”ALEXANDRU IOAN CUZA” UNIVERSITY OF IAŞI
FACULTY OF PHYSICAL EDUCATION AND SPORTS
DOCTORAL SCHOOL IN SCIENCE OF SPORT AND PHYSICAL EDUCATION
AREA OF STUDY: SCIENCE OF SPORT AND PHYSICAL EDUCATION

OPTIMIZATION OF THE PHYSICAL THERAPY REHABILITATION PROCESS IN PATELLOFEMORAL PAIN SYNDROME

Ph.D. THESIS SUMMARY

Scientific adviser:
Prof. Ph.D. Adrian COJOCARIU

Ph.D. Student:
Ioana-Bianca DOBREANU (MD. IOJA)

2023

TABLE OF CONTENTS

Keywords: patellofemoral syndrome, knee, tendinopathy, glide, functional rehabilitation, optimization.

INTRODUCTION

The sources in the specialized literature that follow the ways of approaching the functional rehabilitation program in the case of patients diagnosed with patellofemoral syndrome are limited. Numerous research is carried out regarding symptomatology and the methods of producing or analyzing this syndrome type. Still, the means of treatment and functional rehabilitation programs used today can be exponentially improved by using the modern techniques that we have at our disposal and that evolve from year to year.

The doctoral thesis entitled *Optimization of the physical therapy rehabilitation process in patellofemoral pain syndrome* includes two approaches to the proposed topic. In the first part of the doctoral thesis, entitled *CURRENT ASPECTS IN THE FUNCTIONAL RECOVERY OF PATIENTS WITH PATELLOFEMORAL PAIN SYNDROME*, the data found in the specialized literature, represented by the scientific research of specialists in the field of medical recovery and functional rehabilitation, were analyzed. With the help of the data presented in the specialized international literature, we noted that although it is widespread, the therapeutic approach to femoral-patellar syndrome has remained relatively the same in recent years.

In the application part, in the third chapter, entitled Preliminary study on the efficiency study on the efficiency of some *physiotherapeutic methods involved in the physiotherapeutic recovery of the functional deficit at the knee level with patellofemoral pain syndrome*, the results of the application of four different protocols were followed. The protocols applied in the preliminary study were represented by the classic rehabilitation approach in the case of this diagnosis and also by the implementation of modern equipment. Using the four different functional rehabilitation protocols, we aimed to improve the classic protocols and achieve the objectives proposed within the practical rehabilitation programs in a shorter time.

In the fourth chapter, entitled *The contribution of high-intensity magnetic field and shockwave therapy in the process of kinetotherapeutic recovery in patients with patellofemoral pain syndrome*, the second research direction proposed in the doctoral thesis was outlined, which focused on the introduction of state-of-the-art electrotherapy in the functional rehabilitation program, using physiotherapy devices based on Shockwave therapy and high-intensity electromagnetic field therapy. If in the first part of the research, we considered testing four different types of functional rehabilitation programs to outline the evolution of the subjects participating in the study and establish their influence, in the second part, we focused our attention on the impact that it has the latest generation electrotherapy equipment within the kinetotherapeutic program.

PART I – THEORETICAL FOUNDATION OF THE RESEARCH THEME

CHAPTER 1 – CURRENT ASPECTS IN THE FUNCTIONAL RECOVERY OF PATIENTS WITH PATELLOFEMORAL PAIN SYNDROME

Running is a widely used form of physical education and sport and is associated with many injuries, particularly in the lower extremities, including patellar pain, muscle cramps, especially in the hamstrings, ankle sprains, iliotibial band syndrome, plantar fasciitis, Achilles tendinitis, and stress fractures.

Lopes et al. (2011) stated that the knee is the joint most frequently cited for musculoskeletal pain in running. Pain in this area often reflects overuse injuries such as patellofemoral syndrome. This condition is usually caused by repetitive stress on the same tissue, lack of proper recovery, or inadequate physical condition. The runner's knee is the most common cause of localized knee pain, medically known as patellofemoral pain syndrome (Bebeley et al., 2016).

Some specialized studies support that extrinsic risk factors include training errors and changes in activity frequency and intensity, and intrinsic factors include joint malalignments and muscle and soft tissue imbalances (Hryvniak et al., 2014).

Patellofemoral syndrome is an overuse condition that leads to increased pain and pressure on the patellofemoral joint and is generally unrelated to trauma or intra-articular damage to the knee.

This syndrome is characterized by pain in the anterior region of the knee joint or at the retro-patellar level, which worsens during activities that overload the patellofemoral joint, such as running, prolonged sitting, climbing stairs, kneeling, or squatting.

The dominant symptom is peripatellar or retro-patellar pain, often of mechanical cause. Patellofemoral pain syndrome affects physically active individuals and accounts for 25–40% of all painful knee diagnoses observed by Boling et al. (2010) in a study in a sports trauma clinic. The same study found that the incidence of patellofemoral syndrome was reported in several age groups, with women having a higher prevalence than men.

Onset may be gradual or the result of a single incident and is often caused by a change in a training regimen that includes a dramatic increase in training time, distance, or intensity. Its impact can be far-reaching, often reducing the ability to perform sports and physical and work-related activities without initially feeling pain.

Heintjes et al. (2004) conducted a study on the prevalence of patellofemoral syndrome in military personnel. According to the study, the annual incidence is 3.8% in men and 6.5% in women.

Therefore, to understand the severity of the patellofemoral syndrome, it is essential to determine an optimal strategy for its diagnosis, evaluation, and rehabilitation with the help of the various treatment methods available nowadays, as effectively as

possible and in as short a period as possible, aspects that will be debated in the first part of this doctoral thesis.

1.1. SPECIFIC ANATOMOPATHOLOGICAL NOTIONS FOR THE KNEE JOINT DIAGNOSED WITH PATELLOFEMORAL PAIN SYNDROME

The development of the patella and the patellofemoral joint is closely related to the development of the quadriceps tendon and knee joint, which are morphologically and functionally integrated, providing the articular component for the extension mechanism.

The femoral-patellar joint on the anterior part of the knee has the patella and the femoral trochlea as articular components. It works like a reflection pulley through the flexion-extension movements of the knee, similar to how a mechanical pulley slides. The anatomy, biomechanics, and function of this joint are well known. However, aspects such as the origin of pain and the natural consequences of cartilage damage are still being determined as the most effective means of diagnosis and the surgical techniques' reliability.

In this subchapter, we will attempt to explain all the relevant anatomical data underlying patellofemoral biomechanics and pathology. From a morphological point of view, according to the authors Jiménez Collado, Guillen Garcia, and Sobrado Perez (1994), the patella can theoretically be studied by its anterior or superficial part, by its posterior part and by its deep or articular facet, as well as by the top or base edge, top or bottom angle, and sidelines.

From a morphological point of view, the patella is considered a short bone rounded and flattened anteroposteriorly, with a degree of freedom of movement. Changes in the shape of the patella through the prism of its sides or changes in the level of the femoral trochlea can determine a degree of patellar instability during the first degrees of flexion and major overloading of the femoral-patellar joint.

The trochlear angle defines the angle of opening of the trochlea visualized on a radiograph taken in the axial plane in a position of the knee of 30° flexion. The normal trochlear angle is 140°; larger angles cause greater lateral instability, and tips below regular are more likely to cause cartilage damage.

According to Collado et al. (2014), the ligamentous and tendinous structures for patellar support are formed by the quadriceps tendon and its insertion into the superior border of the patella; the patellar tendon inserted into the lower wall and the external and internal patellar retinaculum. These structures make up the cruciform elements.

The arciform fibers are found in the anterior part of the patella and form a biomechanically important tendon because they stabilize the position of the patella when flexion-extension movements of the knee occur. Suppose there is damage or retraction in the area of the patellar retinaculum due to a scar. In that case, the flexion-extension movement is limited, and a femoral-patellar displacement may occur, constituted by a

subluxation or an articular imbalance. At the muscular level, the quadriceps fasciae join in its tendon, located in the proximal area at the upper edge of the patella (Gullen et al., 1997).

According to Collado et al. (2014), the femoral nerve divides into anterior and posterior areas. From the anterior region of the femoral nerve, the femoral cutaneous branch comes off, which innervates the outer upper edge of the patella. The innervation of the superior external border of the patella depends mainly on the parapatellar branch of the saphenous nerve, which, near the knee joint, divides into the infrapatellar branch that innervates the integument in the pre-patellar region.

1.2. MECHANISMS OF PRODUCTION OF THE PATELLOFEMORAL PAIN SYNDROME

The incidence of "localized anterior knee pain" is present at 22/1,000 persons per year and is estimated by the authors to be high (Boling et al., 2010; Robinson & Nee, 2007). Regarding localized knee pain, women are affected approximately twice as often as men (Boling et al., 2010; Fulkerson & Arendt, 2000; Robinson & Nee, 2007).

The causes of anterior knee pain are multifactorial and include excessive damage to the extensor apparatus of the knee (tendinitis or insertional tendinosis), patellar instability, chondral and osteochondral injuries (Park & Stefanyshyn, 2011).

The Q angle

The Q angle or quadriceps angle reflects the valgus vector of the quadriceps pull acting on the patella and provides information regarding possible knee joint diagnoses. It is usually measured from standing by drawing lines through the center of the patella and generally measures 15° in healthy individuals.

In some cases, localized knee problems can be triggered by associated pathologies, which can play an essential role in young athletes during the competitive period. Thus, the stagnation or reduction of the performance level can be justified by using them. (Petersen et al., 2010).

The symptoms generated by this syndrome can determine the limitation of sports activity and lead, finally, to the appearance of arthrosis (Blønd & Hansen, 1998), and according to some authors, the patellofemoral syndrome will eventually lead to the formation of arthrosis (Myer and et al., 2010; Thomas et al., 2010; Utting et al., 2005).

The pathogenesis is multifactorial and involves various functional disorders of the lower extremity (Barton et al., 2011). The purpose of literature reviews is to highlight the evidence regarding the underlying pathology of patellofemoral syndrome and identify the most effective means of treatment.

Static and dynamic deviations in patellofemoral pain syndrome

Incorrect movement of the patella is considered a controversial issue that plays an essential role in the occurrence of patellofemoral syndrome.

Studies show that incorrect patella movement plays a crucial role in this pathology. Draper et al. (2012) demonstrated by dynamic MRI imaging that patients with patellofemoral syndrome have an increased lateral inclination of the patella, and Witvrouw et al. (2000) showed that a hypermobile patella has a significant correlation with the incidence of patellofemoral pain.

The role of the vastus lateralis and vastus medialis muscles in patellofemoral pain syndrome

Pal et al. (2011) demonstrated that 'patellar mistracking in patients with patellofemoral syndrome correlates with a delayed response of the vastus medialis muscle. An imbalance in the response of the vastus medialis and vastus lateralis was also shown by Cowan et al. (2002). In the case of patients with patellofemoral syndrome, the vastus lateralis reacted earlier than the vastus medialis when climbing the stairs, and in the control group, this imbalance did not exist, aspects also supported by other studies in the field (Cavazzuti et al., 2010; Chen et al., 2012; Witvrouw et al., 2000). Patients with patellofemoral dysfunction have shown hypotrophy of the vastus medialis (Pattyn et al., 2011); however, despite these results, it is unclear whether vastus lateralis and vastus medialis imbalance are the leading cause of patellar maltracking.

Hip abductor muscle tone

Recent research has shown that functional malalignment does not occur strictly at the level of the knee joint but rather projects at this level through internal rotation of the femur due to weakness of the external rotators (posterior part of the gluteus medius, gluteus maximus, iliopsoas, piriformis, obturator internus and external, quadratus femoris, pectineus, and tailor) and external hip abductors (gluteus minimus, gluteus medius, and gluteus maximus) (Baldon et al., 2009; Bolgla et al., 2008; Brent et al., 2008; Padua et al., 2005; Prins & Van der Wurff, 2009).

Weakness of the hip muscles can be demonstrated by raising the contralateral leg. If the patient's hip cannot hold the position for 1 minute and signs of imbalance, appear, then the patient has a hip abductor deficiency. (Petersen et al., 2014).

Deviations of the talocrural joint

The eversion of the talocrural joint can also cause an internal rotation of the tibia. A study published by Barton et al. (2011) showed that patients with patellofemoral syndrome may have several disorders of the biomechanics of the lower limb. These disorders include delayed timing of maximum eversion of the talocrural joint and increased eversion of the talocrural joint at heel strike.

In conclusion, the specialized literature provides essential data regarding the correlation between ankle deviations and patellofemoral syndrome.

Implications of the iliotibial tract in patellofemoral pain syndrome

Kaplan fibers are connections between the iliotibial band and the distal femur. They are divided into two distinct structures, the proximal and distal fibers, which may participate in the control of knee stability. These fibers are different and constant anatomical structures of the lateral compartment of the knee, whose anatomical features participate in the control of knee stability (Sayak et al., 2021).

Dynamic valgus can also influence the length of the iliotibial tract. Wu et al. (2004) showed that the iliotibial lot can also affect patellar gliding. This can be explained anatomically by the fibers of Kaplan, which connect the iliotibial tract to the patella. No other studies on the role of the iliotibial lot in patients with patellofemoral syndrome were identified.

Hamstring imbalance and stiffness

Some evidence in the specialized literature shows that abnormal knee joint movements are not only present in the frontal plane in patients with patellofemoral syndrome.

Two studies identified a significant association between patellofemoral pain syndrome and hamstring stiffness (Patil et al., 2010; White et al., 2009).

These authors found significant hamstring stiffness in a group of patients with this syndrome compared to a control group. Patil et al. (2010) showed by electromyography that in patients with patellofemoral syndrome, the lateral hamstrings contracted earlier than the medial ones during maximal isometric contractions.

Besier et al. (2009) showed that patients with patellofemoral syndrome present a stronger contraction in the quadriceps and hamstrings than patients without symptoms specific to this syndrome. In this study, women showed 30-50% greater muscle strength in their hamstrings and gastrocnemius during walking and running than men. These authors concluded that, through this mechanism, some patients with patellofemoral syndrome might have an increased contact force at the joint level and higher joint stress than healthy subjects.

These changes can lead to higher stress on the kneecap and its supporting structures.

"Knee-Spine Syndrome"

Tsuji et al. (2002) examined the correlation between patellofemoral pain, lumbar lordosis, and sacral inclination in elderly patients with anterior knee pain. There was a significant difference in sacral inclination between subjects with and without previous knee pain. The tip of the sacrum was lower (by approximately 5°) in patients with patellofemoral pain. This pathological concept was called "knee-spine syndrome."

However, the literature has not determined this mechanism for younger patients with patellofemoral syndrome. More research is needed to elucidate the role of this mechanism in the pathogenesis of patellofemoral syndrome.

Psychological factors that contribute to the occurrence of patellofemoral pain syndrome

The importance of psychological factors for developing patellofemoral syndrome should be considered.

In the research of Jensen et al. (2007), it was shown that knee pain and function may also be associated with psychological factors in some patients with patellofemoral syndrome. These authors showed that patients with this syndrome have a higher level of depression than healthy subjects.

The study by Domenech et al. (2013) supports the fear-avoidance model. This study demonstrated high psychological distress, such as anxiety and depression, exaggeration of perceived pain level, and kinesophobia in patients with patellofemoral syndrome. These factors strongly predict pain and functional decline in patients with this syndrome.

Trigger factors for patellofemoral pain syndrome

A possible trigger for patellofemoral pain syndrome can be overloading the patellofemoral joint (for example, practicing high-intensity training). The combination of overload with dynamic valgus position and lateral sliding of the patella can lead to overstressing of the patellofemoral joint structures (MacIntyre et al., 2006).

This overload can cause localized pain at the front of the knee and can be a vicious cycle, as the muscle activity of the lower extremity can be inhibited.

The neurophysiological cause of pain in patients with patellofemoral syndrome

The exact cause of pain in patients diagnosed with patellofemoral syndrome is unclear. According to some authors, the pain most likely develops at the extensor mechanism insertion level or the subchondral bone status (Dye, 2005).

There is additional evidence that the subchondral bone may also play an essential role in the origin of pain in patients with patellofemoral syndrome. Draper et al. (2009) demonstrated increased metabolic bone activity in patients with this syndrome using imaging.

Other specialists have shown that peripheral and central mechanisms can cause pain in patients with patellofemoral syndrome. Adolescents with patellofemoral syndrome at the knee had a significantly lower pressure pain threshold (localized hyperalgesia) than a control study group. However, in the area of the anterior tibialis, adolescents with patellofemoral syndrome also had lower pain thresholds (distal hyperalgesia) than the control group (Rathleff et al., 2013). Jensen et al. (2005) demonstrated more significant sensory function in patients with patellofemoral syndrome. In their study, the average temperature detection threshold was significantly higher in patients with patellofemoral syndrome than in healthy individuals.

1.3. CLINICAL, FUNCTIONAL, AND IMAGING DIAGNOSIS IN PATELLOFEMORAL SYNDROME

Diagnosing disorders of the patellofemoral joint is a challenge for doctors due to the complicated pathophysiology underlying them. The origin of patellofemoral symptomatology is generally multifactorial (Lankhorst et al., 2013), and therefore the clinical examination should consider the history as a whole. Attention should be drawn to the medical history to have a diagnosis precisely, which should be approached correctly. We remind that an appropriate therapeutic approach can only be designed with a thorough analysis of the patient's disorder.

Lankhorst et al. (2013) argue that a thorough and appropriate history should be taken into account, focusing on the patient's symptomatology, duration, and occurrence of pain, as well as its impact on his daily activities. A proper history may indicate the presence of anterior knee pain, with or without patellar instability. Patellar instability can be described as episodes of subluxation or even dislocation. During the assessment, an exact location of the pain by the patient and the time when it occurs should be requested. Any pain mentioned should also be evaluated, as sometimes, even hip pain can radiate to the region surrounding the knee joint. If the patient has instability, it must be ensured that it is due to the patella. The sensation of the knee giving way can often be caused by quadriceps weakness, a meniscal tear, ligamentous deficits, or other disorders in the knee joint. Suppose the patient has undergone surgery at the knee level. In that case, the history of the intervention will be necessary to know the approach applied and to be able to exclude possibilities of medial patellar instability, which may occur after certain types of interventions, such as; lateral release or realignment surgery at the knee joint level. Failure to do so could lead to a misdiagnosis and subject the patient to unnecessary additional surgery, possibly worsening the condition. After a careful history and history taking, a systematic clinical examination should be performed with the patient in different positions, applying various functional tests and adding gait assessment.

1.4. ORTHOPEDIC AND SURGICAL TREATMENT IN PATELLOFEMORAL PAIN SYNDROME

Orthopedic treatment

Kettunen et al. (2007) highlighted that in a study in which patients diagnosed with patellofemoral syndrome were included, physiotherapy applied after arthroscopy had no positive effect in addition to classical physiotherapy used without arthroscopy. Therefore, the therapeutic approach to the patellofemoral syndrome is mainly conservative.

Pharmacological therapy

A meta-analysis by Heintjes et al. (2004) showed limited evidence for what appears to be the effectiveness of NSAIDs in reducing acute anterior knee pain in patients with patellofemoral syndrome.

Knee Tapping

The purpose of knee tapping is to modify the gliding of the patella by applying adhesive strips to the skin. The band should use a medially directed force to counteract lateral maltracking of the patella. The most popular application is the McConnel strip.

The positive influence of the tape on knee pain and function is probably the result of a synergistic effect created between the benefits of the video and the physical therapy program applied. The simultaneous application of a restraint tape and a physical therapy exercise program achieved a better result than a single tape system (Petersen et al., 2014).

Restraint immobilization with rod orthoses

Rods are non-adhesive devices that also apply a medially directed external force that can counteract the maltracking of the patella laterally.

In real-time MRI, Draper et al. (2009) demonstrated that a knee brace that applies a medially directed force to the patella can reduce the risk of patellar lateralization and tilting in women with patellofemoral syndrome much better than a classic applied bandage.

Powers et al. (2009) reviewed an orthosis that applied a medially directed force to the patella in patients with this syndrome. The authors of this paper found that pain decreased and activation of the quadriceps muscle was promoted.

Therefore, we conclude that numerous research studies are needed that can highlight the effect of rod orthoses on joint pain and function in patients with patellofemoral syndrome.

The use of foot orthoses

Increased eversion of the talocrural joint and pronation position may favor internal rotation and a dynamic valgus position in the lower extremity (Barton et al., 2012; Barton et al., 2009; Barton et al., 2011; Boldt et al. ., 2013; Mølgaard, 2011).

Foot insoles or orthotics could be a treatment option to correct the malalignment created.

Studies have yet to be identified that highlight the influence of foot position on pain in patients with patellofemoral syndrome, with research conducted to date reporting conflicting results.

Barton et al. (2011) examined the effect of prefabricated foot orthoses in patients with patellofemoral syndrome and valgus flatfoot in a pilot study involving 60 patients. These authors demonstrated that using foot orthosis reduces pain and improves functional parameters.

In another study, specialists demonstrated that the presence of greater eversion at the level of the posterior part of the foot predicts the effectiveness of foot orthoses in people with patellofemoral syndrome (Barton et al., 2011).

Functional rehabilitation

Physical therapy is the most frequently studied therapy in treating the patellofemoral syndrome. In this regard, two meta-analyses have been published.

In a more recent meta-analysis published in 2011, 10 prospective randomized trials were analyzed (Harvie et al., 2011).

All these studies showed a positive effect of exercise on pain reduction. Positive results have been described, especially with active stretching, squats, ergometers, static quadriceps, active leg raises, and lifting and lowering movements. Four of the applied exercise programs also included hip strengthening exercises. In one study, trunk stabilization exercises, including abdominal muscle exercises, were analyzed. The most common duration of exercise programs was six weeks. The activities were performed two to four times a day with ten repetitions. Closed and open kinetic chain, balance, and proprioceptive exercises have been described. (Nagakawa et al., 2008; Clark et al., 2000; Crossley et al., 2000; Herrington & Al-Sherhi, 2007).

In conclusion, there is strong evidence for using exercise in patellofemoral syndrome recovery in the literature. Practices need to engage the hip muscles, trunk stabilizer muscles, quadriceps, hamstrings, and iliotibial tract.

Types of surgery used in the treatment of patellofemoral syndrome and complications

There are different treatment options to address the other problems that occur in the patellofemoral joint. When considering a surgical procedure for a patient with anterior knee pain, an algorithm should be followed to approach the situation and select the best treatment option. The articular surface replacement is necessary for younger patients with isolated patellofemoral arthrosis. As new prosthetic designs give better results, decisions must be reconsidered through alternative means of treatment, weighing the pros and cons. The main surgical options (after basic procedures such as debridement, release, and realignment have been tried but failed) include the anterior or anteromedial transfer of the tibial tubercle to change the contact stress and unload the patellofemoral joint, removal of the patella (patellectomy) and restoration of articular cartilage either by osteochondral transfer or by implantation of cartilage cells.

CHAPTER 2 – FUNCTIONAL REHABILITATION IN PATIENTS DIAGNOSED WITH PATELLOFEMORAL PAIN SYNDROME

Currently, the continuous evolution of the field of medical recovery, together with the optimized protocols and the equipment used in the field of physiotherapeutic applications, have the role of facilitating and maximizing the rehabilitation of patients diagnosed with patellofemoral syndrome. At least two times a week, patients with leisure sports activity present a sample with a high risk of patellofemoral syndrome.

This may be due to an incorrect dose of effort, an incorrect frequency of training hours, overloads during training, or a poor recovery after exercise.

According to specialized studies, after the spread of the SARS-CoV-2 virus worldwide, daily activities and medical practices changed drastically (Luceri et al., 2020; Zagra et al., 2020; Briguglio et al., 2020).

Most people spent around two months in isolation at home, changing their daily habits and adopting a sedentary lifestyle. Lifestyle change is considered to be closely related to the critical consequences that can occur in the case of localized knee pathology.

According to the main findings of a study carried out in Italy by Giorgino et al. (2021) on a group of 1139 patients from the Galeazzi Orthopedic Institute in Milan, pathologies located at the knee level were much more frequently associated with femoral-patellar pain syndrome in 2020 than in 2019. In addition, the follow-up recommendation of a physiotherapy program for patients with localized knee pathology was also more frequent in 2020 than in 2019. The results of this study reflect a partial confirmation of his hypothesis, namely, the fact that blocking daily activities generated by the SARS-CoV-2 pandemic could be a triggering or aggravating factor for many diagnoses with patellofemoral syndrome. The reasoning lies in the consequences caused by the blockade at the global level, namely, the reduction in the level of daily physical activity and the decrease in the number of physical activities available.

Based on the scientific works found in the specialized literature, we can support the fact that the emergence of the pandemic had and continues to have an essential role in the occurrence of femoral-patellar syndrome.

From the specialized literature, we were able to extract the fact that the exact cause responsible for the appearance of patellofemoral syndrome is still unknown. Still, a multifactorial etiology is probably responsible for its appearance. This etiology generally affects young women (Petersen et al., 2014; Boling et al., 2010; Fulkerson & Arendt, 2000).

According to the study by Di Renzo (2020), biomechanical imbalances at the axial level and imbalances at the level of the quadriceps muscles were considered by researchers as common causes for the installation of this type of syndrome. Bowden Davies et al. (2019) reported that the restrictive measures adopted during the isolation period led to a sedentary lifestyle for most of the population, thus causing a significant decrease in muscle tone.

Different authors have offered several recommendations for managing physical activity during the COVID-19-induced lockdown (Füzéki, Groneberg & Banzer, 2020). Decreased muscle tone, such as reduced muscle tone of the vastus medialis muscle, is associated with patellofemoral syndrome (Pttyn et al., 2011).

Cowan et al. (2001) studied the diameter of the vastus medialis muscle in femoropatellar syndrome by nuclear magnetic resonance, demonstrating that its atrophy is a contributing factor in the development of this type of syndrome, possibly playing a role in the mechanism of abnormal sliding of the patella.

Other studies have shown that localized changes in the hip musculature can also be responsible for installing a functional deficit that can encourage the appearance of patellofemoral syndrome. Several works, however, have also highlighted a relative decrease in hip abduction strength, hip external rotators, and extension strength in patients diagnosed with patellofemoral syndrome (Prins & van der Wurrf, 2009; Bolgla et al., 2008; Baldon et al., 2009).

Another aspect that requires attention is a possible correlation between the psychological state and the onset of patellofemoral syndrome. Numerous studies have highlighted that during pandemic isolation, the mental state of individuals suffers (Mukhtar, 2020; Singh et al., 2020; Glowacz & Schmits, 2020). The psychological aspect also plays an essential role in installing the patellofemoral syndrome, an aspect that should be considered. In a descriptive study, Jensen et al. (2005) highlighted that levels of mental distress were higher in patients with patellofemoral syndrome.

So far, very few studies have addressed the impact of quarantine on localized knee pathologies. Endstrasser et al.'s (2020) study highlighted that isolation played a significant role in pain, joint function, and physical activity outcomes in patients diagnosed with localized osteoarthritis of the knee and hip.

Another specialized review reports a high incidence of anxiety and depression among patients with patellofemoral syndrome (Domenech et al., 2013), aspects described as being among the most frequently encountered worldwide during the quarantine period (Rehman et al., 2021; Benke et al., 2020; Fountoulakis et al., 2021).

Another indicator that changed the pandemic was and is still represented by the number of recommendations for physical therapy programs. This is supported by the decrease in muscle tone resulting from the sedentarism during the period of isolation (Bowden Davies et al., 2019) and by the association of other pathologies located at the knee level that encourage the appearance of patellofemoral syndrome and in, which physiotherapy has proven to be one of the most effective treatments (Heintjes et al., 2003).

The presence of the SARS-CoV-2 pandemic did not produce significant changes in the pathology of the knee. Still, it is possible that it impacted it, highlighting an aggravation of femoral-patellar disorders in patients with associated diagnoses located at the knee joint level. Further studies are needed to validate this result comprising more in-depth clinical and radiological elements.

The functional rehabilitation process of patients diagnosed with patellofemoral syndrome can be improved using modern equipment and devices that exist today and evolve in performance from year to year.

That is precisely why specialists in the field of medical recovery should constantly inform themselves and consider the novelties that appear in the area to facilitate, as much as possible, the use of innovative equipment both for the diagnosis process and the medical recovery process of patients diagnosed with patellofemoral syndrome.

Patients diagnosed with patellofemoral syndrome require a complex approach carried out by a multidisciplinary team regarding medical rehabilitation. The main objectives targeted by the specialists in the case of these patients are represented by the reduction of the discomfort generated by the pain located at the level of the affected knee, the regaining of joint mobility, the restoration of the balance at the level of the four distinct segments of the quadriceps muscle and the prevention or avoiding as much as possible potential surgical interventions caused by the possible complications of this syndrome.

The current medical patient education and approach to the care management of patellofemoral syndrome has evolved from the point of view of scientific experts (Willy et al., 2019). Over the years, various clinical options have emerged to address this pathology. Biophysical agents (e.g., cryotherapy, ultrasound, transcutaneous electrical nerve stimulation), once considered a mainstay of patellofemoral syndrome care, are now almost mandatorily supplemented by exercise therapy intervention (Lake & Wofford, 2011; Billy et al., 2008; Yu et al., 2016).

2.1. PROPHYLAXIS OF THE PATELLOFEMORAL PAIN SYNDROME

Patellofemoral pain syndrome prophylaxis using physical therapy

Femoral-patellar pain occurs following an overuse injury and is characterized by pain in the retro-patellar or peri-patellar area, which worsens with running, prolonged sitting, squatting, jumping, or climbing stairs.

The etiology of the pain was related in the previous chapter to the wrong lateral sliding of the patella, caused by muscle weakness of the vastus medialis oblique. It is considered that the abnormal sliding of the patella causes the increase of the lateral stress of the pressure at the level of the femoral-patellar joint (Fulkerson & Arendt, 2000).

As such, therapeutic interventions for patellofemoral syndrome have focused on correcting patellar motion through immobilization and stretching, mobilizing the patella, and strengthening the vastus medialis oblique (Powers, 2010).

Although, according to specialized studies, it is accepted that, in general, conservative treatment of patellofemoral syndrome is beneficial (Bizzini et al., 2003; Crossley et al., 2001; Heintjes et al., 2003), its recurrence rates they are high and vary

between 25 and 91% (Hoch et al., 2005; Nimon et al., 1998; Stathopulu & Baildam, 2003; Witvrouw et al., 2000).

The specialized literature supports the hypothesis that the patellofemoral syndrome has significant influences at the proximal level and powerfully highlights the idea of functional rehabilitation of the pelvic girdle and the coxofemoral joint to positively influence the dysfunction produced by the patellofemoral syndrome.

This approach is supported by recent clinical trials, showing that hip-focused rehabilitation benefits people with patellofemoral syndrome. Earl and Hoch (2011) showed that an 8-week structured rehabilitation program focused on increasing hip and trunk musculature stability significantly reduced pain, improved function, and overall lower limb biomechanics in 19 women with patellofemoral syndrome.

In conclusion, the strategy focused on the hip to prevent internal rotation in the coxofemoral joint and hip adduction, which are responsible for the appearance of the dynamic knee valgus position, is considered to be crucial, especially in the case of reinsertion into sports activity.

2.2. NON-SURGICAL TREATMENT IN PATELLOFEMORAL PAIN SYNDROME

Noninvasive treatment options for femoropatellar syndrome include activity modification, anti-inflammatory/analgesic medication, immobilization with rod devices, physical therapy, steroid injections, infiltrations, weight control, hydrotherapy, and possibly nutritional supplements, and the specific protocol of functional rehabilitation needs to be completely individualized.

Change of activity

A medical specialist may be reluctant to advise patients to avoid the activity they enjoy thoroughly but will remain firm about reducing or modifying certain activities. As a general principle of practice, patients should be educated regarding the occurrence of pain. This should be maintained and avoided altogether.

Weight management is fundamental to the treatment of patients with patellofemoral syndrome. Still, they can be conflicted because weight-bearing activities (climbing stairs, squatting, running, and jumping) are associated with their symptoms, leading to fear of pain and maladaptive coping behavior (Smith et al., 2018). In addition to education about pain mechanisms, arming the patient with pain-coping strategies can improve confidence and outcomes throughout treatment.

Weight control

During activities of daily living, such as rising from a chair or climbing stairs, the knee, especially the patellofemoral joint, is exposed to much greater pressure (Grelsamer & Weinstein, 2001). An increased body mass index (BMI) correlates with a much higher rate of knee pain and, implicitly, patellofemoral arthritis.

Conversely, a weight reduction will significantly decrease the stress on the patellofemoral compartment and may moderate the pain level. Because a person's weight is the only anatomical factor under their control, overweight patients can partially direct their patellofemoral pain progression through a weight reduction program.

Hydrotherapy

Regarding hydrotherapy, at least two aspects of water therapy are beneficial: buoyancy and endurance. Buoyancy allows the patient to attempt activities that would typically be stressful and painful to the patellofemoral compartment. These include, for example, squats. A person could try different exercises in the pool, but as with land exercises, no water activity should be painful. The water's resistance while the subject walks, runs, or kicks will help increase muscle tone (Abdul-Hadi et al., 2009).

Medication

Anti-inflammatory and pain-relieving medications (acetaminophen, tramadol, etc.) can be used alone or in combination for short-term pain relief. Patients should be informed that certain medicines contain several active substances. Acetaminophen, for example, is present in several varieties, and it would not be prudent for a patient to take acetaminophen alone when it is already being taken in combination. On the other hand, with appropriate precautions for liver and kidney function, a variety of anti-inflammatory drugs, acetaminophen, and a third drug, such as tramadol, can be effective. Patients taking any of these drugs regularly require a complete blood count and specific blood tests every 3-4 months (Abdul-Hadi et al., 2009).

Steroid injections

Steroid injections are commonly used to address musculoskeletal inflammation in different body areas, and patellofemoral joint injections are no more or less effective than other areas. They are considered to be cheap and readily available. Their repeated use can hurt the mechanical properties of the tissues and the local immune response (and, therefore, a potentially increased risk of infection with any eventual procedure). Injections should be limited to two or three per year for patients with patellofemoral syndrome (Abdul-Hadi et al., 2009).

Infiltrations

The knee's synovial fluid that becomes arthritic is less viscous than usual and deficient in some of its biomechanical properties. Consequently, hyaluronic acid injections are an accepted adjunct in treating localized knee arthritis. In the case of the femoral-patellar compartment, no better or less good response to this approach was reported compared to the femoral-tibial joint. Because the injected products are synthetic versions of a person's joint fluid, there is no medical limit on the frequency with which this type can infiltrate (Conrozier et al., 2003).

Nutritional supplements

Over-the-counter supplements such as glucosamine and chondroitin sulfate were welcome additions to the fight against, or even the onset of, arthritis. The authors claimed that there are safe, chondroprotective, cartilage-helping, and pain-reducing properties (Reginster et al., 2005). In the same study, although some patients did report positive reactions after taking these supplements, it needs to be better defined than the supplements provide relief in more than 30% of subjects due to the placebo rate. As of 2009, the American Academy of Orthopedic Surgeons no longer supports using nutritional supplements to treat arthritis.

Knee orthotics

The extension position achieved through orthoses should provide relief of localized knee pain in people with patellofemoral syndrome, but the beneficial effects of these orthoses have not been validated. The cutout in the front of the knee brace is designed to minimize pressure on the patella, but this concept is only effective when the patella is centered over the trochlea. When the patella is laterally positioned, the orthosis cutout will be improperly positioned and may increase pressure on the patellofemoral compartment (Mundermann et al., 2003).

Ankle orthotics

Foot position influences knee biomechanics. Specifically, a pronated foot will lead to internal rotation of the lower limb, and at some point, a knee valgus will result. Orthotics can compensate for a vicious foot position and occasionally relieve patellar pain. Mundermann et al. (2003) found that patients with anterior knee pain had increases in global electromyography intensity during running, at least confirming that foot orthoses also influence the knee joint (Mundermann et al., 2003).

2.3. PHYSIOTHERAPY IN PATELLOFEMORAL PAIN SYNDROME

Regaining and increasing muscle strength

Pain in patellofemoral syndrome decreases quadriceps muscle activity, and reduced quadriceps strength is strongly associated with increased symptomatology (Baker et al., 2004; Hodges et al., 2009).

The strength and coordination of the thigh, gluteal, and abdominal muscles decrease pressure on the patellofemoral joint by optimizing muscle diameter and load distribution (Amin et al., 2009). Thus, increasing muscle strength through pain-free exercises is recommended to avoid turning the movement into a counterproductive one.

According to specialist studies, cycling is a beneficial activity with little impact on the femoral-patellar joint. The compressive force is only 1.3 × body weight if the resistance is kept low and the bicycle seat is raised. Cycling training duration can gradually increase (Erricson & Nissell, 1987).

Commonly used manual techniques include patellofemoral joint mobilization, talocrural mobilization, and manipulation (often to improve dorsiflexion), lumbopelvic manipulation, soft tissue mobilization (usually located at the knee joint on the lateral side), and femoral joint mobilization -patellar and femorotibial (Jayaseelan et al., 2018; Eckenrode et al., 2018; Brantingham et al., 2012).

Therapeutic physical exercise for patients with the patellofemoral syndrome is the management strategy supported by most of the evidence in the specialized literature. Combined hip and knee joint exercise reduces chronic pain in the short term while improving functional capacity in the medium and long term (Collins et al., 2017). Resistance exercises to strengthen hip extensors, abductors, and external rotators (Lack et al., 2015), quadriceps (Kooiker et al., 2014), and core muscles (Ferber et al., 2015) are supported by many studies of specialty (Alba-Martin et al., 2015; Clijsen et al., 2014; Nascimento et al., 2018).

More high-quality research is needed to determine the most influential movement parameters to address patellofemoral syndrome, as evidence to guide protocol specificity and exercise dosing is lacking (Holden et al., 2018).

2.4. NEUROMUSCULAR TAPPING IN PATELLOFEMORAL PAIN SYNDROME

The application of the tapes at the level of the patella is aimed at its progressive medial displacement to increase the contact area and decrease the femoral-patellar pressure. There is strong evidence in the literature regarding short-term pain reduction through the application of tapes in the population diagnosed with osteoarthritis. Cushnaghan et al. (1994) found that patellar tapping in a medial direction reduced pain by 25% in patients with patellofemoral and femorotibial osteoarthritis.

Tapping can provide an immediate feeling of relaxation and help support the correct position of the kneecap. Kineosiotape is a latex-free athletic tape that has been used for years. Tapping with these bands supports the injured area while ensuring proper functionality. The same bands are used as support or compression after an injury or later in rehabilitation to support a return to full training.

Although patellar tapping has not demonstrated femoral-patellar biomechanical effects (Leibbrandt & Louw, 2015; Logan et al., 2017; Ho et al., 2017), intention-based tapping strategies to control lateral tilt, slip, and rotation are recommended to achieve pain reduction compared to classical bandaging (Barton et al., 2014).

According to Barton et al. (2014), patellar neuromuscular tapping, for example, can have immediate pain management benefits when combined with exercise in patients with anterior knee pain. Still, other studies claim that it does not influence the contact area of the patellofemoral joint, its alignment, or the correct activation of the quadriceps muscles (Leibbrandt & Louw, 2015; Logan et al., 2017; Ho et al., 2017). Patellar orthoses (e.g., banded) provide no additional benefit (Smith et al., 2015).

2.5. PHYSICAL-KINETIC METHODS APPLIED IN PATELLOFEMORAL PAIN SYNDROME

Some patients may suffer from severe patellofemoral syndrome due to neuromuscular imbalance between the vastus medialis oblique and vastus lateralis muscles. The leading cause is muscle hypotrophy of the vastus medialis oblique power and lateral, excessive/abnormal sliding of the patella due to residual strength in the vastus lateralis. If there is a neuromuscular imbalance between these two muscles, electrical stimulation of the vastus medialis oblique and other applications within physiotherapy programs could be considered to supplement physical therapy programs.

Transcutaneous Electrical Nerve Stimulation (TENS)

TENS is a method of electrical stimulation that primarily aims to provide symptomatic pain relief through excited sensory nerves.

Transcutaneous electrical nerve stimulation can transiently increase quadriceps activation and reduce pain, similar to other modalities such as ice application, but this has not demonstrated any additional benefit over exercise (Billy et al., 2008; Yu et al., 2008). , 2016; Gabler et al., 2016).

Research is limited in the area of TENS and specific knee pain. Therefore we consider it necessary to use current research on TENS for pain and clinical judgment.

Ultrasound therapy

According to Watson (2005), therapeutic ultrasound has two effects: thermal and non-thermal, but each of the two effects can be used in functional rehabilitation protocols. In the same study, it was suggested that ultrasound may help speed up and improve the quality of tissue healing.

In the knee, the tissue that can be influenced by ultrasound therapy is the patellar tendon and ligaments.

Regarding tendon pathology (tendinopathy) and the effectiveness of therapeutic ultrasound, little evidence has specifically evaluated this. Positive results related to the influence of ultrasound on human tissue are confirmed by a systematic review and meta-analysis published in 2015 regarding the treatment of shoulder tendinopathy. The authors found no feasible studies to support the recommendation of ultrasound as a treatment modality (Desmeules et al. 2015).

Also, electromyography-based biofeedback of the vastus medialis during exercise therapy appears to have no additional benefit on knee joint pain or function (Dursun et al., 2001).

Laser therapy

According to a study carried out by Nouri et al. (2019) regarding the inclusion of high-prevention laser in the kinetotherapeutic functional rehabilitation program for patients with patellofemoral syndrome, it was proven that therapeutic exercises

accompanied by laser therapy had better results in terms of pain reduction compared to the control group.

2.6. SHOCKWAVE THERAPY IN PATELLOFEMORAL PAIN SYNDROME

From the field specialists' perspective, treating patellar tendinopathy represents a challenge (Leal et al., 2015). According to several studies, there is no specific evidence-based protocol for the appropriate management of patellar tendinopathy (Mani-Babu et al., 2014; Figueroa et al., 2016; Gaida & Cook, 2011; Larsson et al., 2011; Visnes & Bahr, 2007).

Promising results have also been observed in applications with the help of shock wave therapy in several specialized studies.

Wang et al. (2007) compared focused shock wave therapy and conservative treatment in a randomized control trial and found very good or excellent results in 90% of patients who received concentrated shock wave therapy. At 2 to 3 years of follow-up, compared to 50% of the patients who received only conservative treatment.

Furia et al. (2012) performed a retrospective study between radial shock wave treatment and standard treatment one year after the application of the therapies, reporting satisfactory results in 75.8% of patients who received a single session of pressure waves low-energy radial, compared to 17.2% in other non-operative treatments.

In contrast, in another study, Zwerver et al. (2011) compared actual shock wave therapy and placebo in athletes. They found no significant differences between groups regarding knee pain and function at the assessment 22 weeks after treatment. Another recent study was conducted on a group of 52 athletes diagnosed with patellar tendinopathy, where the effect of shock wave therapy was evaluated compared to an eccentric exercise training program. No significant differences between protocols were found during the 6-month post-treatment assessment (Thijs et al., 2017).

However, the studies describing poor results in the use of shock wave therapy included specific methodological errors, such as the lack of performing complementary studies to exclude other associated diagnoses, the application of the treatment was carried out with a piezoelectric device, the adaptation of the intensity of the therapy was performed according to the patient's tolerance, the rest period was not respected, and the shock wave therapy was used alone, without an associated exercise program.

Peers et al. (2003) retrospectively compared focused shock wave therapy with surgery in 28 patients at a mean of 24 months post-intervention and showed excellent or outstanding results according to the Roles and Maudsley score in 66% in the group of patients who received shock wave therapy, compared to 58% in the group of patients who underwent surgery. The authors concluded that focused shock wave therapy is an alternative to surgery for patients with chronic patellar tendinopathy when conservative treatment is unsuccessful without leading to disability. The Roles and Maudsley score is a 4-parameter structured subjective assessment for patients regarding pain and functional limitations.

Literature review supports that Shockwave therapy is safe and effective in treating patellar tendinopathy (Mani-Babu et al., 2014; Leal et al., 2015; Everhart et al., 2017).

Current evidence supports focused and radial shock wave therapy for patellar tendinopathy associated with moderate to low-intensity protocols, particularly in patients seeking to avoid invasive intervention.

2.7. HIGH-INTENSITY ELECTROMAGNETIC FIELD THERAPY (SUPER INDUCTIVE SYSTEM) IN PATELLOFEMORAL PAIN SYNDROME

The super-inductive electromagnetic field is used to treat various central and peripheral disorders.

In this thesis, we focus exclusively on the realization of the peripheral application, which is less widely used than the transcranial application. Considering that almost every musculoskeletal disorder is accompanied by pain, other treatment options that can influence its presence should be investigated.

Several research works have been carried out regarding the specific effect of super inductive electromagnetic fields on human tissue. The analgesic effect is described by Poděbradský, Lee, and Uher (2012). Their studies used a stimulator with a frequency of 50 Hz. Therefore, they influenced the level of pain based on the endorphin theory of pain. In this thesis, I applied the Super Inductive System technology, which reaches a frequency of up to 150 Hz.

The super inductive system, which uses the beneficial effects of the high-intensity electromagnetic field, represents an optimal treatment of localized pain in the neuromuscular system and joints. The construction of the applicator allows the administration of the therapy without the need for direct contact with the skin, which leads to increased comfort for the patient and the therapist.

According to a study conducted by Zarkovic and Kazalakova in 2016 on a group of 40 patients (23 women and 17 men) with acute and chronic musculoskeletal pain, which made their daily activities difficult, it was demonstrated that by applying super technology inductively, the level of pain analyzed by the VAS scale after 5/10 applications decreased significantly in approximately 87% of the study participants.

THEORETICAL CONCLUSIONS

Based on the research carried out from specialized sources, we can conclude that the femoral-patellar pain syndrome is a clinical entity that leads to the appearance of pain in the anterior area of the knee in patients without pathological changes present in the cartilage of the femoral-patellar joint.

Considering the importance of the knee joint in everyday life, both for carrying out daily and professional activities, we can conclude that the functional rehabilitation of this pathology is imperative.

The production mechanisms of the patellofemoral syndrome are multiple, thus requiring the implementation of a rehabilitation program as effectively as possible, based on the most accurate and detailed evaluation.

Patellar maltracking (incorrect sliding) due to a functional axial deviation or dynamic valgus may be an underlying cause of this pathology. Possible causes of dynamic valgus may be low hip abductor strength or the presence of a flat foot in the valgus. Deviations at the knee joint level are associated with the quadriceps muscle imbalances and the reds at the tendons or iliotibial tract level.

Current imaging techniques can provide us with essential data regarding the functionality of the knee joint, which can facilitate the diagnosis of patellofemoral syndrome.

Orthopedic treatment can be considered adjuvant in combating the pain caused by femur-patellar syndrome if it is associated with an individualized and well-structured physical therapy program.

The literature provides evidence for a multimodal non-invasive therapy concept, with short-term use of nonsteroidal anti-inflammatory drugs, short-term use of medially directed taping, and complex exercise programs involving the lower extremity and hip and trunk muscles. There is also evidence for the benefit of rod restraints and foot orthoses.

Surgical interventions are indicated only for patients with an anatomical defect of the bone structures or the patella's pathological alignment maintains the cartilage's destruction. After any surgical intervention, it is mandatory to establish specialized physiotherapy programs with specific objectives to ensure a high post-operative success rate.

Regarding the modification of physical activity, several contraindications are imposed, such as: avoiding maximum knee flexion against resistance and maintaining an adequate body mass index. Muscle toning exercises are recommended without crossing the painful threshold, performed especially in a closed kinetic chain, and hydrotherapy offers numerous benefits in performing movements by reducing joint stress.

In addition to establishing an appropriate physical therapy program, specialist sources also provide essential information related to physical therapy procedures that, along with exercise, provide positive results in reducing pain and restoring function in a

shorter time. Shockwave therapy has been studied and applied in current medical rehabilitation programs and has shown positive results in symptom relief.

Regarding physiotherapy methods, they can be considered very important from the point of view of reducing pain in the case of patients with femoral-patellar syndrome because, with their help, we can implement the kinetotherapeutic exercise program early and without the presence of pain.

Through a correct anamnesis, following the indications correctly, using the therapeutic protocols of Shockwave therapy, and its appropriate application, we can make an important contribution to the evolution of the non-invasive treatment of patellofemoral syndrome.

Regarding applying the super inductive system with a high-intensity electromagnetic field, there are no specific specialized studies in the case of people diagnosed with femoral-patellar syndrome, but only generalized studies on the reduction of acute or chronic pain. Studies have reported a significant decrease in patients with various musculoskeletal pain.

PART II – THE APPLIED PART

CHAPTER 3 – PRELIMINARY STUDY ON THE EFFICIENCY OF SOME PHYSIOTHERAPEUTIC METHODS INVOLVED IN THE PHYSIOTHERAPEUTIC RECOVERY OF THE FUNCTIONAL DEFICIT AT THE KNEE LEVEL WITH PATELLOFEMORAL PAIN SYNDROME

3.1. THE PREMISES OF THE RESEARCH

Following the review of the data collected from the specialized literature regarding the research topic, we found that we have an increased incidence of the diagnosis of patellofemoral syndrome, and the treatment methods used in the case of patients are generally the classic ones.

In addition to implementing an appropriate physical therapy program, specialist sources have provided new research directions and important information related to physiotherapy procedures, which, together with therapeutic physical exercises, offer positive results in pain reduction and restoring function in a shorter time. Because at least Shockwave therapy has shown positive results in the evolution of patients in studies conducted by specialists, we will focus our attention on integrating this type of therapy in the main study.

I believe that, at present, the field of functional rehabilitation has a varied range in terms of equipment and physical treatment methods, which has not been applied to patients with this diagnosis, and especially has not been integrated into the programs of kinetotherapeutic functional rehabilitation, based on physical exercise.

3.2. PURPOSE, OBJECTIVES, TASKS, AND HYPOTHESES OF THE RESEARCH

The purpose of this research is to highlight the contribution of different types of protocols in the case of patients diagnosed with patellofemoral syndrome and how they can be optimized or combined to obtain a rehabilitation program that is appropriate and customized for the patient to obtain functional recovery.

The objectives of the research are:

- Identifying how the functional rehabilitation program of patients diagnosed with femoral-patellar syndrome can be improved using state-of-the-art physical therapy;

- identifying an optimal association in terms of applied therapy methods to achieve the objectives of the functional rehabilitation program for patients diagnosed with the patellofemoral syndrome;
- carrying out a detailed analysis of the results obtained with the help of the applied rehabilitation protocol and comparing the values obtained to establish an optimal protocol for the rehabilitation of patients diagnosed with patellofemoral syndrome;
- formulating some conclusions to highlight the importance of using state-of-the-art therapy, represented by Shockwave therapy and high-frequency electromagnetic field therapy, as an essential part of the rehabilitation protocol for patients diagnosed with the patellar-femoral syndrome.

The research started with the following assumptions:

GENERAL HYPOTHESIS I: We assume that, by using state-of-the-art physiotherapy devices, we can influence the results of functional rehabilitation protocols for patients diagnosed with the patellofemoral syndrome positively, from the point of view of pain reduction, from the level of the affected lower limb.

Specific HYPOTHESIS I.1: We assume that using the kinetotherapeutic rehabilitation program associated with Shockwave therapy can reduce pain in patients diagnosed with femoral-patellar syndrome to a greater extent than classical rehabilitation methods.

Specific HYPOTHESIS I.2: We assume that the use of the kinetotherapeutic rehabilitation program, associated with high-frequency magnetic wave therapy (Super Inductive System), can lead to a more significant reduction of pain in patients diagnosed with the patellofemoral syndrome than classic rehabilitation methods.

Specific HYPOTHESIS I.3: We assume that the use of state-of-the-art devices in the rehabilitation program (Shockwave therapy and Super Inductive System therapy), without also using the kinetotherapeutic exercise program, has limited effects in terms of pain reduction.

Specific HYPOTHESIS I.4: We assume that the use of functional rehabilitation programs involving the kinetotherapeutic program associated with state-of-the-art therapies (Shockwave therapy and Super Inductive System therapy) can have better results compared to functional rehabilitation programs that use the associated kinetotherapeutic program with classical physiotherapy, from the point of view of reducing pain from the affected knee.

GENERAL HYPOTHESIS II: We assume that, by using state-of-the-art physiotherapy devices, we can positively influence the results of functional rehabilitation protocols for patients diagnosed with patellofemoral syndrome from the point of view of restoring mobility to the affected lower limb.

Specific HYPOTHESIS II.1: We assume that using the kinetotherapeutic rehabilitation program associated with Shockwave therapy can increase joint mobility in

patients diagnosed with the patellofemoral syndrome to a greater extent than classical rehabilitation methods.

Specific HYPOTHESIS II.2: We assume that the use of the kinetotherapeutic rehabilitation program associated with high-frequency magnetic wave therapy (Super Inductive System) can lead to an increase in joint mobility, in the case of patients diagnosed with patellofemoral syndrome, to a greater extent higher than classic rehabilitation methods.

Specific HYPOTHESIS II.3: We assume that the use of state-of-the-art devices in the rehabilitation program (Shockwave therapy and Super Inductive System therapy), without also using the kinetotherapeutic exercise program, has limited effects in terms of the results of the rehabilitation program, from the point of view of joint mobility.

Specific HYPOTHESIS II.4: We assume that the use of functional rehabilitation programs, which involve the kinetotherapeutic program associated with the latest generation therapies (Shockwave therapy and Super Inductive System therapy), can have better results compared to the functional rehabilitation programs that use the kinetotherapeutic program associated with classical physiotherapy, from the point of view of joint mobility at the level of the affected knee.

The independent variables of the preliminary study were constituted by the four functional rehabilitation protocols used in the study. The pain level represented the dependent variables felt and the articular amplitude at the level of the affected knee (difference in flexion).

3.3. RESEARCH METHODS

The bibliographic documentation was used to know the scientific experience in functional rehabilitation concerning the particularities of the femoral-patellar syndrome, the known treatment methods, and the functional rehabilitation protocols used in the case of this diagnosis.

The experiment method was adapted and had a clinical character; since the subjects were selected according to the pathology, the comparison was made on similar groups without a control group.

The testing method was used, initially and finally, to eliminate associated pathologies and to evaluate the level of pain felt and joint mobility at the level of the affected knee. The tests used in the preliminary study were the patellar slide test, the McMurray test, the VAS scale, and the joint balance.

The statistical method was used to test the hypotheses of the preliminary study. As such, we used the test for normality of distribution (Shapiro-Wilk), T-test for paired samples, Pearson correlation, ANOVA, and Wilcoxon analysis. The research results were statistically analyzed with the help of SPSS version 29.0.1.0 (171).

3.4. ORGANIZATION AND CONDUCT OF RESEARCH

The research of the preliminary study within the doctoral thesis occurred between October 19, 2021, and February 8, 2022, in the Kinego medical recovery clinic in Iași. The clinic has all the equipment for the four functional rehabilitation protocols, including the latest generation equipment for applying shock waves and high-frequency electromagnetic field therapy. During the research, I received support and suggestions from the specialist doctor of the clinic, who helped me strictly follow the evolution and results of the subjects.

Anumebr of 40 subjects diagnosed with the patellofemoral syndrome were included in the research; they were both female (18) and male (22), aged between 18 and 49 years. The subjects were randomly divided into four groups:

- ten subjects were included in the first group, who followed a medical rehabilitation protocol represented by classical physiotherapy procedures and specific physical therapy, lasting approximately 14 weeks;
- in the second group, ten subjects were included, who followed a rehabilitation protocol represented by Shockwave therapy and specific physical therapy, lasting approximately 14 weeks;
- in the third group, ten subjects were included, who followed a rehabilitation protocol represented by high-intensity electromagnetic wave therapy (SIS) and specific physical therapy, lasting approximately 14 weeks;
- and in the last group, ten subjects were included, who followed a rehabilitation protocol based on Shockwave therapy and high-intensity electromagnetic wave therapy (SIS), lasting approximately three weeks. (without specific physical therapy exercises).

The inclusion criteria for the subjects participating in the study were their diagnosis, age over 18 years, the presence of a positive result for the sliding patellar test, the company of a negative result for the McMurray test, the presence of pain at the anterior level of the knee joint when maintaining the position of prolonged sitting or going up or down stairs, the absence of relevant femoral-patellar degenerative changes in the imaging examination, the lack of a positive history regarding knee trauma and the completion of individualized medical rehabilitation programs for each group.

The exclusion criteria for the patients participating in the study were the absence of any inclusion criteria described above and non-compliance with the applied functional rehabilitation protocol, either in terms of therapy frequency or time interval.

3.5. RESULTS AND DISCUSSION

GENERAL HYPOTHESIS I – To test the general hypothesis I and the derived specific hypotheses, the Shapiro-Wilk statistical tests, the T-test for paired samples, the Pearson correlation, the ANOVA analysis, and the Wilcoxon test were used for the parameter represented by the VAS scale (pain reduction). Based on the information presented in the tests, we can say that from the point of view of pain reduction, the best results were reported in group 2 (physical therapy protocol + Shockwave) and 3 (physical therapy protocol + Super Inductive System). At the level of group 4 (Shockwave protocol + Super Inductive System), there is also a significant decrease in pain in the case of the subjects. In conclusion, we can consider that the protocols that include the latest generation therapies positively influence pain reduction – **general hypothesis I was validated.**

Specific hypothesis I.1. – From the point of view of pain reduction, the group that followed the physical therapy protocol associated with shockwave therapy experienced a pain reduction like the group that followed the classical physiotherapy protocol associated with the physical therapy program. In conclusion, **the specific hypothesis I.1. has not been validated.**

Specific hypothesis I.2. – At the group level that followed the physical therapy protocol associated with high-intensity magnetic wave therapy, a more pronounced decrease in pain seems to be manifested compared to the group that followed the classical physiotherapy protocol associated with the physical therapy program. In conclusion, **the specific hypothesis I.2. was partially validated.**

Specific hypothesis I.3. – From the point of view of pain reduction, the best results were reported in group 2 (physical therapy protocol + Shockwave) and 3 (physical therapy protocol + Super Inductive System). Group 1 (classical physiotherapy protocol + physical therapy) experienced less pain reduction. In conclusion, we can consider that the protocols that include the kinetotherapeutic exercise program associated with innovative treatments positively influence pain reduction more than the classical physiotherapy related to the kinetotherapeutic program. **Specific hypothesis I.4. was partially validated.**

Specific hypothesis I.4. – From the point of view of pain reduction, the best results were reported in group 2 (physical therapy protocol + Shockwave) and 3 (physical therapy protocol + Super Inductive System). Group 1 (classical physiotherapy protocol + physical therapy) experienced less pain reduction. In conclusion, we can consider that the protocols that include the kinetotherapeutic exercise program associated with innovative treatments positively influence pain reduction more than the classical physiotherapy associated with the kinetotherapeutic program. **Specific hypothesis I.4. was partially validated.**

GENERAL HYPOTHESIS II – To test the general hypothesis II and the specific hypotheses derived, the Shapiro-Wilk statistical tests, the T-test for paired samples, the Pearson correlation, the ANOVA analysis, and the Wilcoxon test for the parameter represented by the difference in flexion (joint mobility). Based on the information exposed in the previously mentioned tests, we can say that the best results were reported for group 4 (Shockwave + Super Inductive System) in restoring mobility to the affected knee. Groups 2 and 3 experienced a similar restoration in the case of the mobility of the affected knee. Given that group 4 did not have the kinetotherapeutic exercise program as part of the protocol, we can interpret this increase in joint mobility due to the significant reduction of pain and the resumption of daily activities that were initially difficult or impossible. In conclusion, we can consider that the protocols that include the latest generation therapies positively influence joint mobility, and **the general hypothesis II has been validated.**

Specific hypothesis II.1. – In terms of restoring mobility to the affected knee, the group that followed the kinesiotherapy protocol associated with shockwave therapy experienced an improvement in joint mobility to a greater extent than the group that followed the classical physiotherapy protocol associated with the program kinetotherapeutic. In conclusion, **the specific hypothesis II.1. was partially validated.**

Specific hypothesis II.2. – In terms of restoring mobility at the level of the affected knee, the group that followed the physical therapy protocol associated with high-intensity magnetic wave therapy experienced an improvement in knee mobility to a greater extent than the group that followed the protocol of classical physiotherapy associated with the kinetotherapeutic program. In conclusion, **the specific hypothesis II.2. was partially validated.**

Specific hypothesis II.3. – From the point of view of restoring mobility, the results reported in groups 2 (physical therapy protocol + Shockwave) and 3 (physical therapy protocol + Super Inductive System) are similar. At the level of group 4 (Shockwave protocol + Super Inductive System), we have a significantly better increase in the joint mobility of the affected knee. In conclusion, according to the presented results, the protocols, including the kinetotherapeutic exercise program, do not influence joint mobility to a greater extent than the latest generation of physical therapy. **Specific hypothesis II.3. has not been validated.** Still, as we stated previously in the case of general hypothesis II, we can consider this increase in mobility an effect based exclusively on the significant reduction of pain and the return to daily or professional activities of the subjects.

Specific hypothesis II.4. – From the point of view of restoring joint mobility, the best results were reported in groups 2 (physical therapy protocol + Shockwave) and 3 (physical therapy protocol + Super Inductive System). Group 1 (classical physiotherapy protocol + physical therapy) experienced less increase in mobility compared to the other two groups. In conclusion, we can consider that the protocols that include the kinetotherapeutic exercise program associated with innovative therapies positively

influence joint mobility more than the classical physiotherapy related to the kinetotherapeutic program. **Specific hypothesis II.4. was partially validated.**

3.6. PARTIAL CONCLUSIONS

In this preliminary study, we obtained confirmation of the beneficial effect of different functional rehabilitation programs in the case of patients diagnosed with patellofemoral syndrome. All four groups of subjects participating in the study achieved satisfactory results in terms of pain reduction. Still, statistical analyses support that functional rehabilitation programs with state-of-the-art therapies reduce pain more than classical physical therapy.

From the point of view of restoring joint mobility at the level of the affected knee, we can state that the protocols that include the kinetotherapeutic exercise program, associated with innovative therapies, positively influence joint mobility to a greater extent than the classical physiotherapy related to the program kinetotherapeutic. Although group number 4 subjects experienced significant improvements in combined balance, these were only unilateral. This group recorded positive results on the side of the affected lower limb because the protocol only focused on physiotherapeutic methods based on the latest technology, without being accompanied by kinetotherapeutic programs based on physical exercise. Because one of the principles of physical therapy and implicitly of functional recovery is to work bilaterally, we can consider the protocol of group number 4 of subjects incomplete, even if it was completed in a shorter period. It had positive effects on the side of the affected knee from the point of view of pain reduction and the evolution of joint balance.

Through the study, we obtained confirmation of the fact that by using state-of-the-art physical therapy devices (Shockwave and Super Inductive Systems), we can influence the results offered by classic functional recovery protocols for patients diagnosed with patellofemoral syndrome positively, from the point of view of reducing pain and restoring mobility to the affected lower limb.

The association of medical recovery methods was performed correctly and had an essential role in the evolution and duration of the recovery program in the case of patients diagnosed with patellofemoral syndrome. The results of this study provide new directions regarding the association of recovery techniques—the latest generation with the physiotherapy program to optimize positive outcomes for patients with this diagnosis. No side effects were observed during the study.

According to the specialized studies consulted in previous chapters, we could conclude that the functional rehabilitation programs applied to patients diagnosed with the patellofemoral syndrome were in continuous development. Here we report both from the point of view of kinetotherapeutic programs of functional rehabilitation, as well as from the point of view of physiotherapeutic methods that currently benefit from modern equipment that can facilitate a correct approach, at least from the point of view of reducing pain.

From the point of view of kinetotherapeutic functional rehabilitation protocols, however, in the previous chapter, it was emphasized that no specific protocol for this condition was identified in the literature, the approach being less concise. However, the functional rehabilitation program that was the basis of the present research was constituted by a program of specific exercises, focused primarily on the knee joint, the hip joint, and the talocrural joint and was individualized and adapted according to the function by each subject participating in the study, working bilaterally according to the target objectives.

The biological effects mentioned in specialized studies support that shock wave therapy can reduce pain, increase blood flow in ischemic tissues, and improve post-traumatic stiffness of the knee joint, thus improving physical function and performance in sports activities.

In our study, the Super Inductive System Therapy focused exclusively on making the application at the peripheral level since almost every musculoskeletal disorder is accompanied by pain, and we tried to influence its presence using this type of therapy.

CHAPTER 4 – THE CONTRIBUTION OF HIGH-INTENSITY MAGNETIC FIELD AND SHOCKWAVE THERAPY IN THE PROCESS OF KINETOTHERAPEUTIC RECOVERY IN PATIENTS WITH PATELLOFEMORAL PAIN SYNDROME

4.1. THE PREMISES OF THE RESEARCH

In the third chapter, entitled Preliminary study on the efficiency study on the efficiency of some *physiotherapeutic methods involved in the physiotherapeutic recovery of the functional deficit at the knee level with patellofemoral pain syndrome*, we obtained significant improvements from a statistical point of view for group 2, 3, and 4. These groups of subjects followed functional rehabilitation protocols consisting of a specific kinesitherapy program and Shockwave therapy – (group 2), a specific kinesitherapy program and high-intensity electromagnetic field therapy (SIS) – (group 3), and therapy-based functional rehabilitation program Shockwave and high-intensity electromagnetic field (SIS), without the association of the specific kinetotherapeutic exercise program – (group 4).

This chapter aims to implement a medical recovery protocol based on specific exercises for patients diagnosed with patellofemoral syndrome. The association of state-of-the-art technology with a kinetotherapeutic protocol strictly focused on the imbalances generated by the patellofemoral syndrome at the knee joint level can optimize the medical rehabilitation program from a qualitative point of view and the point of view of treatment duration.

The assessment of muscle strength and the supra-patellar perimeter at the level of the affected lower limb will constitute two additional dependent variables in this chapter, which can provide important information for the protocols used in the research. The performance of statistical analyzes on gender, age differences, and weighting might provide another perspective on the outcomes of functional recovery programs.

4.2. PURPOSE, OBJECTIVES, TASKS, AND HYPOTHESES OF THE RESEARCH

This research aims to highlight the contribution of physical therapy associated with high-intensity magnetic wave therapy and shockwave therapy, in functional rehabilitation, in patients with patellofemoral syndrome.

The objectives of the research are:

- identifying how the functional recovery program of patients diagnosed with patellofemoral pain syndrome can be improved using shockwave therapy;
- carrying out a detailed analysis of the results obtained with the help of the applied recovery protocol and comparing the values obtained to establish an optimal protocol for the rehabilitation of patients diagnosed with patellofemoral pain syndrome;
- formulating some conclusions to highlight the importance of using Shockwave therapy and high-frequency electromagnetic field therapy as an integral part of the functional rehabilitation protocol in the case of patients diagnosed with patellofemoral pain syndrome.

The research started with the following assumptions:

GENERAL HYPOTHESIS I: We assume that, by using the kinetotherapeutic functional rehabilitation program associated with shock wave therapy, in the case of patients with patellofemoral syndrome, we can positively influence the active status of patients with this diagnosis.

Specific HYPOTHESIS I.1: We assume that pain decreases significantly in patients who follow the kinetotherapeutic program associated with shock wave therapy.

Specific HYPOTHESIS I.2: We assume that the mobility of the affected knee can be restored, to a greater extent, in patients who follow the kinetotherapeutic program associated with shock wave therapy.

Specific HYPOTHESIS I.3: We assume that muscle strength can be beneficially influenced, to a greater extent, in patients who follow the kinetotherapeutic program associated with shock wave therapy.

Specific HYPOTHESIS I.4: We assume that muscle volume can be beneficially influenced, to a greater extent, in patients who follow the kinetotherapeutic program associated with shock wave therapy.

GENERAL HYPOTHESIS II: We assume that the effectiveness of each functional rehabilitation program is different, depending on the gender of the subjects.

Specific HYPOTHESIS II.1: We assume that there are gender differences in the reduction of pain in the affected knee through the functional rehabilitation programs used in the study.

Specific HYPOTHESIS II.2: We assume that there are gender differences in terms of restoring mobility to the affected knee through the functional rehabilitation programs used in the study.

Specific HYPOTHESIS II.3: We assume gender differences regarding regaining muscle strength at the level of the affected knee through the functional rehabilitation programs used in the study.

Specific HYPOTHESIS II.4: We assume gender differences regarding restoring muscle trophic from the affected lower limb through the functional rehabilitation programs used in the study.

GENERAL HYPOTHESIS III: We assume that the effectiveness of each of the two functional rehabilitation programs used is different, depending on the age of the subjects.

Specific HYPOTHESIS III.1: We assume that there are age differences regarding reducing pain from the affected knee through the functional rehabilitation programs used in the study.

Specific HYPOTHESIS III.2: We assume that there are age differences in restoring mobility to the affected knee through the functional rehabilitation programs used in the study.

Specific HYPOTHESIS III.3: We assume age differences in regaining muscle strength at the level of the affected knee through the functional rehabilitation programs used in the study.

Specific HYPOTHESIS III.4: We assume age differences regarding the restoration of muscle trophic from the level of the affected lower limb through the functional rehabilitation programs used in the study.

GENERAL HYPOTHESIS IV: We assume that the efficiency of each functional rehabilitation program is different, depending on the subjects' weight.

Specific HYPOTHESIS IV.1: We assume that there are significant differences in the reduction of pain in the affected knee through the functional rehabilitation programs used in the study.

Specific HYPOTHESIS IV.2: We assume that there are weighting differences in restoring mobility to the affected knee through the functional rehabilitation programs used in the study.

Specific HYPOTHESIS IV.3: We assume that there are weighting differences regarding regaining muscle strength at the level of the affected knee through the functional rehabilitation programs used in the study.

Specific HYPOTHESIS IV.4: We assume that there are weighting differences in restoring muscle trophic from the affected lower limb through the functional rehabilitation programs used in the study.

The independent variables of the main study were constituted by the two functional rehabilitation protocols used in the study, the gender, age, and weight of the subjects, and the dependent variables were represented by the level of pain felt, joint amplitude, muscle strength and the supra-patellar perimeter at the level the affected knee.

4.3. RESEARCH METHODS

The bibliographic documentation was used to deepen the information from the specialized literature regarding the application of innovative therapies in the case of patients with patellofemoral syndrome.

Again, **the experimental method** was used in a clinically adapted form on subjects selected according to pathology, the comparison being made on similar groups without a control group.

The testing method was used to create the personal files of the patients and to centralize the results obtained from the tests carried out, from the initial and final point of view, from the point of view of the perceived pain level, joint mobility, muscle strength and perimeter supra-patellar from the level of the affected knee. The tests used in the main study were the VAS scale, joint balance, muscle balance, and thigh circumference measurement.

The statistical method was used to test the hypotheses of the main study. The statistical analyses used to test the ideas were represented by the test for normality of distribution (Shapiro-Wilk), the T-test for paired samples, the Pearson correlation, the independent T-test, the Mann-Whitney test, and the Welch test. The research results were statistically analyzed with the help of SPSS version 29.0.1.0 (171).

4.4. ORGANIZATION AND CONDUCT OF RESEARCH

The research of the main study in the framework of the doctoral thesis took place between June 15 and October 26, 2022, in the Kinego medical rehabilitation clinic in Iași. The clinic has all the necessary equipment for both functional rehabilitation protocols. And this time, I got help and suggestions from the specialist doctor of the clinic.

A number of 64 subjects diagnosed with the patellofemoral syndrome were included in the research of the main study. The subjects included in the research were female (32) and male (32), equally divided into the 2 study groups, aged between 20 and 39 years. They were divided into two groups:

- in the first group, 32 subjects were included who followed a functional rehabilitation program based on Shockwave therapy and high-intensity electromagnetic wave therapy (SIS), lasting approximately three weeks. (without specific physical therapy exercises);
- in the second group, 32 subjects were included who followed a functional rehabilitation program based on Shockwave therapy and specific physical therapy, lasting approximately 14 weeks.

The inclusion criteria for the subjects participating in the study were represented by their diagnosis, age over 18 years, the presence of pain at the anterior level of the knee joint in the case of maintaining a prolonged sitting position or going up and down stairs, the absence of relevant femoral-patellar degenerative changes on imaging,

lack of a positive history of knee trauma, and completion of individualized medical rehabilitation programs for each group.

The exclusion criteria for the patients participating in the study were the absence of any inclusion criteria described above and non-compliance with the applied recovery protocol, either in terms of therapy frequency or time interval.

4.5. RESULTS AND DISCUSSION

GENERAL HYPOTHESIS I – To test the general hypothesis I and the derived specific ideas, the Shapiro-Wilk statistical tests, the paired sample T-test, the Pearson correlation, the Independent T-test, the Mann-Whitney test, and the Welch test were used for each parameter tested, at both groups.

Specific hypothesis I.1. – From the point of view of pain reduction, both groups recorded a favorable evolution in pain reduction. However, the group that followed the protocol of physical therapy associated with shockwave therapy seems to show a more significant reduction of pain than the group that followed the protocol of shockwave therapy associated with high-intensity magnetic wave therapy. In conclusion, the **specific hypothesis I.1. was partially validated.**

Specific hypothesis I.2. – From the point of view of restoring mobility to the affected lower limb, the group that followed the kinesitherapy protocol associated with shockwave therapy experienced a more significant increase in joint mobility compared to the group that followed the protocol consisting of shockwave therapy associated with magnetic wave therapy high intensity. In conclusion, **the specific hypothesis I.2. has been validated.**

Specific hypothesis I.3. – Based on the information presented for testing the specific hypothesis I.3. we can say that from the point of view of restoring the muscle strength of the quadriceps muscle of the affected lower limb. This group that followed the protocol of physical therapy associated with shockwave therapy experienced a more significant increase in muscle strength compared to the group that followed the protocol of shockwave therapy associated with high-intensity magnetic wave therapy. In conclusion, **the specific hypothesis I.3. has been validated.**

Specific hypothesis I.4. – According to the results presented for testing the specific hypothesis I.4. we can say that from the point of view of the supra-patellar perimeter of the affected lower limb, the group that followed the kinesitherapy protocol associated with shockwave therapy experienced a slightly more significant increase in the supra-patellar perimeter compared to the group that followed the protocol formed by shockwave therapy associated with high-intensity magnetic wave therapy. In conclusion, **the specific hypothesis I.4. was partially validated.**

Because the four specific hypotheses statistically support the general hypothesis I, we can conclude that the association of state-of-the-art therapies with the kinetotherapeutic functional rehabilitation program positively influences pain, joint mobility, strength, and muscle trophic. As a result, the general hypothesis was confirmed.

GENERAL HYPOTHESIS II – To test the general hypothesis II and the derived specific hypotheses, the Shapiro-Wilk statistical tests, the paired sample T-test, the Pearson correlation, the Independent T-test, the Mann-Whitney test, and the Welch test were used for each parameter tested, at both groups separated by gender.

Specific hypothesis II.1. – Based on the statistical analyses to test the specific hypothesis II.1. we can say that from the point of view of pain reduction, there are no differences given the gender of the subjects in terms of pain reduction in the affected knee. The group that followed the physical therapy protocol combined with shockwave therapy experienced pain reduction to a greater extent in both men and women than the group that followed the protocol of shockwave therapy combined with high-intensity magnetic wave therapy. In conclusion, the **specific hypothesis II.1. has not been validated.**

Specific hypothesis II.2. – Based on the statistical analyzes carried out to test the specific hypothesis II.2., we can say that from the point of view of restoring mobility at the level of the affected knee, there are no differences given by the gender of the subjects in terms of increasing mobility. The group that followed the physical therapy protocol combined with shockwave therapy experienced increased mobility to a greater extent in both men and women compared to the group that followed the protocol of shockwave therapy combined with magnetic wave therapy of high intensity. If we refer to the results of the Pearson correlation, the means used in protocol 2 (kinetotherapy+shockwave) significantly influenced the flexion values of the female subjects. Some specialized studies support that female patients present differences based on the anatomy and biomechanics of the knee joint, which also explains the increased incidence of this diagnosis among female patients. The specialized literature supports that, in women, the knee joint is more minor and has weaker muscle mass than in men. Gender differences are also indicated in the contact areas of the femoral-patellar joint, the pressure exerted differently at the joint level, and the different response to stimuli of the vastus medialis muscle depending on the gender of the subjects. (Csintalan, R.P., et al. 2002). Considering these anatomical differences in the knee joint, we can assume that regardless of the applied functional rehabilitation program, female subjects could be influenced differently than male subjects. Still, too few subjects participating in the study can affect the present results. In conclusion, **the specific hypothesis II.2. has not been validated.**

Specific hypothesis II.3. – Based on the statistical analyses to test the specific hypothesis II.3. we can say that from the point of view of restoring the muscle strength of the quadriceps muscle of the affected knee, there are no differences given the gender of the subjects in terms of the increase in muscle strength. The group that followed the physical therapy protocol combined with shockwave therapy experienced increases in muscle strength to a greater extent in both men and women compared to the group that followed the protocol consisting of shockwave therapy combined with magnetic wave therapy high intensity.

Suppose we refer to the analysis of the independent T-test. In that case, we can conclude that after the implementation of functional rehabilitation protocols, regardless of which one, men had statistically significant results in the final evaluation of muscle strength compared to women. Given that there are specialized studies supporting potential differences in different muscle masses in women compared to men, these differences could also be observed in our study. To our knowledge, no study to date has compared the strength performance of male and female athletes regarding body composition and muscle architecture, but these indices may be different (Bartolomei, S., Grillone, G., Di Michele, R., & Cortesi, M., 2021). In conclusion, the **specific hypothesis II.3. has not been validated.**

Specific hypothesis II.4. – Based on the statistical analyses to test the specific hypothesis II.4. we can say that from the point of view of the supra-patellar perimeter of the affected knee, there are no differences given the gender of the subjects regarding the increase of this parameter. The group that followed the physical therapy protocol associated with shockwave therapy experienced an increase in suprapatellar perimeter to a greater extent in both men and women compared to the group that followed the protocol of shockwave therapy associated with high-intensity magnetic waves therapy. Given that muscle trophicity is closely related to muscle strength at the level of the quadriceps, there is the possibility that there may also be differences, given the gender of the subjects. Still, the number of subjects participating in the study is too small to reveal statistically significant differences. In conclusion, **the specific hypothesis II.4. has not been validated.**

Given that the four specific hypotheses do not statistically support general hypothesis II, we can conclude that there are no differences given the gender of the subjects in terms of the results of the functional rehabilitation programs used in the study.

GENERAL HYPOTHESIS III – To test the general hypothesis III and the specific hypotheses derived, the Shapiro-Wilk statistical tests, the paired sample T-test, the Pearson correlation, the Independent T-test, the Mann-Whitney test, and the Welch test were used for each parameter tested, at both groups separated by age.

Specific hypothesis III.1. – Based on the statistical analyses to test the particular hypothesis III.1. we can say that from the point of view of pain reduction, the group that followed the physical therapy protocol associated with shockwave therapy experienced pain reduction to a greater extent, both in the case of patients aged between 20-30 years and in the case of subjects aged over 30 years, compared to the group that followed the protocol consisting of shockwave therapy associated with high-intensity magnetic wave therapy. Suppose we refer to the results obtained within the Pearson correlation. In that case, we can see that at the level of subjects aged between 20-30 years, there are enormously significant positive correlations regardless of the applied protocol, while in the case of issues over 30 years old, we correlate positive, very substantial only in the case of group 1 (Shockwave protocol + Super Inductive System). Because the occurrence of associated diagnoses is more common in the case of subjects over 30 years old, and

subjects aged between 20-30 years old have a more alert rhythm of life compared to those over 30 years old, we can affirm the fact that the option of physical treatment with the help of state-of-the-art devices could have better effects at this age. In conclusion, **the specific hypothesis III.1. has not been validated.**

Specific hypothesis III.2. – Based on the statistical analyses to test the specific hypothesis III.2. we can say that from the point of view of restoring mobility from the affected knee, the group that followed the kinesitherapy protocol associated with shockwave therapy experienced an increase in mobility to a greater extent, both in the case of patients aged between 20-30 years and in the case of subjects over 30 years old, compared to the group that followed the protocol consisting of shockwave therapy associated with high-intensity magnetic wave therapy. When analyzing through the independent T-test, we can see that at the level of subjects over 30 years old, we have a statistically significant value for joint mobility at the final evaluation. In conclusion, the **specific hypothesis III.2. has not been validated.**

Specific hypothesis III.3. – Based on the statistical analyses to test the particular hypothesis III.3. we can say that from the point of view of muscle strength, the group that followed the physical therapy protocol associated with shockwave therapy experienced an increase in muscle strength to a greater extent, both in the case of patients aged between 20-30 years and in the case of subjects over 30 years of age, compared to the group that followed the protocol consisting of shockwave therapy associated with high-intensity magnetic wave therapy. Suppose we refer to the results obtained within the Pearson correlation. In that case, we can see that there are enormously significant positive correlations only in the case of protocol 2 (Shockwave + physical therapy) for both age categories. Thus we can affirm that there are no age-related differences in applying functional rehabilitation protocols from the point of view of regaining muscle strength. **Specific hypothesis III.3. has not been validated.**

Specific hypothesis III.4. – Based on the statistical analyses to test the specific hypothesis III.4. we can say that from the point of view of the supra-patellar perimeter, the group that followed the kinesitherapy protocol associated with shockwave therapy experienced a reduction of pain to a greater extent, both in the case of patients aged between 20-30 years and in subjects over 30 years of age, compared to the group that followed the protocol consisting of shockwave therapy associated with high-intensity magnetic wave therapy. From the point of view of restoring muscle trophicity, the programs used in the study are not influenced by the age of the patients. **Specific hypothesis III.4. has not been validated.**

Given that none of the four specific hypotheses statistically support general hypothesis III, we can conclude that the functional rehabilitation protocols used in the study are not influenced differently, depending on the age of the subjects.

GENERAL HYPOTHESIS IV – To test the general hypothesis IV and the specific hypotheses derived, the Shapiro-Wilk statistical tests, Paired Samples T-Test,

Pearson Correlation, Independent T-Test, Mann-Whitney Test, and Welch Test were used for each parameter tested at both groups separated by weight.

Specific hypothesis IV.1. – Based on the statistical analyses conducted to test the particular hypothesis IV.1. we can say that from the point of view of pain reduction, the group that followed the physical therapy protocol associated with shockwave therapy experienced pain reduction to a greater extent, both in the case of average weight and in the case of overweight, compared to the group that followed the protocol consisting of shockwave therapy associated with high-intensity magnetic wave therapy. Thus we can underline that pain reduction by the protocols used in the study is not influenced differently, depending on the subjects' weight. In conclusion, **the specific hypothesis IV.1. has not been validated.**

Specific hypothesis IV.2. – Based on the statistical analyses to test the specific hypothesis IV.2. we can say that from the point of view of restoring the mobility of the affected knee, the group that followed the kinesitherapy protocol associated with shockwave therapy experienced an increase in the mobility of the knee to a greater extent, both in the case of average weight and in the case of overweight, compared to the group that followed the protocol consisting of shockwave therapy combined with high-intensity magnetic wave therapy. Thus we can underline that the restoration of mobility with the help of the protocols used in the study is not influenced differently, depending on the subjects' weight. In conclusion, **the specific hypothesis IV.2. has not been validated.**

Specific hypothesis IV.3. – Based on the statistical analyses to test the specific hypothesis IV.3. we can say that from the point of view of the restoration of muscle strength at the level of the quadriceps, the group that followed the protocol of physical therapy associated with shockwave therapy experienced an increase in muscle strength to a greater extent, both in the case of average weight and in the case of overweight, compared to the group that followed the protocol consisting of shockwave therapy associated with high-intensity magnetic wave therapy. Suppose we refer to the results of the Pearson correlation. In that case, we can see that the presence of enormously significant positive correlations exists only at the level of group 2 of subjects (Shockwave protocol + physical therapy) regardless of the weight of the issues. Thus we can underline that the restoration of muscle strength with the help of the protocols used in the study is not influenced differently, depending on the subjects' weight. In conclusion, **the specific hypothesis IV.3. has not been validated.**

Specific hypothesis IV.4. – Based on the statistical analyses conducted to test the specific hypothesis IV.4. we can say that from the point of view of the supra-patellar perimeter, the group that followed the physical therapy protocol associated with shockwave therapy experienced an increase in muscle strength to a greater extent, both in the case of average weight and in the case of overweight, compared to the group that followed the protocol consisting of shockwave therapy combined with high-intensity magnetic wave therapy. Thus we can underline that the increase of the supra-patellar perimeter with the help of the protocols used in the study is not influenced differently,

depending on the subjects' weight. In conclusion, **the specific hypothesis IV.4. has not been validated.**

Given that the four specific hypotheses do not statistically support the general hypothesis IV, we can conclude that the functional rehabilitation protocols used in the study are not influenced differently, depending on the subjects' weight.

4.6. PARTIAL CONCLUSIONS

Following the results obtained in the study, we can state that the association of state-of-the-art therapies with the kinetotherapeutic functional rehabilitation program positively influences pain, joint mobility, muscle strength, and thigh circumference, to a greater extent, compared to classical physiotherapy associated with the schedule of kinetotherapeutic functional rehabilitation.

Following the results of the statistical tests used, we can conclude that the functional rehabilitation protocols are equally effective, regardless of the gender of the subjects. Some of the correlations that emerged may have important significance. The relationships between the tested parameters may differ or have different degrees of relevance. Still, based on the evaluated sample, we can conclude that the functional rehabilitation protocols used in the study are equally effective, regardless of the age or weight of the subjects.

CONCLUSIONS

Analyzing the results of the present study leads to the conclusion that the identification of a strategy to optimize the functional rehabilitation protocol intended for patients diagnosed with the patellofemoral syndrome is very important because, according to the current studies presented previously, patients in this category are prone to chronic pain, at the installation of imbalances at the level of neighboring joints and implicitly at the level of the spine and the impact of daily personal or professional activities.

The present research suggests that the protocols used in the study beneficially influenced the study participants. In addition, through this study, it was demonstrated that the association of kinesitherapy with Shockwave therapy has a beneficial influence on functional rehabilitation in terms of reducing pain, respectively improving strength, muscle trophic, and joint mobility at the level of the affected knee joint to a greater extent compared to classical functional rehabilitation programs.

The existing correlations regarding the tested parameters highlight new directions of study for researchers in the field of medical rehabilitation, which can help improve the quality of functional rehabilitation programs for patients with this diagnosis.

From the point of view of innovative therapies, the specialist studies consulted in chapters 1 and 2 of this thesis support the applicability of the super inductive system only from the point of view of reducing pain from the affected knee. In contrast, shock wave therapy is based on its applicability within the healing process of patellofemoral syndrome by reducing inflammation and forcing the body to perceive the microtrauma caused, stimulating metabolic reactions. Thus, high-intensity magnetic wave therapy supports only the symptom relief part, while shock wave therapy intervenes and influences the treatment of the cause of the patellofemoral syndrome.

Another important aspect is the contraindications of protocols, including physiotherapy performed with innovative devices. If the therapy is carried out with a high-intensity electromagnetic field, there is a contraindication regarding patients diagnosed with a neoplasm or metal implants in the vicinity of the knee joint (hip, tibia, ankle); They do not influence shockwave therapy and have no contraindications. There are situations in which patients face a patellofemoral syndrome that appears after total hip arthroplasty precisely because of the weakened muscles at the level of the hip joint, and they can only benefit from Shockwave therapy, having the metal implant inserted much too close to the knee joint. If we refer to patients with oncological diagnoses, high-intensity electromagnetic field therapy has contraindications, just as classical physiotherapy is applied to relieve pain. Based on these considerations, from the point of view of the applicability of the protocols used in the study, the protocol that includes Shockwave therapy is more compliant in the case of patients with patellofemoral syndrome.

I believe the functional rehabilitation programs used in the study could undergo significant improvements by selecting the exercises used and increasing the number of repetitions or sets to determine an early increase in muscle strength and supra-patellar

perimeter. The correct execution of the activities within the functional rehabilitation programs is another factor that could contribute positively to improving the results offered by this program, together with the observance of the indications and contraindications provided by the therapist for the performance of leisure activities.

At the same time, I believe that a specific guide in the strategy to approach patellofemoral syndrome can help specialists in the field with detailed information from the point of view of knowledge, prevention, diagnosis, and rehabilitation of this disease.

No side effects were observed during the study. More detailed studies must be conducted to confirm the results and further impact.

LIMITATIONS AND FUTURE DIRECTIONS OF RESEARCH

Following the realization of this doctoral thesis, several research limits were highlighted, as well as some future directions of research, presented in the following.

From the point of view of the limits of the present research, several factors can be listed, such as the number of subjects participating in the study, their selection and evaluation methods, or the way of interpreting the data obtained.

In terms of selection, for the main study, subjects in group 1 (SIS+Shockwave protocol) had a mean age of 29.18 years (standard deviation ± 3.70), and subjects in group 2 (Shockwave+Kinetotherapy) had had an average age of 28 years (standard deviation ± 5.10). Therefore, the subjects' ages were close enough to constitute a valid study.

An aspect that could have been framed within the limits of the research can be represented by how the subjects participating in the study took into account the contraindications and the specific recommendations of the functional rehabilitation program; each subject participating in the study received a series of instructions that they had to follow, and within the rehabilitation program carried out they were respected, but outside the functional rehabilitation program, compliance with the recommendations was up to the subjects participating in the study.

The interpretation of the results was based on both the graphical method and the statistical analysis. This interpretation was based on the collection of the results of several 64 subjects divided into two groups. To carry out research with a broad perspective on the topic addressed in this study, it would have been necessary to include a more significant number of subjects. However, the analysis of the results included in this research allows us to draw some conclusions, at least preliminary ones.

I believe that conducting a study on a larger group of patients could provide more apparent evidence regarding the differences in results by gender, age, and weight in the case of patients diagnosed with patellofemoral syndrome.

Implementing testing through other instruments could be an additional dependent variable through which we could more accurately assess knee joint stability and knee common injury risk bilaterally.

On the other hand, as a direction of practical applicability, the rehabilitation protocols can also be used in the case of patients with associated pathologies because some of them usually accompany the diagnosis of patellofemoral syndrome. Since high-intensity electromagnetic field therapy has shown excellent results in pain reduction, it can form an integral part of the functional rehabilitation protocol based on physical therapy and shockwave therapy in patients who do not present contraindications.

DISSEMINATION OF RESULTS

The results of this research were disseminated by writing and publishing scientific articles, supporting research reports within the Doctoral School in Sports Science and Physical Education, and communicating the data obtained to the subjects participating in the study.

Papers in ISI Proceedings volumes

1. Solomon-Pârțac, M.Ș., Solomon-Pârțac, S. & Dobreanu, I.B. (2020), Study Regarding the Importance of Physical Therapy in the Relief of Vertigo Syndrome in Patients with Cervical Spondylosis, *Proceedings of the 6th International Conference of Universitaria Consortium FEFSTIM: Physical Education, Sports and Kinesiotherapy – Implications in quality life*, Timișoara, 176-183, FILODIRITTO PUBLISHER, **ISBN 979-12-80225-05-4**, https://www.webofscience.com/wos/woscc/full-record/WOS:000682773700027

Papers in international databases

2. Dobreanu, I.B. & Cojocariu, A. (2023), Effects of Physical Therapy in Muscular Strenght and Balance, Pain Relief and Functional Capacity in Patients with Patellofemoral Pain Syndrome, *Sport, And Society, Interdisciplinary Journal of Physical Education and Sports*, 23(1), https://doi.org/10.36836/2023/1/05

3. Dobreanu, I.B. & Cojocariu, A. (2023), Approaching the Patellofemoral Pain Syndrome Through Physiotherapeutic Methods versus Kinetotherapy, *Sport And Society, Interdisciplinary Journal of Physical Education and Sports*, 23(1), https://doi.org/10.36836/2023/1/02

Papers in conference volumes

4. Dobreanu, I.B., & Solomon-Pârțac S. (2021), Study on the Efficacy of Extracorporeal Shock Wave Therapy in the Rehabilitation Treatment of Patients Diagnosed with Jumper Knee, *The 7th International Conference of the Universitaria Consortium in Physical Education, Sports and Physical Therapy*, Iași, 127-133. http://www.edlearning.it/ebook/EY12.pdf

Papers under publication

5. Dobreanu, I.B. & Cojocariu, A. (2021), Study on the efficacy of high intensity electromagnetic field therapy (Super Inductive System) in the management of mechanical knee pain, *First International Conference for PhD Students and PhD Graduates in Sports Science New Trends of Fundamental Research in Sport Science - From research to performance*, Craiova.

6. Dobreanu, I.B., Neculăeș M. & Lucaci P. (2022), Functional Recovery of the Patient after Surgically Reduced Humerus Fractures, *The 8th International Conference of the Universitaria Consortium Education for Health & Performace,* Cluj-Napoca.

7. Neculăeș, M., Lucaci, P. & Dobreanu, I.B. (2022), Current Aspects of Physiotherapy in the Treatment of Plantar Pain, *The 8th International Conference of the Universitaria Consortium Education for Health & Performace,* Cluj-Napoca.

ACKNOWLEDGMENT

The doctoral thesis was developed within the "Alexandru Ioan Cuza din Iasi" University - Doctoral School in Sports Science and Physical Education, based on the Scientific Research Program approved by the Doctoral School Council.

This work was co-funded by the European Social Fund, through Operational Programme Human Capital 2014-2020, project number POCU/993/6/13/153322, project title “Educational and training support for PhD students and young researchers in preparation for insertion in the labor market”.

SELECTIVE REFERENCES

1. Alba-Martín, P., Gallego-Izquierdo, T., Plaza-Manzano, G., Romero-Franco, N., Núñez-Nagy, S., & Pecos-Martín, D. (2015). Effectiveness of therapeutic physical exercise in the treatment of patellofemoral pain syndrome: a systematic review. *Journal of physical therapy science*, *27*(7), 2387–2390. https://doi.org/10.1589/jpts.27.2387
2. Baldon, R., Nakagawa, T. H., Muniz, T. B., Amorim, C. F., Maciel, C. D., & Serrão, F. V. (2009). Eccentric hip muscle function in females with and without patellofemoral pain syndrome. *Journal of athletic training*, *44*(5), 490–496. https://doi.org/10.4085/1062-6050-44.5.490
3. Barton, C. J., Menz, H. B., & Crossley, K. M. (2011). Effects of prefabricated foot orthoses on pain and function in individuals with patellofemoral pain syndrome: a cohort study. Physical therapy in sport : official journal of the Association of Chartered Physiotherapists in Sports Medicine, 12(2), 70–75. https://doi.org/10.1016/j.ptsp.2010.09.002
4. Barton, C. J., Menz, H. B., Levinger, P., Webster, K. E., & Crossley, K. M. (2011). Greater peak rearfoot eversion predicts foot orthoses efficacy in individuals with patellofemoral pain syndrome. British journal of sports medicine, 45(9), 697–701. https://doi.org/10.1136/bjsm.2010.077644
5. Bebeley, Samuel & Wu, Yi-Gang & Liu, Yang. (2016). Athletes' Knowledge about Preventing Sports Injuries as Prime Prevention Strategies in Slowing Ageing Process. *Journal of Exercise Science and Physiotherapy*. 12. 25-37. 10.18376//2016/v12i1/86809
6. Benke, C., Autenrieth, L. K., Asselmann, E., & Pané-Farré, C. A. (2020). Lockdown, quarantine measures, and social distancing: Associations with depression, anxiety and distress at the beginning of the COVID-19 pandemic among adults from Germany. *Psychiatry research*, *293*, 113462. https://doi.org/10.1016/j.psychres.2020.113462
7. Besier, T. F., Fredericson, M., Gold, G. E., Beaupré, G. S., & Delp, S. L. (2009). Knee muscle forces during walking and running in patellofemoral pain patients and pain-free controls. *Journal of biomechanics*, *42*(7), 898–905. https://doi.org/10.1016/j.jbiomech.2009.01.032
8. Blønd, L., & Hansen, L. (1998). Patellofemoral pain syndrome in athletes: a 5.7-year retrospective follow-up study of 250 athletes. Acta orthopaedica Belgica, 64(4), 393–400.
9. Boldt, A. R., Willson, J. D., Barrios, J. A., & Kernozek, T. W. (2013). Effects of medially wedged foot orthoses on knee and hip joint running mechanics in females with and without patellofemoral pain syndrome. Journal of applied biomechanics, 29(1), 68–77. https://doi.org/10.1123/jab.29.1.68
10. Bolgla, L. A., Malone, T. R., Umberger, B. R., & Uhl, T. L. (2008). Hip strength and hip and knee kinematics during stair descent in females with and without patellofemoral pain syndrome. The Journal of orthopaedic and sports physical therapy, 38(1), 12–18. https://doi.org/10.2519/jospt.2008.2462
11. Boling, M., Padua, D., Marshall, S., Guskiewicz, K., Pyne, S., & Beutler, A. (2010). Gender differences in the incidence and prevalence of patellofemoral pain syndrome. Scandinavian journal of medicine & science in sports, 20(5), 725–730. https://doi.org/10.1111/j.1600-0838.2009.00996.x

12. Bowden Davies, K. A., Pickles, S., Sprung, V. S., Kemp, G. J., Alam, U., Moore, D. R., Tahrani, A. A., & Cuthbertson, D. J. (2019). Reduced physical activity in young and older adults: metabolic and musculoskeletal implications. *Therapeutic advances in endocrinology and metabolism*, *10*, 2042018819888824. https://doi.org/10.1177/2042018819888824
13. Brantingham, J. W., Bonnefin, D., Perle, S. M., Cassa, T. K., Globe, G., Pribicevic, M., Hicks, M., & Korporaal, C. (2012). Manipulative therapy for lower extremity conditions: update of a literature review. *Journal of manipulative and physiological therapeutics*, *35*(2), 127–166. https://doi.org/10.1016/j.jmpt.2012.01.001
14. Brent, J. & Myer, G. & Ford, K. & Hewett, T. (2008). A Longitudinal Examination of Hip Abduction Strength in Adolescent Males and Females: 731. Medicine and Science in Sports and Exercise - MED SCI SPORT EXERCISE. 40. 10.1249/01.mss.0000321665.14617.fb
15. Briguglio, M., Giorgino, R., Dell'Osso, B., Cesari, M., Porta, M., Lattanzio, F., Banfi, G., & Peretti, G. M. (2020). Consequences for the Elderly After COVID-19 Isolation: FEaR (Frail Elderly amid Restrictions). *Frontiers in psychology*, *11*, 565052. https://doi.org/10.3389/fpsyg.2020.565052
16. Cavazzuti, L., Merlo, A., Orlandi, F., Campanini, I. (2010). Delayed onset of electromyographic activity of vastus medialis obliquus relative to vastus lateralis in subjects with patellofemoral pain syndrome. *Gait Posture 32* (3):290–295
17. Chen, H.Y., Chien, C.C., Wu, S.K., Liau, J.J., Jan, M.H. (2012). Electromechanical delay of the vastus medialis obliquus and vastus lateralis in individuals with patellofemoral pain syndrome. *J Orthop Sports Phys Ther 42* (9):791–796
18. Clark, D. I., Downing, N., Mitchell, J., Coulson, L., Syzpryt, E. P., & Doherty, M. (2000). Physiotherapy for anterior knee pain: a randomised controlled trial. Annals of the rheumatic diseases, 59(9), 700–704. https://doi.org/10.1136/ard.59.9.700 Claudon, B., Poussel, M., Billon-Grumillier, C., Beyaert, C., Paysant, J. (2012). Knee kinetic pattern during gait and anterior knee pain before and after rehabilitation in patients with patellofemoral pain syndrome. *Gait Posture. 36*(1):139–43.
19. Collins, N. J., Barton, C. J., van Middelkoop, M., Callaghan, M. J., Rathleff, M. S., Vicenzino, B. T., Davis, I. S., Powers, C. M., Macri, E. M., Hart, H. F., de Oliveira Silva, D., & Crossley, K. M. (2018). 2018 Consensus statement on exercise therapy and physical interventions (orthoses, taping and manual therapy) to treat patellofemoral pain: recommendations from the 5th International Patellofemoral Pain Research Retreat, Gold Coast, Australia, 2017. *British journal of sports medicine*, *52*(18), 1170–1178. https://doi.org/10.1136/bjsports-2018-099397
20. Cowan, S. M., Bennell, K. L., & Hodges, P. W. (2002). Therapeutic patellar taping changes the timing of vasti muscle activation in people with patellofemoral pain syndrome. Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine, 12(6), 339–347. https://doi.org/10.1097/00042752-200211000-00004
21. Desmeules, F., Boudreault, J., Roy, J. S., Dionne, C., Frémont, P., & MacDermid, J. C. (2015). The efficacy of therapeutic ultrasound for rotator cuff tendinopathy: A systematic review and meta-analysis. Physical therapy in sport : official journal of the Association of Chartered Physiotherapists in Sports Medicine, 16(3), 276–284. https://doi.org/10.1016/j.ptsp.2014.09.004
22. Domenech, J., Sanchis-Alfonso, V., López, L., & Espejo, B. (2013). Influence of kinesiophobia and catastrophizing on pain and disability in anterior knee pain

patients. *Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA*, *21*(7), 1562–1568. https://doi.org/10.1007/s00167-012-2238-5

23. Draper, C. E., Besier, T. F., Santos, J. M., Jennings, F., Fredericson, M., Gold, G. E., Beaupre, G. S., & Delp, S. L. (2009). Using real-time MRI to quantify altered joint kinematics in subjects with patellofemoral pain and to evaluate the effects of a patellar brace or sleeve on joint motion. Journal of orthopaedic research : official publication of the Orthopaedic Research Society, 27(5), 571–577. https://doi.org/10.1002/jor.20790
24. Draper, C. E., Fredericson, M., Gold, G. E., Besier, T. F., Delp, S. L., Beaupre, G. S., & Quon, A. (2012). Patients with patellofemoral pain exhibit elevated bone metabolic activity at the patellofemoral joint. Journal of orthopaedic research : official publication of the Orthopaedic Research Society, 30(2), 209–213. https://doi.org/10.1002/jor.21523
25. Dursun, N., Dursun, E., & Kiliç, Z. (2001). Electromyographic biofeedback-controlled exercise versus conservative care for patellofemoral pain syndrome. *Archives of physical medicine and rehabilitation*, *82*(12), 1692–1695. https://doi.org/10.1053/apmr.2001.26253
26. Dye S. F. (2005). The pathophysiology of patellofemoral pain: a tissue homeostasis perspective. Clinical orthopaedics and related research, (436), 100–110. https://doi.org/10.1097/01.blo.0000172303.74414.7d
27. Eckenrode, B. J., Kietrys, D. M., & Parrott, J. S. (2018). Effectiveness of Manual Therapy for Pain and Self-reported Function in Individuals With Patellofemoral Pain: Systematic Review and Meta-analysis. *The Journal of orthopaedic and sports physical therapy*, *48*(5), 358–371. https://doi.org/10.2519/jospt.2018.7243
28. Everhart, J. S., Cole, D., Sojka, J. H., Higgins, J. D., Magnussen, R. A., Schmitt, L. C., & Flanigan, D. C. (2017). Treatment Options for Patellar Tendinopathy: A Systematic Review. Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association, 33(4), 861–872. https://doi.org/10.1016/j.arthro.2016.11.007
29. Fulkerson, J. P., & Arendt, E. A. (2000). Anterior knee pain in females. Clinical orthopaedics and related research, (372), 69–73. https://doi.org/10.1097/00003086-200003000-00009
30. Füzéki, E., Groneberg, D. A., & Banzer, W. (2020). Physical activity during COVID-19 induced lockdown: recommendations. *Journal of occupational medicine and toxicology (London, England)*, *15*, 25. https://doi.org/10.1186/s12995-020-00278-9
31. Gabler, C. M., Lepley, A. S., Uhl, T. L., & Mattacola, C. G. (2016). Comparison of Transcutaneous Electrical Nerve Stimulation and Cryotherapy for Increasing Quadriceps Activation in Patients With Knee Pathologies. *Journal of sport rehabilitation*, *25*(3), 294–300. https://doi.org/10.1123/jsr.2014-0292
32. Glowacz, F., & Schmits, E. (2020). Psychological distress during the COVID-19 lockdown: The young adults most at risk. *Psychiatry research*, *293*, 113486. https://doi.org/10.1016/j.psychres.2020.113486
33. Grelsamer, R. (2000). Current concepts review. Patellar malalignment. *J Bone Joint Surg 82A*:1639–1650
34. Harvie, D., O'Leary, T., & Kumar, S. (2011). A systematic review of randomized controlled trials on exercise parameters in the treatment of patellofemoral pain: what works?. Journal of multidisciplinary healthcare, 4, 383–392. https://doi.org/10.2147/JMDH.S24595

35. Heintjes, E., Berger, M. Y., Bierma-Zeinstra, S. M., Bernsen, R. M., Verhaar, J. A., & Koes, B. W. (2003). Exercise therapy for patellofemoral pain syndrome. The Cochrane database of systematic reviews, (4), CD003472. https://doi.org/10.1002/14651858.CD003472
36. Heintjes, E., Berger, M. Y., Bierma-Zeinstra, S. M., Bernsen, R. M., Verhaar, J. A., & Koes, B. W. (2004). Pharmacotherapy for patellofemoral pain syndrome. The Cochrane database of systematic reviews, 2004(3), CD003470. https://doi.org/10.1002/14651858.CD003470.pub2
37. Herrington, L., Al-Sherhi, A. A controlled trial of weight-bearing versus non-weight-bearing exercises for patellofemoral pain. J *Orthop Sports Phys Ther*. 2007;37(4):155–160.
38. Hoch, A. Z., Pepper, M., & Akuthota, V. (2005). Stress fractures and knee injuries in runners. Physical medicine and rehabilitation clinics of North America, 16(3), 749–777. https://doi.org/10.1016/j.pmr.2005.02.008
39. Hryvniak, D., Magrum, E., Wilder, R. (2014). Patellofemoral Pain Syndrome. *Current Physical Medicine and Rehabilitation Reports*; *2*:16.
40. Jayaseelan, D. J., Scalzitti, D. A., Palmer, G., Immerman, A., & Courtney, C. A. (2018). The effects of joint mobilization on individuals with patellofemoral pain: a systematic review. *Clinical rehabilitation*, *32*(6), 722–733. https://doi.org/10.1177/0269215517753971
41. Jensen, R., Hystad, T., Kvale, A., & Baerheim, A. (2007). Quantitative sensory testing of patients with long lasting Patellofemoral pain syndrome. European journal of pain (London, England), 11(6), 665–676. https://doi.org/10.1016/j.ejpain.2006.10.007
42. Jimenez Collado, J., Guillen Garcia, P., Sobrado, J. (1994). *Rodilla. Morfogénesis, anatomíaclínica; vías de acceso*, Ed. Mapfre. Madrid, Spain. ISBN: 84-7100-962-5.
43. Kettunen, J. A., Harilainen, A., Sandelin, J., Schlenzka, D., Hietaniemi, K., Seitsalo, S., Malmivaara, A., & Kujala, U. M. (2007). Knee arthroscopy and exercise versus exercise only for chronic patellofemoral pain syndrome: a randomized controlled trial. BMC medicine, 5, 38. https://doi.org/10.1186/1741-7015-5-38
44. Lake, D. A., & Wofford, N. H. (2011). Effect of therapeutic modalities on patients with patellofemoral pain syndrome: a systematic review. *Sports health*, *3*(2), 182–189. https://doi.org/10.1177/1941738111398583
45. Lankhorst, N. E., Bierma-Zeinstra, S. M., & van Middelkoop, M. (2013). Factors associated with patellofemoral pain syndrome: a systematic review. British journal of sports medicine, 47(4), 193–206. https://doi.org/10.1136/bjsports-2011-090369
46. Lopes, A. D., Costa, L. O., Saragiotto, B. T., Yamato, T. P., Adami, F., & Verhagen, E. (2011). Musculoskeletal pain is prevalent among recreational runners who are about to compete: an observational study of 1049 runners. Journal of physiotherapy, 57(3), 179–182. https://doi.org/10.1016/S1836-9553(11)70039-X
47. Luceri, F., Morelli, I., Accetta, R., Mangiavini, L., Maffulli, N., & Peretti, G. M. (2020). Italy and COVID-19: the changing patient flow in an orthopedic trauma center emergency department. *Journal of orthopaedic surgery and research*, *15*(1), 323. https://doi.org/10.1186/s13018-020-01816-1
48. MacIntyre, N. J., Hill, N. A., Fellows, R. A., Ellis, R. E., & Wilson, D. R. (2006). Patellofemoral joint kinematics in individuals with and without patellofemoral pain syndrome. The Journal of bone and joint surgery. American volume, 88(12), 2596–2605. https://doi.org/10.2106/JBJS.E.00674

49. Mølgaard, C., Rathleff, M. S., & Simonsen, O. (2011). Patellofemoral pain syndrome and its association with hip, ankle, and foot function in 16- to 18-year-old high school students: a single-blind case-control study. Journal of the American Podiatric Medical Association, 101(3), 215–222. https://doi.org/10.7547/1010215
50. Mukhtar S. (2020). Psychological health during the coronavirus disease 2019 pandemic outbreak. *The International journal of social psychiatry*, *66*(5), 512–516. https://doi.org/10.1177/0020764020925835
51. Myer, G. D., Ford, K. R., Barber Foss, K. D., Goodman, A., Ceasar, A., Rauh, M. J., Divine, J. G., & Hewett, T. E. (2010). The incidence and potential pathomechanics of patellofemoral pain in female athletes. Clinical biomechanics (Bristol, Avon), 25(7), 700–707. https://doi.org/10.1016/j.clinbiomech.2010.04.001
52. Nagakawa, T., Muniz, T., de Marche Baldon, R. The effect of additional strengthening of hip abductor and lateral rotator muscles in patellofemoral pain syndrome: a randomised controlled pilot study. *Clin Rehabil*. 2008;22(12):1051–1060.
53. Nascimento, L. R., Teixeira-Salmela, L. F., Souza, R. B., & Resende, R. A. (2018). Hip and Knee Strengthening Is More Effective Than Knee Strengthening Alone for Reducing Pain and Improving Activity in Individuals With Patellofemoral Pain: A Systematic Review With Meta-analysis. *The Journal of orthopaedic and sports physical therapy*, *48*(1), 19–31. https://doi.org/10.2519/jospt.2018.7365
54. Nimon, G., Murray, D., Sandow, M., & Goodfellow, J. (1998). Natural history of anterior knee pain: a 14- to 20-year follow-up of nonoperative management. Journal of pediatric orthopedics, 18(1), 118–122.
55. Nouri, F., Raeissadat, S. A., Eliaspour, D., Rayegani, S. M., Rahimi, M. S., & Movahedi, B. (2019). Efficacy of High-Power Laser in Alleviating Pain and Improving Function of Patients With Patellofemoral Pain Syndrome: A Single-Blind Randomized Controlled Trial. Journal of lasers in medical sciences, 10(1), 37–43. https://doi.org/10.15171/jlms.2019.06
56. ountoulakis, K. N., Apostolidou, M. K., Atsiova, M. B., Filippidou, A. K., Florou, A. K., Gousiou, D. S., Katsara, A. R., Mantzari, S. N., Padouva-Markoulaki, M., Papatriantafyllou, E. I., Sacharidi, P. I., Tonia, A. I., Tsagalidou, E. G., Zymara, V. P., Prezerakos, P. E., Koupidis, S. A., Fountoulakis, N. K., & Chrousos, G. P. (2021). Self-reported changes in anxiety, depression and suicidality during the COVID-19 lockdown in Greece. *Journal of affective disorders*, *279*, 624–629. https://doi.org/10.1016/j.jad.2020.10.061
57. Padua, D.A., Marshall, S.W., Beutler, A.I., Demaio, M., Boden, B.P., Yu, B., Garrett, W.E. (2005). Predictors of knee valgus angle during a jump-landing task. *Med Sci Sports Exerc 37*:398–404
58. Pal, S., Draper, C. E., Fredericson, M., Gold, G. E., Delp, S. L., Beaupre, G. S., & Besier, T. F. (2011). Patellar maltracking correlates with vastus medialis activation delay in patellofemoral pain patients. The American journal of sports medicine, 39(3), 590–598. https://doi.org/10.1177/0363546510384233
59. Park, S. K., & Stefanyshyn, D. J. (2011). Greater Q angle may not be a risk factor of patellofemoral pain syndrome. Clinical biomechanics (Bristol, Avon), 26(4), 392–396. https://doi.org/10.1016/j.clinbiomech.2010.11.015
60. Patil, S., White, L., Jones, A., & Hui, A. C. (2010). Idiopathic anterior knee pain in the young. A prospective controlled trial. Acta orthopaedica Belgica, 76(3), 356–359.

61. Pattyn, E., Verdonk, P., Steyaert, A., Vanden Bossche, L., Van den Broecke, W., Thijs, Y., & Witvrouw, E. (2011). Vastus medialis obliquus atrophy: does it exist in patellofemoral pain syndrome?. *The American journal of sports medicine*, *39*(7), 1450–1455. https://doi.org/10.1177/0363546511401183
62. Petersen, W., Ellermann, A., Gösele-Koppenburg, A., Best, R., Rembitzki, I. V., Brüggemann, G. P., & Liebau, C. (2014). Patellofemoral pain syndrome. Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA, 22(10), 2264–2274. https://doi.org/10.1007/s00167-013-2759-6
63. Petersen, W., Ellermann, A., Liebau, C., Brüggemann, GP., Best, R., Gösele-Koppenburg, A., Semsch, H., Albasini, A., Rembitzki, I. (2010). Das patellofemorale schmerzsyndrom. *Orthopädische Praxis 46*(8):34–42
64. Prins, M. R., & van der Wurff, P. (2009). Females with patellofemoral pain syndrome have weak hip muscles: a systematic review. The Australian journal of physiotherapy, 55(1), 9–15. https://doi.org/10.1016/s0004-9514(09)70055-8
65. Rathleff, M. S., Roos, E. M., Olesen, J. L., Rasmussen, S., & Arendt-Nielsen, L. (2013). Lower mechanical pressure pain thresholds in female adolescents with patellofemoral pain syndrome. The Journal of orthopaedic and sports physical therapy, 43(6), 414–421. https://doi.org/10.2519/jospt.2013.4383
66. Rehman, U., Shahnawaz, M. G., Khan, N. H., Kharshiing, K. D., Khursheed, M., Gupta, K., Kashyap, D., & Uniyal, R. (2021). Depression, Anxiety and Stress Among Indians in Times of Covid-19 Lockdown. *Community mental health journal*, *57*(1), 42–48. https://doi.org/10.1007/s10597-020-00664-x
67. Robinson, R. L., & Nee, R. J. (2007). Analysis of hip strength in females seeking physical therapy treatment for unilateral patellofemoral pain syndrome. The Journal of orthopaedic and sports physical therapy, 37(5), 232–238. https://doi.org/10.2519/jospt.2007.2439
68. Sayac, G., Goimard, A., Klasan, A., Putnis, S., Bergandi, F., Farizon, F., Philippot, R., & Neri, T. (2021). The anatomy of Kaplan fibers. Archives of orthopaedic and trauma surgery, 141(3), 447–454. https://doi.org/10.1007/s00402-020-03718-7
69. Singh, S., Roy, D., Sinha, K., Parveen, S., Sharma, G., & Joshi, G. (2020). Impact of COVID-19 and lockdown on mental health of children and adolescents: A narrative review with recommendations. *Psychiatry research*, *293*, 113429. https://doi.org/10.1016/j.psychres.2020.113429
70. Smith, B. E., Moffatt, F., Hendrick, P., Bateman, M., Rathleff, M. S., Selfe, J., Smith, T. O., & Logan, P. (2018). The experience of living with patellofemoral pain-loss, confusion and fear-avoidance: a UK qualitative study. *BMJ open*, *8*(1), e018624. https://doi.org/10.1136/bmjopen-2017-018624
71. Stathopulu, E., & Baildam, E. (2003). Anterior knee pain: a long-term follow-up. Rheumatology (Oxford, England), 42(2), 380–382. https://doi.org/10.1093/rheumatology/keg093
72. Thomas, M. J., Wood, L., Selfe, J., & Peat, G. (2010). Anterior knee pain in younger adults as a precursor to subsequent patellofemoral osteoarthritis: a systematic review. BMC musculoskeletal disorders, 11, 201. https://doi.org/10.1186/1471-2474-11-201
73. Tsuji, T., Matsuyama, Y., Goto, M., Yimin, Y., Sato, K., Hasegawa, Y., & Ishiguro, N. (2002). Knee-spine syndrome: correlation between sacral inclination and patellofemoral joint pain. Journal of orthopaedic science : official journal of the Japanese Orthopaedic Association, 7(5), 519–523. https://doi.org/10.1007/s007760200092

74. Utting, M. R., Davies, G., & Newman, J. H. (2005). Is anterior knee pain a predisposing factor to patellofemoral osteoarthritis?. The Knee, 12(5), 362–365. https://doi.org/10.1016/j.knee.2004.12.006
75. White, L. C., Dolphin, P., & Dixon, J. (2009). Hamstring length in patellofemoral pain syndrome. Physiotherapy, 95(1), 24–28. https://doi.org/10.1016/j.physio.2008.05.009
76. Willy, R. W., Hoglund, L. T., Barton, C. J., Bolgla, L. A., Scalzitti, D. A., Logerstedt, D. S., Lynch, A. D., Snyder-Mackler, L., & McDonough, C. M. (2019). Patellofemoral Pain. *The Journal of orthopaedic and sports physical therapy*, *49*(9), CPG1–CPG95. https://doi.org/10.2519/jospt.2019.0302
77. Witvrouw, E., Lysens, R., Bellemans, J., Cambier, D., & Vanderstraeten, G. (2000). Intrinsic risk factors for the development of anterior knee pain in an athletic population. A two-year prospective study. The American journal of sports medicine, 28(4), 480–489. https://doi.org/10.1177/03635465000280040701
78. Witvrouw, E., Lysens, R., Bellemans, J., Peers, K., & Vanderstraeten, G. (2000). Open versus closed kinetic chain exercises for patellofemoral pain. A prospective, randomized study. The American journal of sports medicine, 28(5), 687–694. https://doi.org/10.1177/03635465000280051201
79. Wu, C. C., & Shih, C. H. (2004). The influence of iliotibial tract on patellar tracking. Orthopedics, 27(2), 199–203. https://doi.org/10.3928/0147-7447-20040201-12
80. Yu, H., Randhawa, K., Côté, P., & Optima Collaboration (2016). The Effectiveness of Physical Agents for Lower-Limb Soft Tissue Injuries: A Systematic Review. *The Journal of orthopaedic and sports physical therapy*, *46*(7), 523–554. https://doi.org/10.2519/jospt.2016.6521
81. Zagra, L., Faraldi, M., Pregliasco, F., Vinci, A., Lombardi, G., Ottaiano, I., Accetta, R., Perazzo, P., & D'Apolito, R. (2020). Changes of clinical activities in an orthopaedic institute in North Italy during the spread of COVID-19 pandemic: a seven-week observational analysis. *International orthopaedics*, *44*(8), 1591–1598. https://doi.org/10.1007/s00264-020-04590-1