pain free based on the patient movement limitations and improve her ROM which would likely be indicative of good outcomes. The patient reported feeling less swelling and tension at the knee and was better able to bend both knees. It was asked to keep these exercises at home at least for 2 to 3 sets, 2 to 3 times per day until the next session, except for the leg curl exercise which couldn´t be replicated at home.

Week 1 Results:



Graph 1 – Case Study 1. Week 1 in session ROM progress throughout the exercises

4.4.1.1.2. Week 2

The patient arrived still with some knee swelling. Manual therapy was done before the intervention to help with the swelling. This also helped improving the knee pain sensation and ROM. The patient was able to continue the exercises at home at least 2 times per day and reported feeling more ease of movement after the exercises. Now a 6 or 7/10 in terms of pain was mentioned.

We then performed and compared the assessment with the previous week.

Table 10 – Week 2. Assessment table comparing the end results of the previous week

TESTS	Week1 Left	Week2 Left (After)	Week1 Right	Week2 Right (After)	Goal
Sh. Flexion	80	71	87	75	150-180º
Sh. ER	85	77	90	86	90º
Sh. IR	37	33	30	24	70-90º
Hip Flexion	95	89	91	84	120º
Hip ER	54	55	49	42	40-60º
Hip IR	13	6	16	8	30-45º
SLR	64	58	66	61	70-90º

After the assessment we could see that although the changes from the end of the last session didn´t stick, meaning the ROM measures weren´t as good as she left the previous week, they still presented better from the initial assessment which shows some progress.

We decided to complete 1 set of the home exercises given to reinforce the cues and see if they were being performed correctly while also trying to reacquire more ROM.

After one set of the exercises given previously the following measures were seen:

Table 11 – Week 2. Assessment table of the before and after the home exercises given

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	71	82	75	90	150-180º
Sh. ER	77	85	86	90	90º
Sh. IR	33	36	24	28	70-90º
Hip Flexion	89	94	84	88	120º
Hip ER	55	55	42	48	40-60º
Hip IR	6	10	8	14	30-45º
SLR	58	63	61	65	70-90º

We then decided to progress the intensity of the exercises by focusing on specific strength work based on the assessment while still trying to improve ROM and relative movement.

1) 60/60 Wall Sit

Using a wall to create some support, it was asked to maintain contact with the PSIS as well as the upper thoracic spine while keeping a vertical squat position with around 60 degrees of hip flexion, the foot below the knee and to keep the inner heel and base of the first metatarsal head pushing the floor without losing the outside part of the foot. This would reinforce the first exercise mechanics given previously in the hooklying position but emphasizing more load and requiring more internal rotation to produce force. This was evident, since the patient initially started to let the knees cave in, creating a valgus stress at the knee and reproducing pain at the knees. When cued to align the knee with the hips and feet, her low back would tend to arch, as a possible strategy to acquire hip internal rotation. To ensure a good positioning of the knees we've opted to utilize a small band above the knees to give her a reference to try to maintain the knee alignment which improved her pain sensitivity and helped keep the PSIS contact with the wall. In this position deep breaths were performed with a low reach lead by the elbows with 90 degrees of flexion, at around 45-60 degrees of shoulder flexion to try to expand her upper back during the inhalation.

4 sets of 40 seconds, at a RPE of 7 were performed with 60 seconds in between sets.

After this exercise the following measures were observed:

Table 12 – Week 2. Assessment table of the before and after the first exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	82	86	90	94	150-180º
Sh. ER	85	85	90	90	90º
Sh. IR	36	35	28	28	70-90º
Hip Flexion	94	97	88	91	120º
Hip ER	55	58	48	50	40-60º
Hip IR	10	14	14	15	30-45º
SLR	63	62	65	66	70-90º

2) Unilateral Leg Extension Iso Hold 15-30º

The goal with this activity was to try to load the quadriceps by emphasizing the vastus medialis oblique (VMO) work by keeping an isometric contraction close to full knee extension. During the exercise, it was added a contralateral turn where the contralateral arm of the working leg would grab the front part of the bench crossing the working leg, therefore also create a hip turn towards the working leg, creating relative femoral internal rotation which would give more leverage for the VMO to work by matching more appropriately the muscle positioning with the line of force. This would help the patella to be relative pulled medially which based on the patient assessment and previous imaging suggested a lateral tracking tendency of the patella.

4 sets of 30 seconds at a RPE of 5-6 on each leg with 60 seconds in between sets.

Table 13 – Week 2. Assessment table of the before and after the second exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	86	86	94	95	150-180º
Sh. ER	85	86	90	90	90º
Sh. IR	35	36	28	30	70-90º
Hip Flexion	97	99	91	91	120º
Hip ER	58	57	50	50	40-60º
Hip IR	14	14	15	16	30-45º
SLR	62	63	66	65	70-90º

3) Side Lying Elbow Plank with low hip flexion

As a progression of the Side Lying 45/45 Rolls given previously, we decided to increase the demands of the activity. In a side plank position, we used around a 45 degree angle of hip flexion where it was asked to maintain lateral knee contact, elbow and hand hypothenar as long with infra-digital contact, mainly the second metacarpal head. It was then performed a side plank by pushing through those points of contact and trying to keep a stacked position of the pelvis and ribcage.

The hip flexion angle biases relatively more ER and due to the lateral knee contact push, it would also bias an abduction moment arm creating more demands for the hip external rotators to work. The supporting arm being at 90 degrees of flexion but in an abducted position would also bias more ER while trying to superimpose IR to keep pushing the ground away to stay elevated from the floor. It was also asked to try to keep a slow, deep breathing strategy to also work on the ribcage dynamics and its influence on the system.

3 sets of 30 seconds were performed at a RPE of 5 on each side with 30 seconds in between sets.

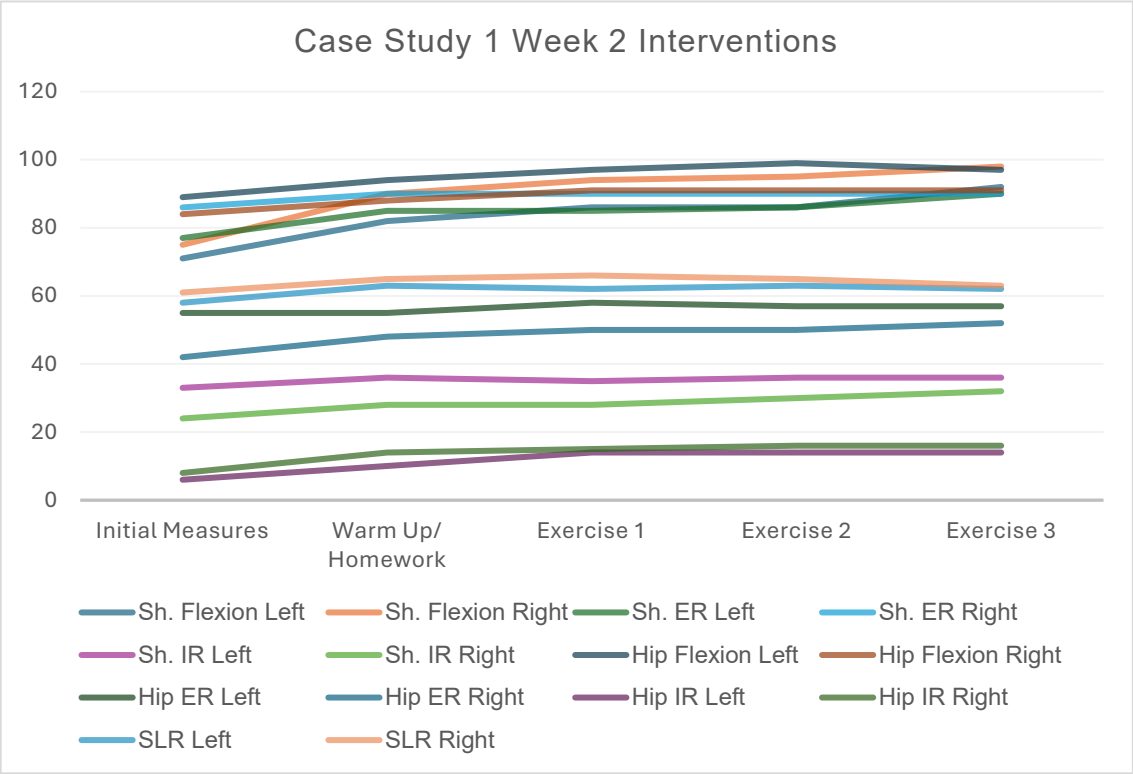
Table 14 – Week 2. Assessment table of the before and after the third exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	86	92	95	98	150-180º
Sh. ER	86	90	90	90	90º
Sh. IR	36	36	30	32	70-90º
Hip Flexion	99	97	91	91	120º
Hip ER	57	57	50	52	40-60º
Hip IR	14	14	16	16	30-45º
SLR	63	62	65	63	70-90º

The same “homework” from the previous session was kept for at least one more week to try to keep on improving the patient mobility and relative movement capabilities. At the end of the session, her pain/discomfort sensation was subjectively reported as improving since the beginning of the intervention which indicated that we were on the right track.

During the session it was discussed that her daughter would do water aerobics during the week. Given the opportunity it was suggested that she would try and experiment with the classes with her to promote joint-friendly movement but also to see how she would feel about it.

Week 2 results:



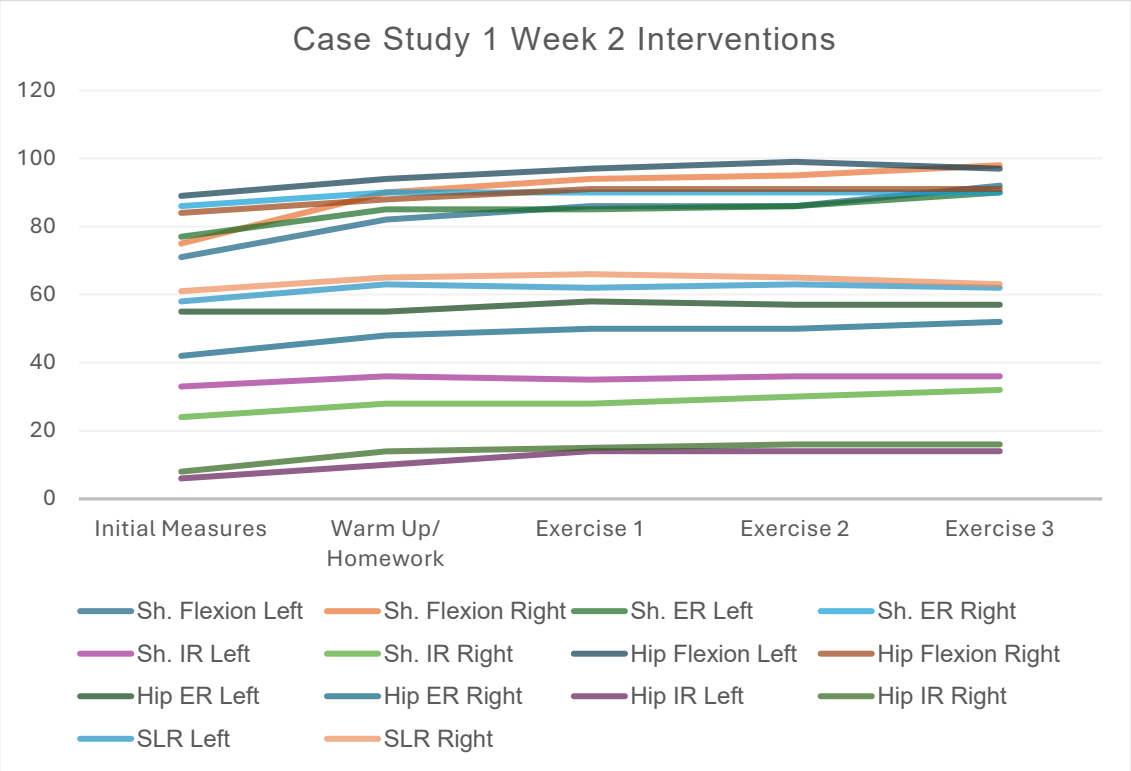
Graph 2 - Case Study 1. Week 2 in session ROM progress throughout the exercises

4.4.1.1.3. Week 3

The patient arrived with some knee swelling, however less compared to the previous week. Manual therapy was done before the intervention and the patient reported that despite having presented with some muscle soreness the days after the previous session, she started to feel less discomfort throughout the day, especially at the shoulder which could have to do with the ROM improvements. She also reported having tried the water aerobics and felting good during and after the class, we then discussed that for patients with OA, aquatic-exercise-based interventions are effective for reducing pain and joint dysfunction and improving quality of life as demonstrated by Song and Oh (2022).

A new assessment was done where it was compared with the last assessment:

Table 15 – Week 3. Assessment table comparing the end results of the previous week



Graph 3 - Case Study 1. Week 2 in session ROM progress throughout the exercises

TESTS	Week2 Left	Week3 Left (After)	Week2 Right	Week3 Right (After)	Goal
Sh. Flexion	92	81	98	86	150-180º
Sh. ER	90	83	90	90	90º
Sh. IR	36	33	32	28	70-90º
Hip Flexion	97	93	91	86	120º
Hip ER	57	54	52	47	40-60º
Hip IR	14	7	16	10	30-45º
SLR	62	57	63	60	70-90º

Although the patient measurements presented better at the end of the last session it was noted that the overall measures were improving when compared with the start of the sessions. Short-term increases in ROM can occur quickly

after an exercise intervention as demonstrated by Muanjai et al., (2017), the long-term effects require ongoing practice. Nakamura et al., (2021) emphasized that sustained ROM gains can be achieved with consistent exercise over weeks but when a detraining occurs the ROM and flexibility gains reverse the adaptations caused by static stretching which are suggested to be developed based on a stretch tolerance through a neuromuscular adaptation. A systematic review also supports the idea that stretching programs improve ROM based on a stretch tolerance rather than a structural or positional change (Konrad et al., 2023). Therefore, although immediate changes from a single session may provide temporary improvements, understanding the changes associated with the session may be a good tool for the effectiveness of certain practices and exercise selection. However, the prescribed exercises are not stretch based, but instead based on a whole body osteokinematic approach, thus the results may differ. Continuous training is, however, still essential for maintaining and maximizing those gains.

Based on the testing we still started with the exercises given to do at home to gain some motion, only progressing the side lying 45/45 Rolls to a 60/60 position instead of a 45/45 position, meaning that we would start working at higher degrees of hip flexion, now 60 degrees instead of 45 which based on the pelvifemoral rhythm should bias more IR than at lower degrees of hip flexion.

Table 16 – Week 3. Assessment table of the before and after the home exercises given

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	81	87	86	92	150-180º
Sh. ER	83	90	90	90	90º
Sh. IR	33	37	28	33	70-90º
Hip Flexion	93	96	86	91	120º
Hip ER	54	57	47	52	40-60º
Hip IR	7	13	10	16	30-45º
SLR	57	66	60	70	70-90º

1) 60/60 Weighted Wall Sit

Progressing the wall sit we now started to add some weight by holding a dumbbell in a front rack position, meaning with the elbows more in front of the body to promote scapular protraction which would reinforce a IR'ed scapula relative to humerus ER. If no compensatory strategies occurred not only, would it make the exercise harder, but it would require pushing the ground more to maintain an upright position, therefore requiring more IR. Cheatham et al., (2018) showed that as weight increases in a squat, we must counteract forces to maintain stability, leading to an increased need for hip IR to manage the center of mass and maintain an upright torso position. This dependence on internal rotation intensifies with rising lifting demands, meaning that we need to push harder in to ground.

3 Sets 30 Seconds at a RPE of 7-8/10 with 90 seconds in between sets.

Table 17 - Week 3. Assessment table of the before and after the first exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	87	90	92	94	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	37	36	33	33	70-90º
Hip Flexion	96	96	91	91	120º
Hip ER	57	56	52	52	40-60º
Hip IR	13	14	16	18	30-45º
SLR	66	66	70	71	70-90º

2) Foam Roller Bridge

Progressing and based on the hooklying breathing drill, a foam roller was added to increase instability and consequently the demands of the hamstrings and calves to co-contract and hold the position. A stacked position of the pelvis and ribcage was cued during the exercise. During the exercise we first aimed for 40 seconds, but due to the hamstrings starting the cramp after the 35 seconds time frame we´ve decided to stay at 30 seconds and progress the exercise to unilateral once the 40 seconds could be maintained without cramping.

3 Sets of 30 seconds were done at a RPE of 7 with 45 seconds in between sets.

Table 18 - Week 3. Assessment table of the before and after the second exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	90	90	94	94	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	36	34	33	32	70-90º
Hip Flexion	96	97	91	92	120º
Hip ER	56	57	52	51	40-60º
Hip IR	14	16	18	18	30-45º
SLR	66	67	71	71	70-90º

3) Unilateral Leg Extension Iso Hold 15-30º

Since she now could hold the 30 seconds easily, we increased the time to 45 seconds.

4 Sets of 45 seconds were done at a RPE of 7 on each leg with 40 seconds in between sets.

Table 19 - Week 3. Assessment table of the before and after the third exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	90	91	94	94	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	34	35	32	32	70-90º
Hip Flexion	97	97	92	93	120º
Hip ER	57	57	51	52	40-60º
Hip IR	16	17	18	18	30-45º
SLR	67	67	71	71	70-90º

4) Side Lying Elbow Plank with low hip flexion

Progressing the side plank, now it was asked to keep the upward leg reaching down, parallel to the ground, without touching the floor. This would increase the demands of the downward ER hip muscles like the piriformis, glute

maximus and posterior fibers of the glute med and create some additional length through the side of the ribcage that´s facing up.

3 sets of 30 seconds were performed at a RPE of 5-6 on each side with 40 seconds in between sets.

Table 20 - Week 3. Assessment table of the before and after the fourth exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	91	95	94	98	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	35	41	32	37	70-90º
Hip Flexion	97	98	93	95	120º
Hip ER	57	57	52	54	40-60º
Hip IR	17	18	18	21	30-45º
SLR	67	67	71	71	70-90º

5) Soleus Slouch

As a progression to the 90/90 Wall Calf Raises, in this exercise, the goal was to load the soleus unilaterally while working on hip extension, to try to improve some hip IR, but also to maintain the knee in a mid-stance position regarding the gait cycle, meaning on top of the foot (vertical shin angle) while pushing down, but in a slightly flexed position.

A wedge was used at the forefoot where it was cued to keep heavy at the base of the metatarsal heads while feeling the heel almost off the ground. While maintaining the COM on the top of the foot, a hip hinge like motion was performed, by pushing the hips backwards and trying to keep a stacked positioned of the pelvis and ribcage.

Initially, there were challenges in understanding the correct hip movement. This led to repetitions performed with improper technique, primarily involving excessive spinal movement and extension. The desired outcome should have been to push the hips backward without extending the spine and knees, which was not consistently achieved, resulting in undesirable technique. An assessment was done after the unwanted technique was done.

Table 21 - Week 3. Assessment table of the before and after the fifth exercise performed incorrectly

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	95	90	98	94	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	41	39	37	36	70-90º
Hip Flexion	98	93	95	91	120º
Hip ER	57	51	54	50	40-60º
Hip IR	18	25	21	29	30-45º
SLR	67	74	71	82	70-90º

Interesting we saw some favorable and unfavorable changes. We noticed an increase in hip IR and at the SLR and a decrease in hip ER as well as hip and shoulder flexion. This might be due to a compensatory strategy by utilizing an anterior pelvic tilt accompanied by a spinal extension strategy, it magnified the IR and decreased the ER at the hip due to an orientation of the pelvis. If a favorable change occurred, we would probably see an increase in both ER and IR measures or at least in one of those without a decrease in the opposing test.

To fix the undesirable motion, it was cued to round the spine segmentally starting through the neck all the way to lumbar spine while trying to touch the floor, it was then asked to push the wedge with the mid and forefoot while going up and segmentally extending the spine back to the starting conditions. This was more helpful, making the patient better feel the calves and glutes working.

3 Sets of 8 repetitions on each side were performed at a RPE of 8-9.

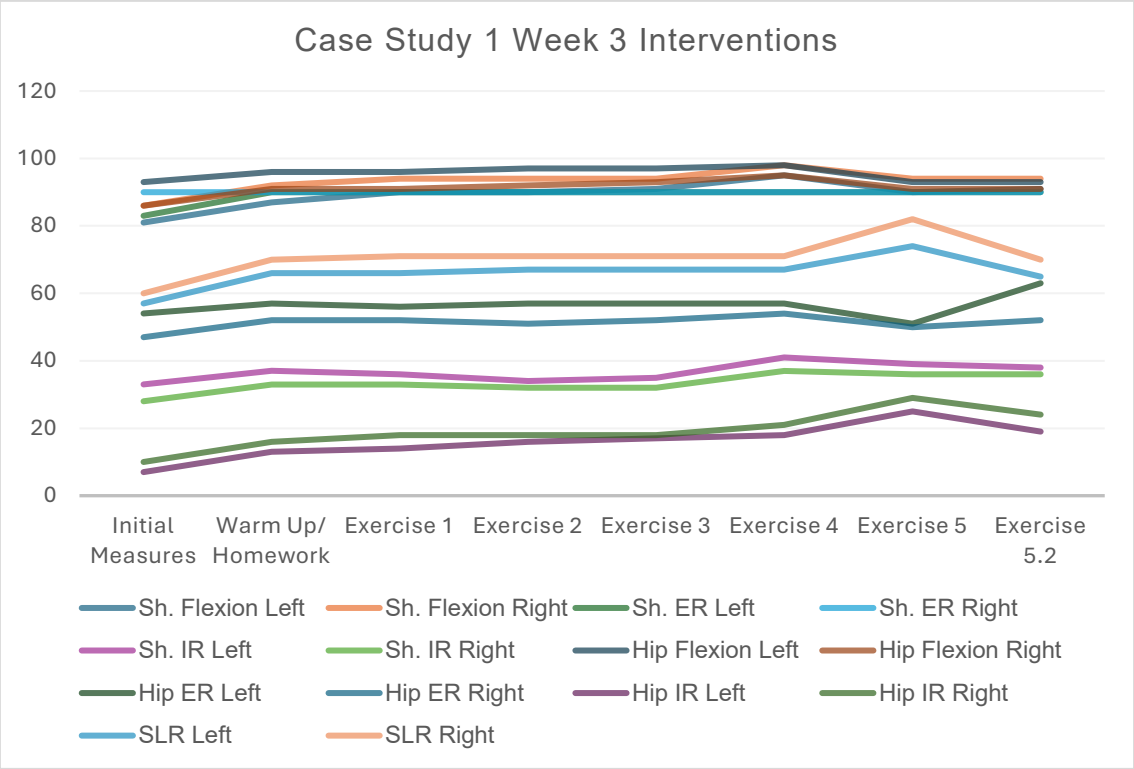
Table 22 - Week 3. Assessment table of the before and after the fifth exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	90	91	94	94	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	39	38	36	36	70-90º
Hip Flexion	93	93	91	91	120º
Hip ER	51	63	50	52	40-60º
Hip IR	25	19	29	24	30-45º
SLR	74	65	82	70	70-90º

After the modifications on the exercise, we saw that the increase in hip IR and decreased ER previously seen were reverted, but the IR decrease was still favorable compared to before doing the exercise. The patient also reported feeling the knee more stable and less swollen.

At the end of this session the exercises to do at home were changed to: Foam Roller Bridge, Wall Sit 60/60 and the Soleus Slouch in that order for 1 to 2 sets of the same repetitions each day, depending on the fatigue levels.

Week 3 Results:



Graph 4 - Case Study 1. Week 3 in session ROM progress throughout the exercises

4.4.1.1.4. Week 4

The patient arrived reporting feeling muscle soreness in the days following the last session, which was training related. During the week, the patient started to feel less discomfort throughout the day, especially when going down and up the stairs rating it a 4/10. Some manual therapy was performed to help reduce the swelling, which was less than the previous week. She also mentioned that she had committed to water aerobics classes twice a week and had already started, which was a big win.

The results obtained at the beginning of the session were compared with those of the previous session.

Table 23 - Week 4. Assessment table comparing the end results of the previous week

TESTS	Week3 Left	Week4 Left (After)	Week3 Right	Week4 Right (After)	Goal
Sh. Flexion	91	92	94	97	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	38	37	36	33	70-90º
Hip Flexion	93	96	91	88	120º
Hip ER	63	58	50	54	40-60º
Hip IR	19	15	29	19	30-45º
SLR	65	61	82	65	70-90º

Overall, table 20 showed the ROMs were improving, and the patient has been able to continue routinely with her homework. Also, when performing a squat, without cues, it was noted that she was now able to reach the squat parallel without letting the knees caving in, reaching an important milestone to movement quality. However internal hip rotation still presented limited.

We went through the exercises asked to do previously at home for 2 sets to recap, guarantee technique, warm up and see how the testing changed.

Table 24 - Week 4. Assessment table of the before and after the home exercises given

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	92	96	97	102	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	37	39	33	37	70-90º
Hip Flexion	96	97	88	96	120º
Hip ER	58	66	54	59	40-60º
Hip IR	15	18	19	23	30-45º
SLR	61	63	65	68	70-90º

After these exercises, having cleared the 90 degrees of hip flexion at both sides, we started with more dynamic activities to work within those ranges.

1) Unilateral foam roller bridge with 90º arm reach

A progression from the foam roller bridge. Participant was now asked to elevate one leg at around 90 degrees of hip flexion while trying to push the foam roller with the opposite leg midfoot. This exercise not only required more force against the foam roller to be exerted but it also created a rotation force at the hips to the non-supported leg, requiring more stability to not lose the stacked position. Since we already had more than 90 degrees of shoulder flexion, we cued a 90 degree reach with the arms to promote more scapula ER which would potentially improve the pump handle mechanism of the ribcage when breathing.

2 Sets of 40 seconds were done on each leg with 40 seconds in between sets with a RPE of 8.

Contrary to our expectations this exercise resulted in greater ROM improvements at the shoulder flexion, from 96 degrees on the left to 100 and 102 on the right to 110 degrees; hip IR improved 6 degrees on the left and 4 degrees on the right; SLR improved 8 degrees on the left and 10 on the right and even the left sh. IR improved 9 degrees. These changes demonstrate that despite being a lower limb focused exercise the whole body got influenced.

Table 25 - Week 4. Assessment table of the before and after the first exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	96	100	102	110	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	39	48	37	40	70-90º
Hip Flexion	97	103	96	99	120º
Hip ER	66	70	59	64	40-60º
Hip IR	18	24	23	27	30-45º
SLR	63	71	68	78	70-90º

2) Heels Elevated Goblet Box Squat

As a progression of the wall sit exercise, we aimed for a more dynamic movement while working on the available ROM. For that we used a box to prevent going below 90 degrees, at 90 degrees the femur increases the congruency of

the joint, places the posterior capsule and external rotators (e.g., piriformis, gluteus maximus fibers) on greater stretch (Neumann, 2017) increasing the demands of IR. It was encouraged to touch the box with the sit bones when squatting, which requires a slight hinge motion at the hips promoting more hip internal rotation. Two ramps were used to elevate the heels, pushing the center of mass forward. Therefore, to maintain balance, the patient had to lean back creating more space at the anterior ankle and allowing the tibia to translate farther forward due to the initial plantar flexion. This also created less anterior pelvic tilt. The dumbbell in front of the body also helps with the posterior translation of its center of mass. This emphasizes the load being distributed more along the quadriceps compared to the hip and spine musculature because it allows the knees to travel forward and the torso to displace more vertically.

During the execution it was observed a tendency for the knees to cave in, mainly when starting to lift off the box. Despite cuing the knees to be in line with the hips and feet, this caused some medial knee pain in 2 repetitions. Then, a band was placed around the distal femurs so that she would have to push the band outward to keep the knees in the desired position.

3 Sets of 10 repetitions with 90 seconds of rest in between sets were performed with a RPE of 7. It resulted in overall small changes that could have been influenced by testing errors.

Table 26 - Week 4. Assessment table of the before and after the second exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	100	99	110	111	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	48	47	40	42	70-90º
Hip Flexion	103	105	99	102	120º
Hip ER	70	68	64	63	40-60º
Hip IR	24	26	27	28	30-45º
SLR	71	70	78	78	70-90º

3) Wall Supported Hinge Push

Due to limitations being mostly present at the IR measures, it was performed a hinging activity to promote greater activation of the hip internal rotators through posterior hip expansion. This requires more IR by expanding the back of the hip mainly the deep external rotators like the gluteus maximus inferior fibers, gemellus, quadratus femoris, obturator. It was cued a slight bend at the knee, heavy hands against a wall to promote a forward lean of the trunk, a tripod foot meaning having the calcaneus, first and fifth metatarsal heads on the ground but pushing through the first metatarsal and heel on the concentric phase while pushing the hips forward. This exercise mostly improved hip IR, Sh. IR and Sh. flexion.

3 Sets of 12 repetitions were performed with 45 seconds in between sets at a RPE of 5.

Table 27 - Week 4. Assessment table of the before and after the third exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	99	105	111	113	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	47	49	42	45	70-90º
Hip Flexion	105	107	102	103	120º
Hip ER	68	66	63	63	40-60º
Hip IR	26	29	28	31	30-45º
SLR	70	71	78	77	70-90º

4) Flywheel Seated Leg Extension & Prone Leg Curl

At this point we decided to start implementing more isolated work to the quadriceps and hamstrings in a controlled manner. The isoinertial leg extension and leg curl machine was used with emphasis on the eccentric part. The concentric motion was performed at a RPE of 7/10, with added assistance provided to promote an eccentric overload. The movement stopped before 90 degrees of knee flexion at the knee extension machine and full knee extension at the leg curl machine was avoided. During both exercises, a yoga block was placed between the thighs to ensure proper hips, knees and foot alignment.

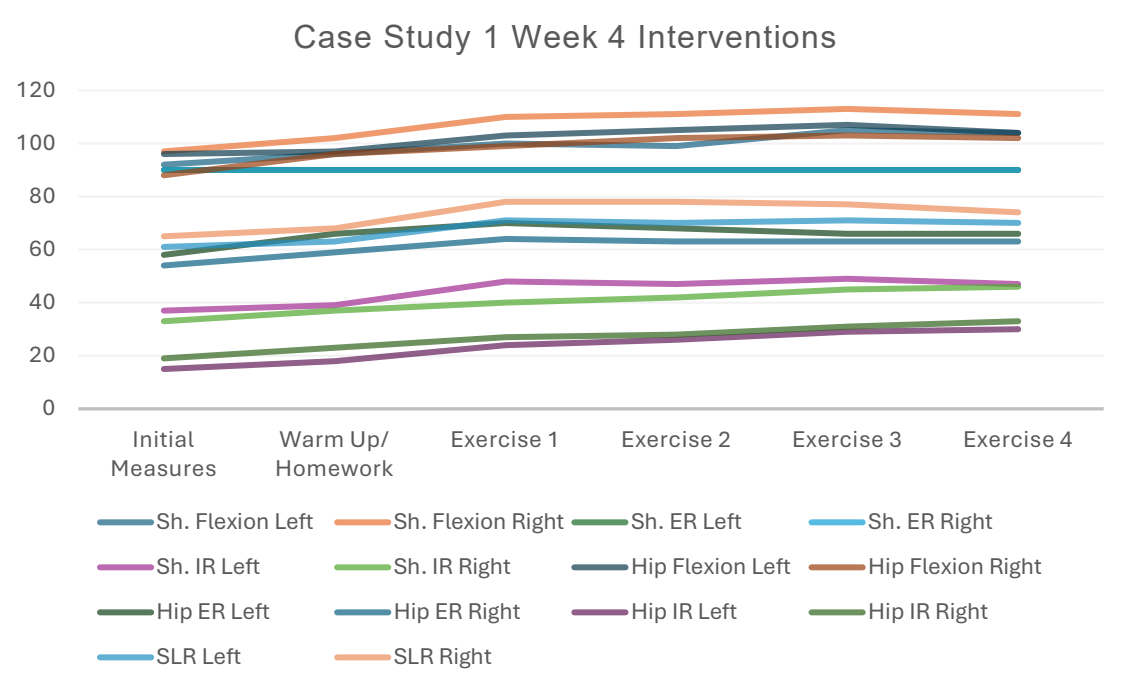
Additionally, there was some IR bias, with the adductor contributing to this effect. The patient reported to be pain free and muscle fatigue during the execution as intended.

4 Sets of alternating both exercises for 8 repetitions resulted in small fluctuations in overall ROM, remaining at similar levels and a slight improvement in hip IR with stable values at the leg extension. This is good since it shows us that we can now endure loading of the knee in an open kinetic chain exercise without compensatory strategies.

Table 28 - Week 4. Assessment table of the before and after the fourth exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	105	104	113	111	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	49	47	45	46	70-90º
Hip Flexion	107	104	103	102	120º
Hip ER	66	66	63	63	40-60º
Hip IR	29	30	31	33	30-45º
SLR	71	70	77	74	70-90º

Week 4 results



Graph 5 - Case Study 1. Week 4 in session ROM progress throughout the exercises

4.4.1.1.5. Week 5

At this point, the patient has reported significant improvement, indicating that this has been her best week concerning knee pain and associated limitations. She has experienced only occasional discomfort, primarily after prolonged periods of standing or sitting, during which her knees felt somewhat "rusty." Regarding her shoulder, although the primary focus of treatment has been the knee, we have observed notable improvements in range of motion (ROM), and the patient reported that her shoulder pain has disappeared this week. Some swelling remains, therefore, we initiated manual therapy, albeit for a reduced duration, as the knee is responding positively with diminished inflammation.

Additionally, we utilized the beginning of the session to discuss the patient's average daily step count. Given her openness to the suggestion, it was recommended that she consider acquiring a smart band to monitor her daily activity and encourage a more active lifestyle. We also discussed practical tips, such as setting reminders post-lunch for brief walks and opting for stairs instead of elevators, provided she remains pain-free, which she gladly considered.

The initial assessment compared to the previous session was as follows:

Table 29 - Week 5. Assessment table comparing the end results of the previous week

TESTS	Week4 Left	Week5 Left (After)	Week4 Right	Week5 Right (After)	Goal
Sh. Flexion	104	98	111	107	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	47	43	46	37	70-90º
Hip Flexion	104	95	102	89	120º
Hip ER	66	64	63	56	40-60º
Hip IR	30	17	33	23	30-45º
SLR	70	61	74	66	70-90º

Having almost full ER at the shoulders and Hips we now aim to try to improve IR measures. For that we would use positions closer to 90 degrees of flexion and hinge-like movements to try to do that.

1) Unilateral Foam Roller Bridge with 90-degree arm reach

3 Sets of 35 seconds were performed with 30 seconds in between sets and a RPE of 8.

Table 30 - Week 5. Assessment table of the before and after the first exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	98	99	107	106	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	43	44	37	40	70-90º
Hip Flexion	95	98	89	93	120º
Hip ER	64	63	56	59	40-60º
Hip IR	17	24	23	27	30-45º
SLR	61	65	66	69	70-90º

2.1) Soleus Slouch

1 Set of 5 repetitions on each side with a RPE of 5-6.

Table 31 - Week 5. Assessment table of the before and after the second exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	99	101	106	109	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	44	42	40	39	70-90º
Hip Flexion	98	99	93	93	120º
Hip ER	63	65	59	63	40-60º
Hip IR	24	21	27	24	30-45º
SLR	65	61	69	67	70-90º

Since the ER measures improved and the IR got worse, we probably saw a flexion orientation strategy which facilitated those improvements.

2.2) Wall Supported Hinge Push

1 Set of 10 repetitions with a RPE of 4.

Table 32 - Week 5. Assessment table of the before and after the third exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	101	103	109	108	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	42	45	39	43	70-90º
Hip Flexion	99	100	93	93	120º
Hip ER	65	64	63	61	40-60º
Hip IR	21	26	24	28	30-45º
SLR	61	66	67	72	70-90º

3) Soleus Hinge

The goal with this exercise was to progress the Soleus Slouch exercise by hinging through the hips instead of utilizing spinal extension. This had been tried during the third week, but the execution was not as intended and for that reason we opted for the Slouch variation. To do that we previously performed the Wall Supported Hinge to try to isolate and teach the desired hinging motion and combine it with the soleus exercise. This worked well and after a few repetitions of coaching the exercise was performed as intended.

3 Sets of 8 on each side with a RPE of 7 and 30 seconds in between sets.

Table 33 - Week 5. Assessment table of the before and after the third exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	103	102	108	108	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	45	49	43	48	70-90º
Hip Flexion	100	103	93	97	120º
Hip ER	64	64	61	60	40-60º
Hip IR	26	30	28	32	30-45º
SLR	66	70	72	73	70-90º

4) Box Squat

Since the Box squat requires a slight hinge like motion at the hips it would increase the hip IR demands compared to a more vertical squat. A small weight was held in front of the body and was asked to reach in line with the chest during the eccentric phase. This would help promote the backward movement at the hips as long as the spinal extension was controlled. The first set was performed by holding a stick to first learn the movement before introducing the weights. By pushing the hips backwards, we´re trying to promote eccentric orientation of ER muscles such as glute max, glute medius, quadratus femoris and piriformis.

3 Sets of 10 repetitions were performed with a RPE of 7 and 60 seconds rest.

Table 34 - Week 5. Assessment table of the before and after the fourth exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	102	102	108	110	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	49	53	48	49	70-90º
Hip Flexion	103	107	97	100	120º
Hip ER	64	65	60	59	40-60º
Hip IR	30	33	32	35	30-45º
SLR	70	68	73	74	70-90º

5) Quadruped Breathing with left hand elevated

To try to promote more IR not only at the hips but at the shoulders as well, a quadruped position was opted due to the 90 degrees of the hip and shoulder flexion angle but also due to the gravity demands at the ribcage. Since the air acts like a fluid at the lungs, it means that the expansion would have a bias to promote the pump handle mechanism which was reinforced with the scapular ER and relative humeral IR. The lower limbs were also at 90 degrees of hip flexion, biasing more hip IR, pelvic position was controlled to avoid excessive spinal flexion or extension. Since there was asymmetry both at the hips and shoulders, a small block under the left hand was implemented to promote an axial turn to emphasize the right anterior pump handles slightly more to see if the right

shoulder IR would improve more than the left. The first 2 sets were done with the knees in contact with the ground and the last one we've tried to take the knees slightly off the ground, however due to the demands fewer repetitions were made. A small yoga block was also placed between the knees to keep the alignment of the hips and knees while promoting some adductor activity which would also help to inhibit the ER muscles.

2 Sets of 8 Breaths, RPE of 4 were performed with the knees supported and 1 Set of 4 Breaths without the knee contact with a RPE of 8 and 30 seconds rest.

Table 35 - Week 5. Assessment table of the before and after the fifth exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	102	111	110	113	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	53	56	49	58	70-90º
Hip Flexion	107	106	100	102	120º
Hip ER	65	63	59	58	40-60º
Hip IR	33	35	35	36	30-45º
SLR	68	70	74	72	70-90º

6) Flywheel Leg Extension and Leg Curl

To finish the session, 3 super sets of the isoinertial leg extension and leg curl machine with a yoga block in between the thighs.

3 Alternated sets of 8 repetitions with a RPE of 7 were performed without rest.

Table 36 - Week 5. Assessment table of the before and after the sixth and seven exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	111	109	113	110	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	56	56	58	58	70-90º
Hip Flexion	106	104	102	100	120º
Hip ER	63	59	58	55	40-60º
Hip IR	35	36	36	35	30-45º
SLR	70	68	72	70	70-90º

At the end of the session, the patient was feeling good but tired from the session. It was asked to continue with the home exercises but to also implement the quadruped breathing exercise and replace the soleus slouch exercise with the hinge variant.

Table 37 – Home exercises sequence

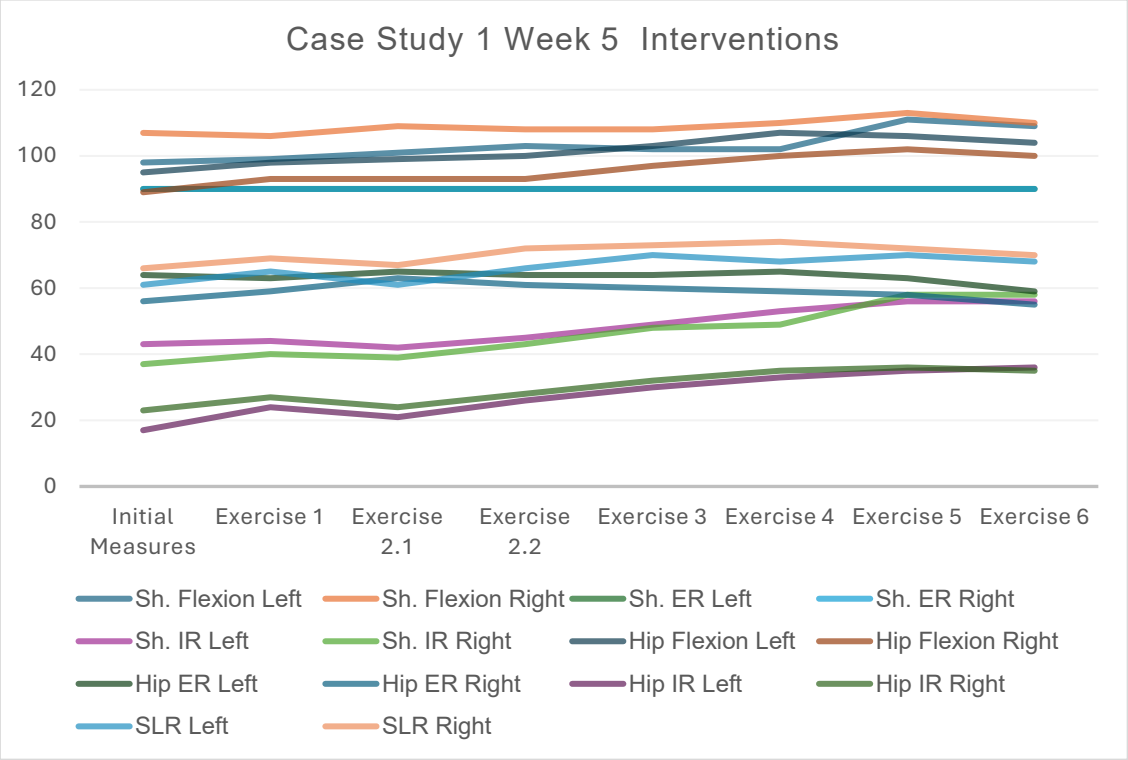
Exercises	Sets/Reps
Foam Roller Bridge	2-3 x 30”
Wall Sit 60/60	2 x 45”
Quadruped Breathing	2 x8-10
Soleus Hinge	2 x8-10

The home exercises were progressively adjusted throughout the intervention period in response to the patient’s clinical evolution. One key reason for these changes was the patient’s increasing proficiency in performing the initial exercises with appropriate control and form. As her movement quality improved, it became necessary to provide more challenging or targeted stimuli to promote continued progress and avoid plateauing.

Additionally, the patient demonstrated measurable gains in PROM particularly in the previously restricted regions. This increase in available range allowed for the safe introduction of exercises that required a broader movement spectrum and greater neuromuscular control. In other words, with more

movement capacity available, it became both appropriate and beneficial to work within those expanded ranges to enhance motor control, strength, and functional integration. This adaptive approach is crucial in personalized rehabilitation, recognizing that as the body changes, so too must the strategies used to support its recovery and performance.

Week 5 results:



Graph 6 - Case Study 1. Week 5 in session ROM progress throughout the exercises

4.4.1.1.6. Week 6

This week, the patient reported experiencing a pain-free week, including when ascending and descending stairs, which had previously been her greatest limitation. The swelling of the knee has significantly improved, especially in comparison to the initial session. She has been consistently performing the exercises daily; however, she has limited herself to one set of the most challenging exercises on the days following the previous session due to delayed onset muscle soreness.

Unfortunately, the patient was short on time due to a medical appointment with the orthopedist for a reevaluation, which gave us only time to review her

home exercises and perform 2 sets of an exercise without being able to perform an assessment after the exercises.

The initial assessment compared to the previous session was as follows:

Table 38 - Week 6. Assessment table comparing the end results of the previous week

TESTS	Week5 Left	Week6 Left (After)	Week5 Right	Week6 Right (After)	Goal
Sh. Flexion	104	100	107	106	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	56	47	54	45	70-90º
Hip Flexion	104	97	100	93	120º
Hip ER	59	61	55	57	40-60º
Hip IR	36	25	35	29	30-45º
SLR	65	64	69	68	70-90º

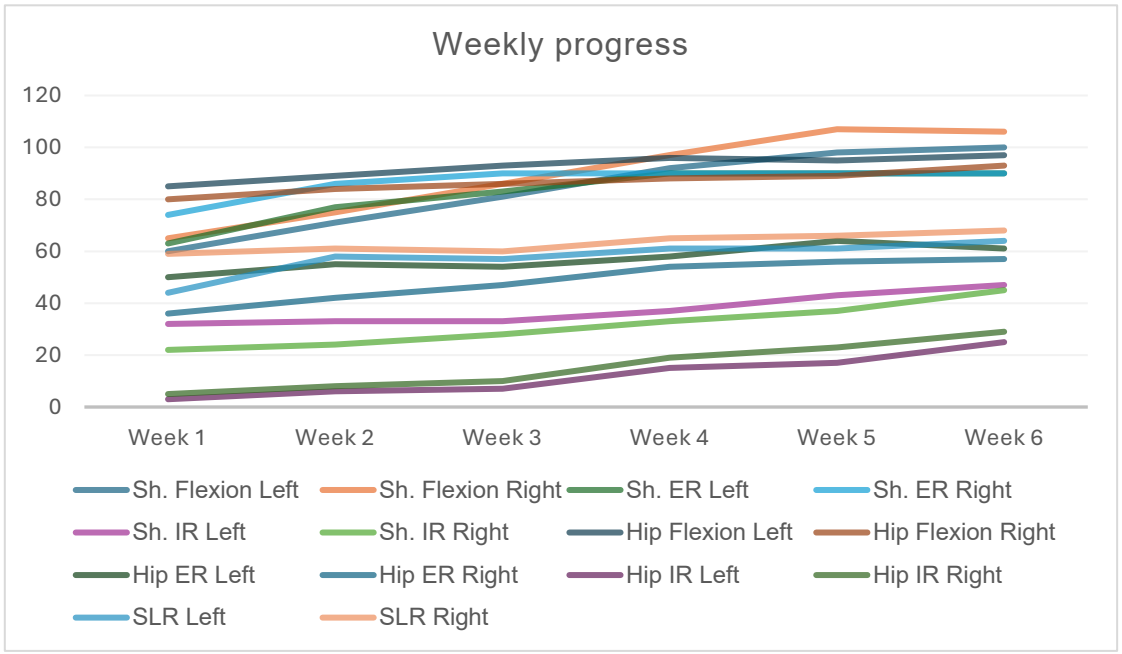
We then reviewed her home exercises and did 2 sets of 12 the Box Squat exercise. Afterwards some manual therapy was done, mainly knee mobilizations and soft tissue work.

The following day, the patient visited the clinic to express her gratitude for the assistance she had received, as her doctor was pleased with her progress thus far. He recommended that she began gym activities, but under supervision. Consequently, she contacted a local gym near her home to initiate her training, which was set to commence the following week. She began training twice a week: once with a personal trainer and once independently, while reducing her water aerobics classes to just once a week.

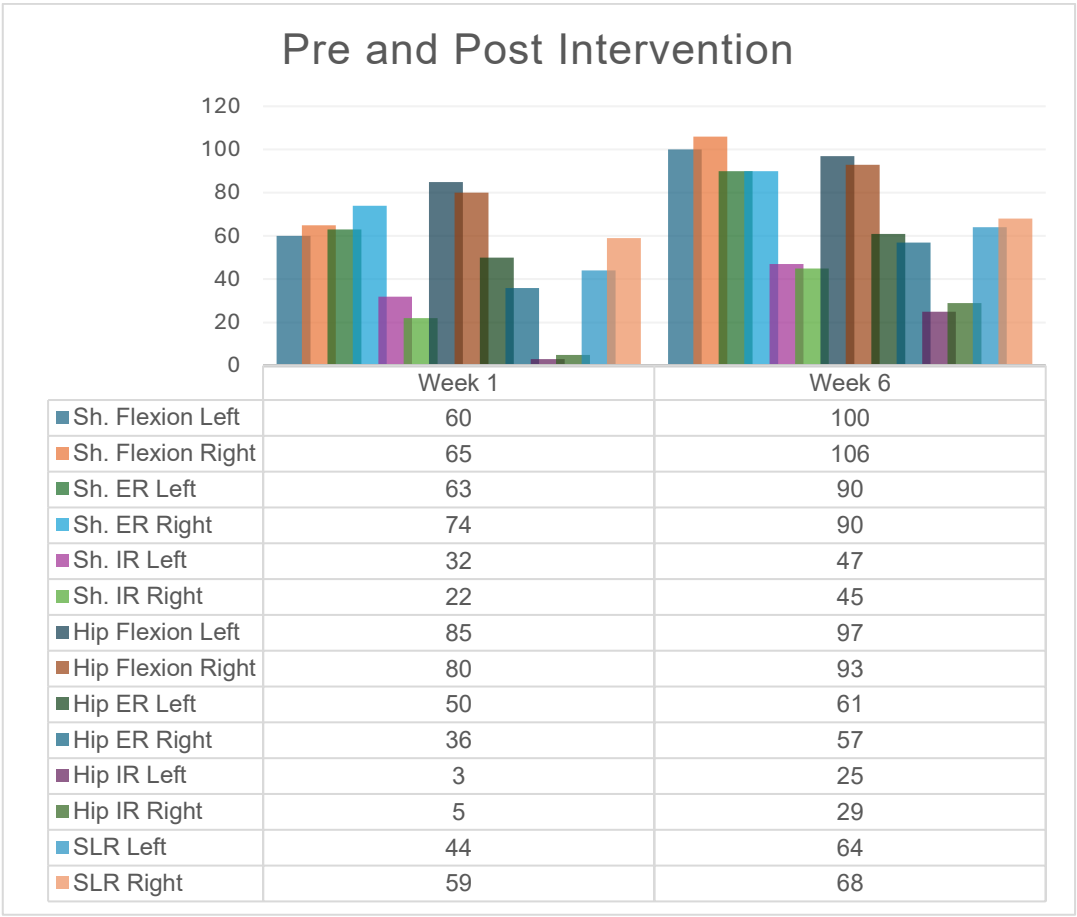
Table 39 - Case Study 1 Intervention with the prescribed sets, repetitions and rate of perceived exertion (RPE) of every exercise

	Exercises	Sets/Reps	RPE 0-10
Week 1	Hooklying Breathing Isometric Push with Low Reach	3 x10	3-4
	Side Lying 45/45 Rolls	2 x120" *	2-3
	Unilateral Seated Cable Leg Curl with tibial IR (Isoinertial)	4 x20	6
	90/90 Wall Calf Raises	3 x15	8
Week 2	60/60 Wall Sit	4x 40"	7
	Unilateral Leg Extension Iso Hold 15-30º	4 x30"	5-6
	Side Lying Elbow Plank with low hip flexion	3 x30"	5
Week 3	60/60 Weighted Wall Sit	3 x30"	7-8
	Foam Roller Bridge	3 x30"	7
	Unilateral Leg Extension Iso Hold 15-30º	4 x45"	7
	Side Lying Elbow Plank with low hip flexion	3 x30"	5-6
	Soleus Slouch	3 x8	8-9
Week 4	Unilateral foam roller bridge with 90º arm reach	2 x40"	8
	Heels Elevated Goblet Box Squat	3 x10	7
	Wall Supported Hinge Push	3 x12	5
	Flywheel Seated Leg Extension & Prone Leg Curl	4 x 8 each	7
Week 5	Unilateral Foam Roller Bridge with 90-degree arm reach	3 x 35"	8
	Soleus Slouch	1x5	5-6
	Wall Supported Hinge Push	1x10	4
	Soleus Hinge	3 x8 e/s	7
	Box Squat	3 x10	7
	Quadruped Breathing with left hand elevated	2 x8 + 1 x4	4-8
	Flywheel Leg Extension and Leg Curl	3 x8 each	7

Weekly progress based on the initial measures before the interventions:



Graph 7 - Case Study 1. Weekly progress



	Week 1	Week 6
Sh. Flexion Left	60	100
Sh. Flexion Right	65	106
Sh. ER Left	63	90
Sh. ER Right	74	90
Sh. IR Left	32	47
Sh. IR Right	22	45
Hip Flexion Left	85	97
Hip Flexion Right	80	93
Hip ER Left	50	61
Hip ER Right	36	57
Hip IR Left	3	25
Hip IR Right	5	29
SLR Left	44	64
SLR Right	59	68

Graph 8 – Case study 1. Comparison between the initial assessment before and after the intervention

Table 40 – Case Study 1. Pre and Post Intervention quantitative analysis

Test	Δ Absolute (degrees)	Δ Relative (%)
Sh. Flexion Left	+44	+73.3%
Sh. Flexion Right	+42	+64.6%
Sh. ER Left	+27	+42.9%
Sh. ER Right	+16	+21.6%
Sh. IR Left	+15	+46.9%
Sh. IR Right	+15	+17.4%
Hip Flexion Left	+19	+22.4%
Hip Flexion Right	+20	+25.0%
Hip ER Left	+11	+22.0%
Hip ER Right	+21	+58.3%
Hip IR Left	+33	+1100.0%
Hip IR Right	+30	+600.0%
SLR Left	+21	+47.7%
SLR Right	+9	+15.3%

A quantitative analysis of the joint range of motion over the six-week intervention period revealed substantial improvements across nearly all evaluated parameters. The progression of results from Week 1 to Week 6 demonstrates the effectiveness of the individualized intervention strategy. A calculated adapted Cohen's d of 0.87 reflects a large effect size, confirming the clinically meaningful impact of the applied therapeutic approach.

The most significant gains were noted in hip IR, with relative increases of approximately +1180% on the left side and +625% on the right, suggesting meaningful neuromuscular and articular adaptation. Similarly, marked improvements were observed in shoulder flexion (+73% on the left) and in SLR performance (+47% on the left), reflecting enhanced mobility, flexibility, and functional range, for example, left shoulder flexion increased from 60° to 100°, highlighting the significant impact of the intervention on this specific variable.

Visual analysis of the data further reinforces these outcomes, displaying a clear and sustained progression throughout the program without any regressions between sessions. The patient reported reduced pain, increased ease of movement, and improved functional capacity demonstrating clinical significance, despite not being able to reach the considered normative values of ROMs.

Throughout the intervention period, I observed how the patient responded positively to the selected exercises. Improvements in ROM were accompanied by enhanced movement quality, and feedback from the patient indicated that she felt more confident and less restricted in her daily activities. This reinforced the clinical value of tailoring exercise dosage and sequencing based on performance feedback, fatigue, and technique quality.

The findings strongly support the efficacy of the individualized intervention program in improving joint mobility and overall function, even in the presence of chronic limitations and arthritic conditions. These results validate the use of structured, adaptable, and patient-specific therapeutic strategies within clinical practice.

4.4.2. Case Study 2

A crossfit athlete with left shoulder pain when performing overhead movements, being more pronounced when loaded during movements.

Table 41 - Case Study 2. Initial assessment

TESTS	Left	Right	Goal
Sh. Flexion	0	0	150-180º
Sh. ER	82	85	90º
Sh. IR	90	86	70-90º
Hip Flexion	93	91	120º
Hip ER	61	43	40-60º
Hip IR	40	48	30-45º
SLR	62	64	70-90º

Additional tests were considered, particularly an active shoulder flexion test. It was observed that there was internal rotation of the humerus accompanied by forward head motion, primarily at the end range. Additionally, his active cervical rotation was notably more limited to the left.

Assessment interpretation

Based on these measures we can presume that since he can´t get his arm in the starting position of the shoulder flexion assessment, meaning in line with the sagittal plane, probably indicates upper dorsal compression, a limitation of the positioning of the scapula that doesn´t allow the positioning of the humerus into ER, so to get his arm overhead, he would have to move his arms more outward, into abduction to create space in the shoulder joint.

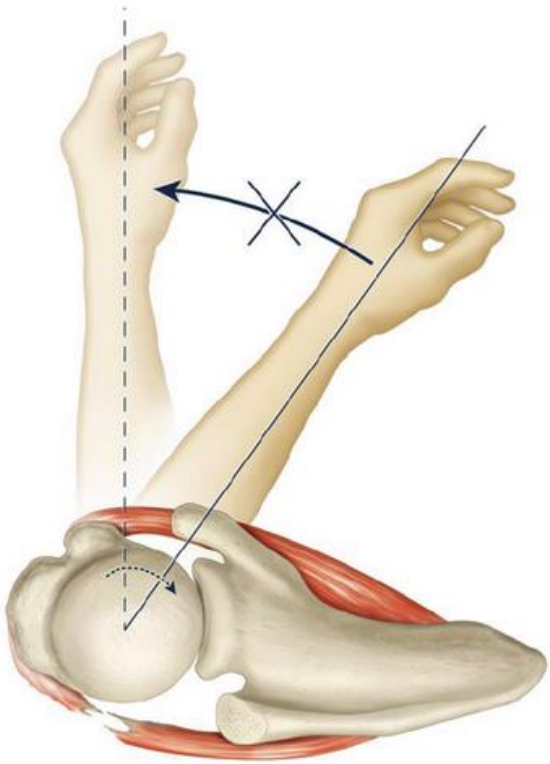


Figure 18 – Representation of a loss of external rotation at low shoulder flexion angle

It´s to note that the shoulder when going fully overhead creates a ipsilateral axial spine turn, and since his cervical rotation measures demonstrated a limitation to the left, combined with the patient blocking/pinching sensation when raising his arm and test results, it would make sense that he lacks the ability to create an effective turn to the left within the axial skeleton. Since the measures of the hip and shoulder present as opposite, meaning more ER on the hips and more IR on his shoulders, it would probably indicate a concentric orientation of rectus abdominis and matching with his swayback posture presentation. This increase in rectus activity creates a posterior pelvic tilt that opens space for more femoral ER to occur, but by depressing the sternum it orients the ribcage and the scapulothoracic in a position that limits ER but allows for more IR at the shoulder via orientation of the scapula, usually with more elevation, external rotation.

With this in mind, we would first try to minimize rectus abdominus concentric orientation, and then try to create posterior expansion, meaning a scapula that can IR while the humerus can ER.

1) Right Side lying Rolling w/120º reach lead

2 sets of 10 on each side at a RPE of 3.

The goal with this exercise was to utilize a sidelying exercise to decrease the rectus activity while trying to promote relative motion at the spine by creating a segmental rotation from the cervical to the lumbar spine guided by the arm. It was cued to make a long reach with the arm at about 120 degrees of abduction while rotating the body with the least amount of tension possible and to maintain the look at his hand. The turn would end when his body wanted to roll to a supine position, and it was cued to inhale at the return of the movement.

After this exercise we´ve managed to get his arms to a neutral position when assessing shoulder flexion, meaning, getting the arm in line with his body to match sagittal plane. However, it still didn´t present significant improvements since it shows resistance when starting to lift the arm from the table and immediately deviates from the sagittal plane.

Table 42 – Case Study 2. Assessment table of the before and after the first exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	0	0	0	0	150-180º
Sh. ER	82	90	85	88	90º
Sh. IR	90	90	86	85	70-90º
Hip Flexion	93	95	91	102	120º
Hip ER	61	60	43	58	40-60º
Hip IR	40	40	48	47	30-45º
SLR	62	72	64	75	70-90º

Cervical rotation still presented limited to the left.

2) Yoga Ball Elbow Plank with head turn (load the rectus in a eccentric orientation while working on cervical rotation)

3 sets of 30 seconds were done with cervical rotation to the left and 2 sets to the right, each with a RPE of 6.

With this exercise the goal would be to use a prone position so that the guts create a downward pressure to help the recuts abdominus to eccentrically orient, but to do this we must ensure that the lumbar spine doesn´t flex excessively and maintains a natural curve to it which requires the rectus abdominis to work in a more eccentrically oriented position while cueing full deep breaths to emphasize the obliques to help the bucket handle motion of the lower ribs but to also help the pump handle action of the upper ribcage during the inhales by keeping the obliques engaged to create more upward pressure at the ribcage. The arms were also cued to keep them above shoulder level, while the hips were at about 45-60 degrees of hip flexion, both with some abduction to work within the available space and to increase the lever arm and consequent difficulty while lowering the odds of concentrically orienting the rectus abdominus. It was also cued to look at his elbow to cue a slight cervical rotation during the inhales and to switch elbows during the exhales.

After this exercise we´ve improved his shoulder flexion on the right to 85º and 45º on the left. Most importantly the pinching/blocking sensation during active shoulder flexion improved although still present.

Table 43 - Case Study 2. Assessment table of the before and after the second exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	0	45	0	85	150-180º
Sh. ER	90	90	88	88	90º
Sh. IR	90	90	85	85	70-90º
Hip Flexion	95	95	102	105	120º
Hip ER	60	59	58	59	40-60º
Hip IR	40	44	47	49	30-45º
SLR	72	71	75	75	70-90º

3) Staggered Stance Bicep Curl with left axial rotation

Since the cervical left rotation was still more restricted, we did a bicep curl with a low angle reach and left axial turn to try to expand his space between the spine and the scapula in the working side, it was also cued to look at his elbow and inhaling during the concentric phase of the movement to promote more cervical rotation and expansion. The low reach angle combined with the turn would eccentrically orient muscles like the trapezius, and rhomboids allowing for expansion on those areas to occur.

After 2 sets of 12 repetitions at a RPE of 6, the left shoulder flexion improved to 92 degrees while the right got to 111, cervical rotation was almost symmetrical, and the pinching was almost gone being only reported a small discomfort.

Table 44 - Case Study 2. Assessment table of the before and after the third exercise

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	45	92	85	111	150-180º
Sh. ER	90	90	88	90	90º
Sh. IR	90	90	85	87	70-90º
Hip Flexion	95	97	105	108	120º
Hip ER	59	60	59	59	40-60º
Hip IR	44	43	49	49	30-45º
SLR	71	71	75	74	70-90º

4) Manual Therapy

We’ve decided that after this intervention some manual therapy would be best to try to improve his cervical rotation. This consisted of lower cervical, upper thoracic rotation and scapula mobilizations.

Some improvements were made, mainly in cervical rotation and shoulder flexion on the left. Now shoulder flexion on the left presented as 100 degrees.

After this intervention the pinching sensation was gone and opted to utilize a more loaded exercise, a landmine press, to reinforce the positions and range of motions gained.

Table 45 – Case Study 2. Assessment table of the before and after the manual therapy

TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	92	100	111	112	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	90	90	87	88	70-90º
Hip Flexion	97	102	108	109	120º
Hip ER	60	58	59	58	40-60º
Hip IR	43	44	49	50	30-45º
SLR	71	72	74	74	70-90º

5) Wall Supported Landmine Press

We´ve selected this exercise to use a vertical press where we kept his shoulder level at around chin level while trying to create an axial turn to the left. The hips and upper back were supported against a wall, maintaining the PSIS contact against the wall to ensure a stacked position, while reaching the right arm forward to create the turn to the left, thus allowing the left posterior expansion. The left arm was the pressing arm, and the bar was allocated in a distance that at the end of the press, the shoulder flexion angle would be around 100-120 degrees. It was also cued to lead the pressing motion with the elbow to ensure good scapular mechanics, therefore preventing a scapular retraction movement which would concentrically orient the muscles between the scapula and spine like the rhomboids and trapezius.2 sets of 15 reps with a RPE of 6 were made.

Table 46 - Case Study 2. Assessment table of the before and after the fifth exercise

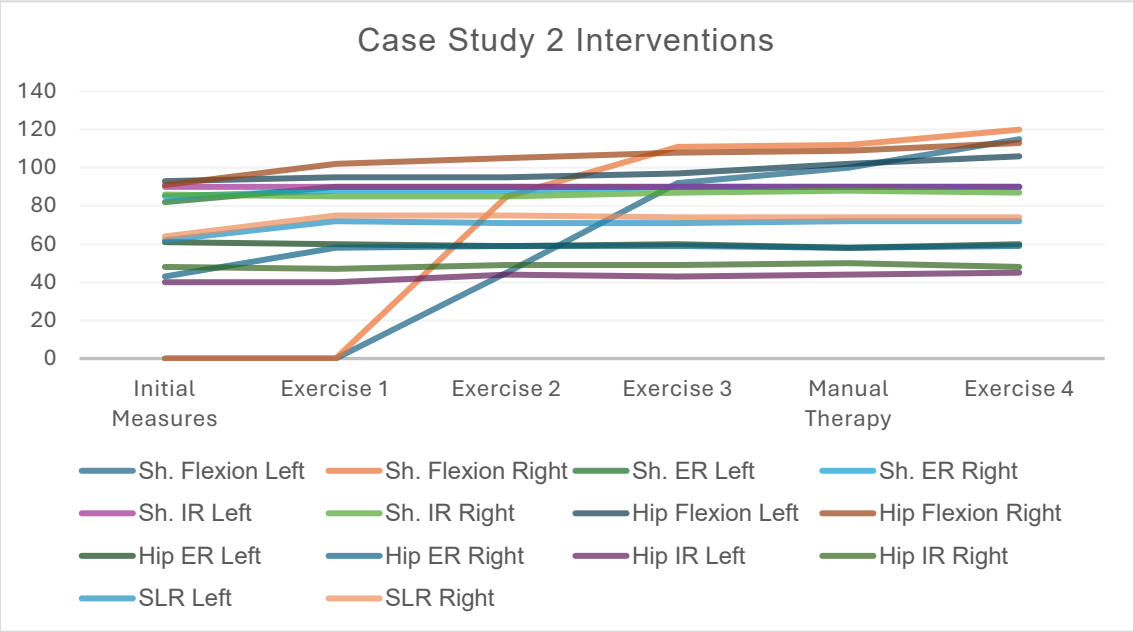
TESTS	Left	Left (After)	Right	Right (After)	Goal
Sh. Flexion	100	115	112	120	150-180º
Sh. ER	90	90	90	90	90º
Sh. IR	90	90	88	87	70-90º
Hip Flexion	102	106	109	113	120º
Hip ER	58	60	58	59	40-60º
Hip IR	44	45	50	48	30-45º
SLR	72	72	74	74	70-90º

After the intervention the patient reported an absence of pinching sensation in the shoulder. He was instructed to continue performing the exercises from the session as a warmup and cooldown in his training routine for a period of 2 weeks. He was also advised to notify the clinical team if any doubts arise or if there is a change in symptoms. To avoid causing interference, the patient was advised to suspend vertical bilateral pressing for the time being.

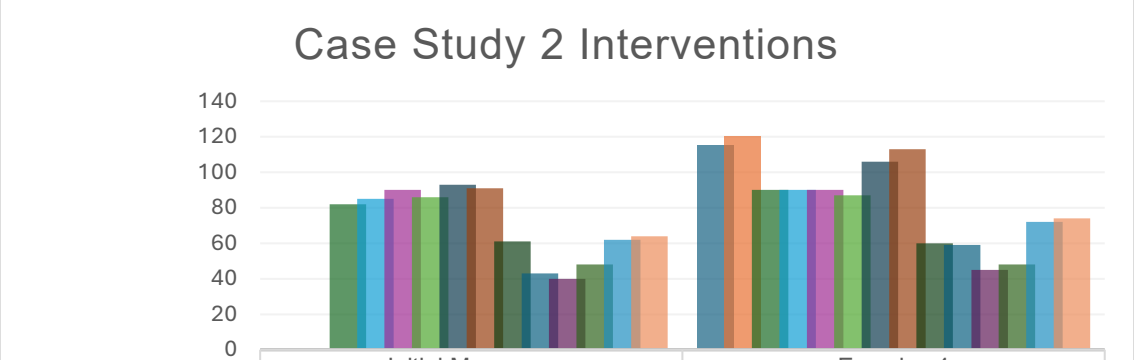
Rehabilitation needs can vary significantly between individuals. While some patients may require closer supervision and more frequent follow-ups—particularly those with lower levels of body awareness, neuromuscular control, or confidence in movement—others, like this patient, may demonstrate a higher degree of autonomy and body perception, enabling them to manage their rehabilitation more independently. These individual characteristics should be considered when designing and adjusting rehab protocols to ensure both safety and adherence.

Following the two-week interval, the patient reported continued improvement in his condition and was able to resume his normal training routine, now incorporating the prescribed exercises to reinforce shoulder stability and prevent recurrence.

In Session progress:



Graph 9 - Case Study 2 Intervention progress



	Initial Measures	Exercise 4
Sh. Flexion Left	0	115
Sh. Flexion Right	0	120
Sh. ER Left	82	90
Sh. ER Right	85	90
Sh. IR Left	90	90
Sh. IR Right	86	87
Hip Flexion Left	93	106
Hip Flexion Right	91	113
Hip ER Left	61	60
Hip ER Right	43	59
Hip IR Left	40	45
Hip IR Right	48	48
SLR Left	62	72
SLR Right	64	74

Graph 10 - Case Study 2. Comparison between the initial assessment before and after the intervention

Table 47 - Case Study 2. Prescribed exercises during the intervention with sets, reps and rate of perceived exertion

	Exercise	Sets/Reps	RPE
Intervention	Right Side lying Rolling w/120º reach lead	2 x10	3
	Yoga Ball Elbow Plank with head turn	3 x30"	6
	Staggered Stance Bicep Curl with left axial rotation	2 x12	6
	Manual Therapy		
	Wall Supported Landmine Press	2 x15	6

Table 48 - Case Study 2. Pre and Post Intervention quantitative analysis

Test	Δ Absolute (degrees)	Δ Relative (%)
Sh. Flexion Left	+115	– (initial value = 0)
Sh. Flexion Right	+120	– (initial value = 0)
Sh. ER Left	+8	+9.8%
Sh. ER Right	+5	+5.9%
Sh. IR Left	0	0.0%
Sh. IR Right	+1	+1.2%
Hip Flexion Left	+13	+14.0%
Hip Flexion Right	+22	+24.2%
Hip ER Left	–1	–1.6%
Hip ER Right	+16	+37.2%
Hip IR Left	+5	+12.5%
Hip IR Right	0	0.0%
SLR Left	+10	+16.1%
SLR Right	+10	+15.6%

A quantitative analysis of joint ROM across the intervention period demonstrated clinically relevant improvements in multiple parameters. The progression of results from the initial assessment to the fourth exercise reflects the positive impact of the individualized and progressive intervention strategy. The overall trend shows meaningful functional improvements. The calculated adapted Cohen's d of 0.38 indicates a small to moderate effect size, suggesting a measurable and positive therapeutic effect.

Among the most prominent improvements were shoulder flexion, which progressed from 0° to 115° (left) and 0° to 120° (right) represent significant functional gains from a clinical perspective. In the lower limb, improvements in hip flexion (+14.0% on the left; +24.2% on the right), hip external rotation (+37.2% on the right), and straight leg raise (SLR) (+16.1% on the left; +15.6% on the

right) contributed to increased movement capacity and efficiency in everyday activities. For example, right hip external rotation improved from 43° to 59°, representing a relative increase of +37.2%, which can meaningfully affect gait, transitional movements, and tasks such as crossing the legs or pivoting.

Although some measures—such as hip internal rotation right (0% change) and hip ER left (-1.6%) no regressions were observed that would indicate a decline in function.

The patient subjectively reported reduced stiffness, improved movement fluidity, and enhanced ability to perform tasks, aligning with the objective measures collected. These findings confirm that patient-specific rehabilitation approaches can result in measurable functional outcomes over a relatively short period.

This case study also shows that manual therapy can enhance and complement the exercise-based interventions, thus potentially enhancing the effects of the intended exercises and demonstrating its importance of a collaboration between therapists/clinicians and exercise professionals.

In conclusion, the data from this case study underscores the value of a personalized rehabilitation model, especially when it incorporates regular reassessment and progressive adaptation.

4.5. Limitations

Sample Size: Given the single-case design, the findings cannot be generalized to a broader population. The outcomes reflect the specific characteristics of the individual involved.

Adherence to the Exercise Program: The success of the intervention was dependent on the patient’s adherence to the prescribed exercises, which may vary.

Measurement variability: Differences in measurements might have occurred due to variability between the positioning of the patient at the table and the exact placement of the goniometer due to human error while performing the tests by the examiner.

External factors: It is unknown if and how much the external factors outside the intervention context might have influenced the outcomes.

Assessment scope: While the assessment protocol provided relevant information regarding the participants' movement capabilities, did not encompass all dimensions of functional performance. Additional tests were performed at the initial assessment (e.g., cervical rotation, standing toe touch and squat) but not tracked longitudinally. As a result, some KPIs could have been more relevant, and future research should consider integrating a wider range of assessment tests to provide a more complete picture of the subject.

Exercise efficacy: While the selected exercises were based on clinical reasoning, their relative efficacy remains uncertain. It is unknown whether alternative could have produced superior or inferior results.

Structural bias: While the assessment aimed to restore relative motion using normative ROM values, it is essential to recognize that individual anatomical differences influence these ROM measurements. Consequently, achieving a specific target, such as 90 degrees of shoulder external rotation, should be evaluated within the context of each patient's unique structural considerations.

Intervention period: The six-week intervention period is insufficient to evaluate the sustainability of the improvements. Long-term effects remain unknown.

<u>Recommendations for future research:</u>

- To implement more KPIs like shoulder and hip extension and abduction, knee flexion and extension, spine flexion, extension, rotation and side bend, and potentially some active tests like the toe touch and squat.
- To investigate if more isolated interventions could have distal effects.
- To compare the effects of high-tension versus low-tension strategies for promoting relative motion.

- To investigate how incorrect execution may alter The effects on exercises performed incorrectly, by an execution standard, on relative motions.
- To examine how individual structure may influence movement limitations.
- Adopt a more holistic lenses on movement capacity to refine assessment and intervention precision.

5. Discussion/ Reflection

One of the most important takeaways from this study is the reaffirmation of the principle that the body operates as an integrated system. Far too often in clinical and training environments, mechanical dysfunctions are approached in isolation, hip pain is treated as a hip problem, shoulder impingement is addressed solely through local mobilizations, and low back pain is tackled with core strengthening alone. While such approaches may provide temporary relief, they frequently overlook the underlying contributors that exist beyond the site of pain or restriction (Sahrmann et al., 2017; Wainner et al., 2007).

The human body is a kinetic chain, a system of interdependent segments where movement or dysfunction in one area may affect the whole movement system (Comerford & Mottram, 2019; Sahrmann et al., 2017; Wainner et al., 2007). For instance, a restriction in ankle dorsiflexion may alter gait mechanics and load distribution, leading to potential compensatory strategies at the knee, hip, or lumbar spine. Similarly, limitations in thoracic rotation may impair scapulothoracic rhythm, leading to shoulder impingement syndromes. Understanding this interdependence is not only foundational to biomechanics but is vital in designing effective and sustainable interventions, as it was shown that during the case studies that lower limb focused exercises can affect the upper limb ROM.

The PROM assessment protocol employed in this research proved to be effective in identifying restrictions and, more importantly, in interpreting patterns of dysfunction that extend beyond localized regions. For example, in analyzing case study 1 limited depth in squatting, PROM tests revealed overall restrictions at the shoulders and hips, mainly IR which may be correlated with the person's squat technique findings, the caving in of the knees, the feet dumping in and the back arching to compensate for the lack of IR. The assessment clarifies the individual's current capabilities and provides clues of how movement is achieved to accomplish specific tasks.

This approach required frequent reassessment throughout the intervention, which was valuable in determining when to adjust variables such as

progressions, loads, ROMs and complexity. Monitoring signs like technique breakdown or increased effort was key in regulating fatigue and ensuring movement quality, reinforcing the role of dynamic decision-making in clinical care.

Limitations, for example in hip internal rotation, asymmetries in shoulder motion, or thoracic compensation patterns help inform the choice and sequence of exercises, ensuring safety and progression. As a result, adaptations were not only biomechanical but also neuromuscular, aligning with each patient's evolving capacity.

Engaging in controlled breathing exercises often enhances parasympathetic activation, resulting in what is termed 'rest and digest' responses. Ertürk and Özden (2025), demonstrated that interventions such as auricular vagus nerve stimulation and deep breathing exercises increase parasympathetic activity, correlating with a reduction in muscle tension in healthy individuals. Additionally, Bazzichi et al., (2010) reported that treatments involving massage and stretching enhance parasympathetic activity and subsequently improve joint mobility, potentially reducing muscle tension. While the parasympathetic system does not directly innervate skeletal muscles, it can play a significant role in regulating muscle tension by influencing the overall autonomic balance and potentially explaining some of the changes observed during the interventions.

Whether the work environment supports the use of table tests or not, understanding how relative movement is produced or limited by position and muscular activity allows constructing a representation of the individual's current strategy. Recognition of this strategy eventually leads to greater predictability in observation of complex movements.

PROM assessments are a unique diagnostic tool in that they provide insight into a joint's available motion without the influence of neuromuscular control, compensation patterns when considered, or pain-related guarding. This makes them highly effective for establishing baseline joint capabilities and anatomical capacity, which can then be compared with active movement to detect discrepancies (Norkin & D Joyce White, 2016). However, it's important to

recognize that the shape, especially body archetype, orientation of the axial skeleton, and other structural differences like longer femurs, pelvic width, femoral neck angle, and acetabular orientation all affect hip range of motion and should be considered when evaluating movement limitations and in determining the available ROM in peripheral joints, thus considering that the normative ROM values might not be an achievable representation for everyone (Neumann, (2017) and Kapandji et al. (2018). However, someone's restrictions and movement improvement capabilities are unknown if there's never an attempt to make a change.

PROM assessments, when conducted systemically, may also help detect rotational asymmetries in the axial skeleton. For example, consider a subject who demonstrates greater ER in the right shoulder and greater IR in the left. Such a pattern may suggest that the subject is more proficient in rotating to the right at the axial level—an observation that can have implications, especially in sports performance, injury prevention, and rehabilitation. Similarly, an anterior pelvic tilt often correlates with enhanced hip internal rotation and reduced external rotation due to the femur's orientation relative to the acetabulum, while a posterior tilt may create the opposite scenario. These relationships reflect the body's functional adaptation to structural alignment and habitual movement tendencies.

The structure and function of the spine and ribcage play fundamental roles in determining movement potential in the shoulder girdle. The ribcage, as the attachment site of the scapula and intercostal musculature, also influences breathing mechanics and the pelvic floor muscles, another often overlooked yet impactful factor in movement assessments. Impaired diaphragmatic function and altered breathing patterns can be related to altered spine curvatures due to changes in muscle behaviors, which can potentially be associated with a center of mass adaptation.

Likewise, the scapula's position also plays a pivotal role in influencing shoulder range of motion. Due to the congruency of scapula at the ribcage, if altered it can limit scapula position and shoulder movement by mechanically altering the length-tension relationships of the musculature. In both case studies,

addressing scapular mechanics was integral to improving overhead motion and resolving discomfort and can be incorporated during lower limb training.

For example, a "winging scapula" is often misinterpreted as a scapular problem (the name misleads perspective) rather than looking at the thorax's role in scapular movement. The scapula's position is influenced by the rib cage's shape and orientation, particularly in tasks like heavy lifting or overhead movements. Solely targeting serratus anterior “strength” deemphasizes the need to create expansion in specific areas of the rib cage to provide a stable platform for the scapula to move against, enabling effective movement. Exercises like backward crawling or bear crawls that promote thorax expansion rather than merely isolated muscle activity can be more effective and tailored to individual needs. Conversely, an increase in anterior compression or a down pump handle which can concentrically orient the pec major, might lead to expansion or eccentric orientation on the posterior thorax musculature, altering the scapular angle and limiting internal rotation. Conversely, reversing this process by focusing on activities that promote concentric orientation of muscles between the scapula can drive expansion forward, allowing for increased internal rotation. Reaching activities often create upper dorsal compression, leading to anterior thoracic expansion and improved pump handle mechanics, ultimately facilitating greater shoulder internal rotation.

Intramuscular pressure gradients within muscles like the pec major during dynamic movements such as baseball pitching play a significant role. As a baseball pitcher internally rotates their shoulder, the pec major's attachment at the shoulder experiences varying degrees of concentric orientation from distal to proximal. This gradient effect may help maintain the pump handle mechanics necessary for optimal shoulder rotation.

Yet, despite the importance of understanding functional interdependencies, it is equally critical to recognize the activity/training and injury history.

Understanding these interactions allows practitioners to approach movement limitations not as isolated problems, but as manifestations of global

system imbalances. The PROM assessment, when interpreted through this system-based lens, becomes a gateway to understanding the body's capacity, preferences, and constraints. It moves the practitioner away from symptom-chasing and toward functional root-cause identification.

Moreover, integrating PROM testing into initial evaluations helps guide smarter exercise selection. By utilizing the test-retest methodology it can provide valuable insight into the effectiveness of the selected intervention. Instead of prescribing generic mobility drills, practitioners can target specific limitations knowing its efficacy. For example, if hip IR or ER is limited, interventions may include selecting constraints or exercises that work in more IR or ER biased ranges and comparing the results before and after, while also potentially adapting the exercise based on someone's restrictions, this might be using a wider stance in squat for someone that has limited IR. The more accurate the testing, the more effective the prescription.

By emphasizing individualized assessments, exercise interventions can address specific movement limitations and compensatory strategies. This approach involves understanding how exercises influence an individual's ability to expand and compress certain areas of the body, particularly focusing on restoring optimal movement.

Thinking beyond exercise prescriptions that emphasize "muscle strengthening" and instead focus on recapturing muscle orientation, enhancing thoracic shape change, and addressing compensatory movements. This allows us to deliver more effective and sustainable approaches to movement, rehab, and performance enhancement tailored to the specific needs and capabilities of each individual.

In sum, the research conducted throughout this internship underscores the critical importance of contextual, individualized assessments. The body must be viewed not as parts, but as a coordinated network of systems, musculoskeletal, neural, and structural, that interact to produce efficient and functional movement. PROM testing, when properly integrated into this systemic view, provides essential information about passive capacity, asymmetry, joint interplay, and

potential compensations. Other testing methods may also be able to represent these findings, but it may be harder to control KPI's.

The protocol developed during this internship was ambitious in its aim to integrate physiotherapy, osteopathy, and exercise rehabilitation through a shared assessment model centered on PROM. One of its key strengths was its structured yet adaptable format, which made it practical to apply in real clinical conditions while retaining enough flexibility to accommodate individual differences. By focusing on PROM as the core metric, the protocol enables practitioners to isolate joint-specific restrictions and establish clear, reproducible baseline measures. This allowed for an objective foundation when correlating changes in ROM with exercise interventions.

A particularly strong aspect was the inclusion of pre- and post-session re-assessments, which provided a continuous feedback loop to inform decision-making and adjust exercises in real time. This systematic approach contributed to more informed selection of therapeutic exercises, ensuring that progress was not merely assumed but demonstrated through measurable improvements.

However, while the protocol successfully provided a framework to unify professionals around common measures, some challenges emerged. Relying heavily on PROM data alone risks overlooking neuromuscular control and motor learning aspects that are often equally relevant to functional improvement. For example, a patient's active control of a movement may remain compromised even after passive motion improves. In this sense, integrating additional functional assessments (e.g., movement screening or load-bearing mobility tests) could have provided a richer understanding of each patient's capacity and limitations. In case study 1, the patient present compensatory strategies during the squat, like the knee valgus, likely due to the lack of hip IR, however the lack of force production capabilities might also be a reason for the same compensatory strategies as it is suggested by Cheatham et al., (2018).

The emphasis on detailed quantitative tracking in each session was also both a strength and a limitation. On the one hand, it contributed to precise monitoring of progress. On the other, it introduced a level of complexity that

sometimes, risked overwhelming patients or constraining time available for treatment. Balancing thorough measurement with pragmatic time management remains a challenge for implementing the protocol in busy multidisciplinary clinics. Although this limitation exists, increased familiarity with the protocol may reduce the time required for its application and potentially eliminating the need for a goniometer in standard settings.

Practical implications for multidisciplinary practice:

- Establishing a Common Assessment Language

Using a structured protocol centered on PROM helps create shared reference points across disciplines.

PROM data can be easily communicated between professionals (e.g., physiotherapists and exercise professionals).

- Improving Continuity of Care

Standardized PROM measures before and after sessions make it easier to track progress objectively.

This facilitates more consistent plans, as each practitioner has access to comparable metrics to inform their decisions.

- Supporting Personalized Exercise Prescription

By identifying joint-specific restrictions, professionals can better individualize exercise progressions (e.g., adapting squat depth, modifying overhead positions) rather than applying generic templates. This is especially important when clients transition between rehabilitation and strength & conditioning environments.

- Enhancing Patient Education and Engagement

PROM measures can be visually demonstrated to patients, improving their understanding of why certain exercises or manual techniques are recommended. This increases buy-in and adherence, as clients can see objective changes over time.

- Facilitating Case Discussions and Referrals

When PROM results are tracked consistently, it becomes easier to discuss cases in multidisciplinary meetings and identify when referral to another professional (e.g., osteopathy for joint mobilization, physio for pain management) is indicated, as well as, reduce duplicated assessments, saving time and improving patient experience.

- Reinforcing Professional Development

Implementing this protocol requires all team members to build skill in standardized measurement and interpretation of ROM. It fosters a culture of ongoing learning and reflective practice, as staff discuss trends, patterns, and best approaches.

Finally, the study design reinforced the necessity of holistic analysis rather than isolated symptom treatment. By linking PROM assessments to broader kinetic chain considerations—such as pelvic alignment, scapulothoracic motion, and breathing patterns, the protocol encourages to think beyond local dysfunction. This perspective was especially valuable in chronic presentations, where compensatory strategies across the body might contribute to the presented symptoms.

One objective of this internship was to investigate methods for leveraging the assessment protocol to enhance the exchange of information among various disciplines, including physical therapists, osteopaths, and exercise professionals. Given that many exercise professionals do not employ PROM assessments, this tool could serve as a valuable resource for gaining deeper insights into patient and client limitations. Conversely, physical therapists and osteopaths might utilize these assessments to inform referrals to exercise professionals such as personal trainers and coaches.

The two case studies not only push critical thinking of the use of the utilized protocol but also served as a microcosm of this broader, integrated philosophy. In each scenario, a PROM assessment facilitated a more precise understanding of the movement ecosystem and allowed for the construction of better intervention strategies. The improvements noted over the course of the respective interventions highlight the potential for this approach to be scaled and

applied across various populations, from athletes to sedentary individuals. However, this is still an area that needs further investigation and understanding.

Although the clinic professionals were used to assessing ROM, what stood out to the clinical team was the protocol's capacity to go beyond symptom-based analysis and instead focus on the functional interplay between different body regions, allowing for a more comprehensive understanding of each individual's movement strategy. By helping to pinpoint which joint segments were contributing to compensatory patterns or performance limitations, the protocol provided more ideas to guide exercise selection and progression. Given its relevance to both injury prevention and rehabilitation, as well as its potential to enhance communication among practitioners by standardizing observation and interpretation, the clinic decided to begin experimenting with the protocol in a broader range of cases. Early conversations suggested that it not only improved diagnostic clarity but also strengthened patient engagement, as the rationale behind each intervention became more transparent and tailored although more work and study is needed to improve the PROM protocol.

As this work concludes, it is clear that movement quality is not the product of isolated parts, but of integrated systems functioning in harmony. Any intervention that ignores this interconnectivity risks overlooking the true sources of dysfunction. Conversely, an approach grounded in systemic understanding, informed by precise assessments, offers a pathway to not only address pain but optimize performance, prevent injury, and enhance quality of life.

6. Conclusion

This internship report explored the intricacies of human movement through the lens of biomechanical analysis, with a focus on ROM assessments, mainly PROM, and their role in uncovering movement limitations. Central to the work was the implementation of a practical assessment and intervention protocol, applied in two case studies, which aimed to identify mobility restrictions and inform personalized intervention strategies. As this work concludes, it is essential to reflect not only on the findings, but also on the broader implications for how we understand and approach the human body in movement assessment and rehabilitation contexts.

Key findings from both case studies showed that individualized PROM-based programming improved joint mobility, reduced pain, and enhanced function. Improvements in hip internal rotation, shoulder flexion, and SLR, but also the patient enhanced movement quality, and feedback confirmed the intervention's effectiveness. These results underline the importance of personalized and progressive interventions.

This work supports the necessity of a holistic, system-wide perspective when assessing and treating movement impairments. Isolated dysfunctions often reflect broader patterns involving compensations, anatomical variability, or segmental restrictions. This highlights the value of global analysis for clinical reasoning and intervention planning.

The implications extend beyond clinical rehabilitation, offering valuable tools for professionals in sports performance, fitness coaching, and injury prevention. PROM assessment protocols help practitioners identify subtle limitations, prioritize exercise choices, and adjust progression based on actual capacity, fostering safer and more effective programming.

With this conclusion, the work laid out here aims to contribute to a shift in mindset, away from reductionist models of micro diagnosis and toward a more complete, dynamic, and macro interconnected view of the body. In doing so, we not only improve our outcomes as healthcare providers but also honor the remarkable complexity and adaptability of the human system.

Ultimately, the internship has been a deeply enriching experience, not only for the clinical knowledge acquired but also for the soft skills gained—particularly in communication, critical thinking, and professional adaptability. It has fostered a mindset of curiosity, humility, and continuous learning that will guide my future.

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Attachements

Table 49 - Internship Scheduling

PHASES / Schedule	01/10/2024 - 13/10/2024	14/10/2024 - 27/10/2024	28/10/2024 - 08/12/2024	9/12/2024 - 5/01/2025	6/01/2025 - 2/02/2025	3/02/2025 - 31/05/2025
Understand the operation and working method						
Intervene and help in the rehabilitation component through physical exercise						
Develop a process for assessing movement competencies						
Application and analysis of the procedure						
Analysis of flaws, limitations and areas for improvement						
Preparation and Completion of the Internship Report						

CONSENTIMENTO INFORMADO, ESCLARECIDO E LIVRE PARA PARTICIPAÇÃO EM ESTUDOS DE INVESTIGAÇÃO (de acordo com a Declaração de Helsínquia e a Convenção de Oviedo)

An_internship_report:

Bridging the gap between physiotherapy osteopathy and exercise rehabilitation

Enquadramento:

No âmbito do 2º ano de Mestrado em Atividade Física, Exercício e Saúde, na Faculdade de Desporto da Universidade do Porto, iremos realizar um estudo cujo objetivo principal é implementar um protocolo de avaliação das amplitudes articulares de forma passiva, de forma a melhor orientar a intervenção e a seleção de procedimentos e exercícios mais especifica e adequada consoante os dados da avaliação.

Explicação do estudo:

O instrumento para recolha de dados será a utilização de um goniómetro manual e um goniómetro digital via aplicação smartphone denominada Angle Meter para medição das amplitudes articulares do ombro e da anca, nomeadamente os movimentos de flexão, rotação interna e externa e o straight leg raise. A execução dos testes será explicada antes da aplicação dos mesmos.

Será mantido o anonimato, bem como a confidencialidade dos dados, e os mesmos serão usados apenas pela equipa responsável pela investigação. Os mesmos serão eliminados no final do trabalho.

A permissão para a realização dos procedimentos de avaliação é voluntária e o participante tem a liberdade de terminar a qualquer momento caso assim o deseje.

Condições e financiamento:

A participação no estudo é totalmente voluntária. Se decidir participar ser-lhe-á pedido que assine este formulário de consentimento informado (a consentir que recebeu informação sobre o estudo, clarificou as suas dúvidas e aceita participar voluntariamente) mas, é totalmente livre de desistir a qualquer momento, sem que para tal tenha de dar qualquer justificação. A decisão de desistir ou de não participar, não afetará a qualidade dos serviços de saúde ou qualquer outro, que lhe são prestados agora ou no futuro, não o prejudicando de qualquer forma. Não se antecipam inconvenientes da participação no estudo.

As recolhas de dados serão realizadas na clínica FOR+. Não estão contempladas quaisquer compensações monetárias pela participação no estudo.

Confidencialidade e anonimato:

Todos os dados no projeto serão recolhidos ao abrigo do Regulamento Geral de Proteção de Dados (RGPD), em vigor desde 25 de maio de 2018.

Os dados recolhidos serão analisados exclusivamente ao abrigo deste estudo, podendo os seus resultados serem utilizados em publicações ou em trabalhos académicos.

Em nenhum caso, será tornada pública qualquer informação de identificação dos participantes.

Agradecemos a sua colaboração

Estamos ao dispor para qualquer esclarecimento. Através do email:

diogo.neves1403@gmail.com

Por favor, leia com atenção a seguinte informação. Se achar que algo está incorreto ou que não está claro, não hesite em solicitar mais informações. Se concorda com a proposta que lhe foi feita, queira assinar este documento.

Declaro ter lido e compreendido este documento, bem como as informações verbais que me foram fornecidas pela pessoa que acima assina. Foi-me garantida a possibilidade de, em qualquer altura, recusar participar neste estudo sem qualquer tipo de consequências. Desta forma, aceito participar neste estudo e permito a utilização dos dados que de forma voluntária forneço, confiando em que apenas serão utilizados para esta investigação e nas garantias de confidencialidade e anonimato que me são dadas pelo/a investigador/a.

Nome: … … … … … … … …... … … … …... … … … … … … … … … … … …

Assinatura:… … … … … … … …... … … … … ... … … … … … … … …
Data: …… /…… /……..

SE NÃO FOR O PRÓPRIO A ASSINAR POR IDADE OU INCAPACIDADE

NOME: …

BI/CC N.º: ..... DATA OU VALIDADE ….. /..… /……..

GRAU DE PARENTESCO OU TIPO DE REPRESENTAÇÃO: .....

ASSINATURA … … … … … … … … … … … … … … … … … … …