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Original Article

Comparative analysis of treatment strategies for groin injuries in athletes: Effects on successful recovery and recurrence of sports conditions – A systematic review☆

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ABSTRACT

Core muscle injuries, characterized by pubic region pain from muscle and tendon damage, present challenges in athletic recovery. Treatment for pubic pain in athletes often involves a combination of clinical approaches and surgical interventions, typically requiring long recovery periods. This study systematically reviews the treatment methods for groin pain in athletes and evaluates the return to sports outcomes. A total of 86 studies were reviewed, with 30 included in the qualitative analysis. The findings suggest a stepwise approach starting with conservative treatments, such as shockwave therapy, manual therapy, and exercise. If no improvement is observed within 3 to 6 months, surgery is considered. Procedures like adductor tenotomy and selective release have shown effectiveness in facilitating return to sports. Core muscle injuries require personalized treatment plans, with promising outcomes from conservative methods and effective surgical options for severe cases, leading to safe and complete recovery in most athletes.
Level of evidence: 1

What is already known:

- Core muscle injuries, also known as sports hernias, are a common cause of pubic pain in athletes, typically affecting the muscles and tendons in the groin region.

- Treatment for these injuries varies and may include both conservative methods (such as shockwave therapy, manual therapy, and exercise) and surgical interventions.

- Recovery from these injuries can be slow, with different approaches leading to varying outcomes in terms of pain relief and return to sports.

What are the new findings:

- The systematic review suggests a stepped strategy for treating groin and adductor region injuries in athletes, beginning with conservative therapies.

- If conservative treatments do not show improvement within 3 to 6 months, surgical interventions, such as adductor tenotomy and selective release, have been effective in allowing athletes to return to sports.

- Surgery, particularly when combined with hernioplasty, has achieved good to excellent outcomes in 80 % of cases, indicating its effectiveness for more severe injuries.

Introduction

The Core Muscle Injury is a medical condition characterized by pain in the inguinal and pubic region, resulting from inflammation or injury to the muscles and tendons in that area.[1] It is common among athletes participating in sports with repetitive movements such as soccer, hockey, and rugby, as well as individuals engaged in activities requiring constant physical effort in the abdominal and pelvic region.[2,3] According

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to the FIFA (Fédération Internationale de Football Association)[4] ranking, athletic groin pain is considered a severe pathology due to the extended absence from the game required for its treatment.[1] The diverse range of injuries affecting the pubic region, associated with various classifications, presents significant challenges in the clinical presentation of this condition.[5,6]

Pain in the pubic region is a frequent issue in sports involving rapid changes of direction.[7–9] Several studies report incidence rates of all injuries in the pubic symphysis of up to 19 % of the total injuries,[4,10–13] with it representing up to 10 % of all absences from sports activities in soccer alone.[13,14] When comparing between men and women, the proportion of groin injuries in soccer ranges from 4 % to 19 % in men and 2 % to 14 % in women during the annual season,[11] often leading to the absence from athletic activities[7,8] and a decline in athletic performance.[9]

The groin region has a complex anatomy with numerous structures that can cause pain during physical activity.[14] The forces exerted on the myofascial structures attached to crucial points can result in tissue injury or compression of pelvic anatomical structures, leading to pain.[13] Symptoms may arise from systemic, gynecological, urogenital, gastrointestinal, neurological, and musculoskeletal structures,[14] making the terminology surrounding groin pain confusing and challenging for research interpretation.[15]

After a brief period of relative rest, the disease's natural history may evolve favorably in some cases, but certain injuries may result in a longer rehabilitation time or become chronic.[16,17] Some studies have established a direct relationship between injuries and the success of professional teams.[6,18,19] Ekstrand[19] demonstrate that sports injuries are so costly that coaches and administrators should be involved in the treatment and prevention process, as it is estimated to cost €500,000 per injury per athlete in total.[19] Due to the multifactorial origin, controlling groin pain becomes a challenge, and the treatment may involve various approaches, including physiotherapy programs, pharmacological treatments, outpatient interventions, and surgical interventions. Long-term groin pain is known to be resistant to many treatment options and may have slow recovery times.[20–22]

A recent systematic review on the management of athletic groin pain highlighted the ongoing challenge posed by the low methodological quality of studies in this area.[20] Furthermore, while some studies have explored both conservative and surgical treatment options for this pathology, clear evidence-based recommendations remain elusive. Similarly, Ramazzina et al.[1] underscored the persistent challenge faced by physicians and researchers in effectively managing inguinal pain in athletes. Generally, conservative treatment is initially attempted, with surgery being considered after failed conservative measures.[14,21,22]

The methodologies used in previous studies involving available literature did not provide a clear answer on the optimal way to treat this multifactorial pathology concerning the goal of a faster return to the game. Thus, this study aims to systematically review pubalgia in athletes, considering treatment methods and successful return to sports with the associated time frame.

Methodology

Data sources and searches

A systematic review was conducted following the recommendations of the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA).[23] The study was pre-registered in the International Prospective Register of Systematic Reviews (PROSPERO: CRD42023430694). The AMSTAR (Assessing the Methodological Quality of Systematic Reviews) criteria was followed to ensure the methodological quality of our systematic review.[24]

The search was performed in three electronic databases: PubMed-MEDLINE, Web of Science, and Cochrane Library, with no date restrictions, from inception until April 30, 2023. Two independent reviewers assessed all potentially eligible studies identified through the search strategy. A systematic search strategy was developed by gathering key ideas following the PICO strategy: (1) population: Athletes with pubalgia; (2) intervention: Treatment options for return to play; (3) control or comparison: Different existing and performed treatments; and (4) variables: Site of the injury, follow-up time, sport practiced, and effect on return to sports.

Data extraction and selection criteria

The following inclusion criteria were considered: (1) Athletes diagnosed with pain in the pubic region treated either conservatively or surgically; (2) A quantitative outcome measure in terms of successful treatment, recovery rate, percentage of athletes returning to play after treatment, pain scores, functional outcome scores, or patient satisfaction; (3) Case-control studies or case series with $n \geq 10$; (4) Studies that clearly indicated the nature of the treatment. Conversely, studies were excluded if they included (1) articles not written in English, Spanish, or Portuguese. (2) studies on intra-articular hip pathologies (e.g., osteoarthritis and femoroacetabular impingement) and isolated nerve injuries. (3) Articles published before 2005 were excluded from the final analysis to stay updated with the advancement of literature on the topic and the latest treatment options.

Studies that met inclusion and exclusion criteria were coded and stored, including participant details (age, gender, BMI, activity level) and methodological aspects (study design, injury type, treatment details, return-to-play time).

Analysis of results

Appropriate treatment of pubalgia is essential to enable a successful return to play and prevent recurrences. When evaluating the results of pubalgia treatment, various variables can be considered to determine the effectiveness of the interventions applied.[6,25] One important variable to consider is improvement in pain scores. Pubalgia is often associated with pain in the groin and pelvic area, which can limit the athlete's ability to participate in their sport.[25] Another variable to consider is the outcome of improved functional scores. Pubalgia can negatively impact function and athletic performance, making the return to play challenging.[26,27] In addition to subjective measures of pain and function, it is essential to consider the percentage of documented athletes returning to play after pubalgia treatment. The primary goal of treatment is to enable athletes to resume their sports activity safely and effectively.

An analysis of pubalgia treatment results was conducted, considering the following variables to determine the return to play: improvement in pain scores, improved functional score results, and the percentage of documented athletes who returned to play. The analysis was carried out by a reviewer who did not have access to information about the study's quality, registered publication data, number of participants, study design, diagnosis, or intervention. Primary results were extracted from published articles to assess the success of the applied interventions.

Bias risk

The methodological quality and risk of bias of the selected studies were assessed using the Downs and Black Scale.[28] The assessment of methodological quality was conducted in duplicate, reaching a consensus in case of any discrepancies between the evaluations.

Results

Search results and general participant characteristics and protocols

A total of 1296 articles were identified in the initial search. After removing duplicate articles, the titles, and abstracts of 858 articles were

reviewed. Subsequently, 86 full articles were examined. Finally, 30 studies were selected for inclusion in the statistical analysis (Fig. 1).

The characteristics of the studies included in the systematic review are described in Table 1. A total of 30 studies with 1931 participants were included in the statistical analyses.[29–58] The follow-up varied among studies, with an average of 19.19 months (range: 2–72). Among the 30 studies included in the systematic review, football was the most prevalent sport studied in 12 of them, followed by athletics with 6 occurrences. Rugby was mentioned 3 times, hockey 3 times, while American football and baseball were mentioned 2 times each. Basketball, triathlon, tennis, cycling, Australian football, and speed skating appeared in one study each. Additionally, 16 studies focused on various sports and/or did not mention the sport they were studying.

The analysis of the studies reveals that groin pain is most associated with adductor injuries in the mentioned studies ($n = 11$). Thirteen studies did not specify the type of pubalgia studied. In this regard, due to the etiology of the pain, a wide range of strategies are observed for treating injuries in the groin and adductor region.

The obtained results show a wide range of approaches to treating injuries in the groin and adductor region. Among the most mentioned surgical procedures are adductor tenotomy, both individually and in combination with other procedures such as hernioplasty. Approaches such as selective partial release of the long adductor and fascial release of the rectus abdominis are also highlighted, each with its own variant of repair. In contrast to surgical interventions, non-surgical approaches are present, such as shock wave therapies, manual therapies, exercise therapies, and modified therapeutic exercise protocols.

Studies have demonstrated a satisfactory long-term outcome, with approximately 75 % of athletes able to return to their previous level in "Adductor Tenotomy," "Rectus Abdominis Tenotomy," or a combination of both.[29] On the other hand, "Selective Partial Release of the Long Adductor" has allowed 42 out of 43 athletes to return to their previous level after an average period of 9.21 weeks.[30] Surgery has also proven effective in cases such as Adductor Tenotomy combined with hernioplasty, achieving 80 % good or excellent results.[31] Additionally, surgery has provided hope for professional football players whose non-surgical treatments had failed, enabling their return to sports activity.

Various repair procedures, from "Placement of an endoscopic mesh after reducing a possible hernia"[42] with all athletes returning to sports, to "Open repair with minimal repair sutures,"[53] have offered viable solutions for the treatment of groin injuries in athletes. Furthermore, "Reinforced open inguinal repair with mesh" has proven to be an effective technique for relieving pain and restoring activity in hockey athletes.[44]

Beyond surgical options, conservative treatments have been explored with encouraging results. "Shock Wave Therapy" has been shown to be effective in reducing pain and returning to sports within 3 months after the injury.[34] Football players receiving shock wave therapy experienced earlier pain relief on the pain scale ($p < 0.001$) and returned to football significantly earlier ($p = 0.048$) than players without this therapy. Forty-two out of forty-four players from both study groups returned to football within four months after starting therapy and did not have recurrent groin pain within the year following the trauma.[34] Both "Manual Therapy" and "Exercise Therapy" led to a significant decrease in pain scores during sports practice, with manual therapy allowing a faster return to sports.[35] Athletes who received manual therapy returned to sports faster (12.8 weeks) than athletes in the exercise therapy group (17.3 weeks; $p = 0.043$).

In terms of exercise protocols, the "Modified Hölmich Therapeutic Exercise Protocol" has achieved significant improvements in all clinical measures within a 10-week period ($p < 0.05$).[38]

Quality of the studies

For the assessment of the studies, we employed the Downs and Black scale.[28] The Downs and Black scale is a tool used to evaluate the quality

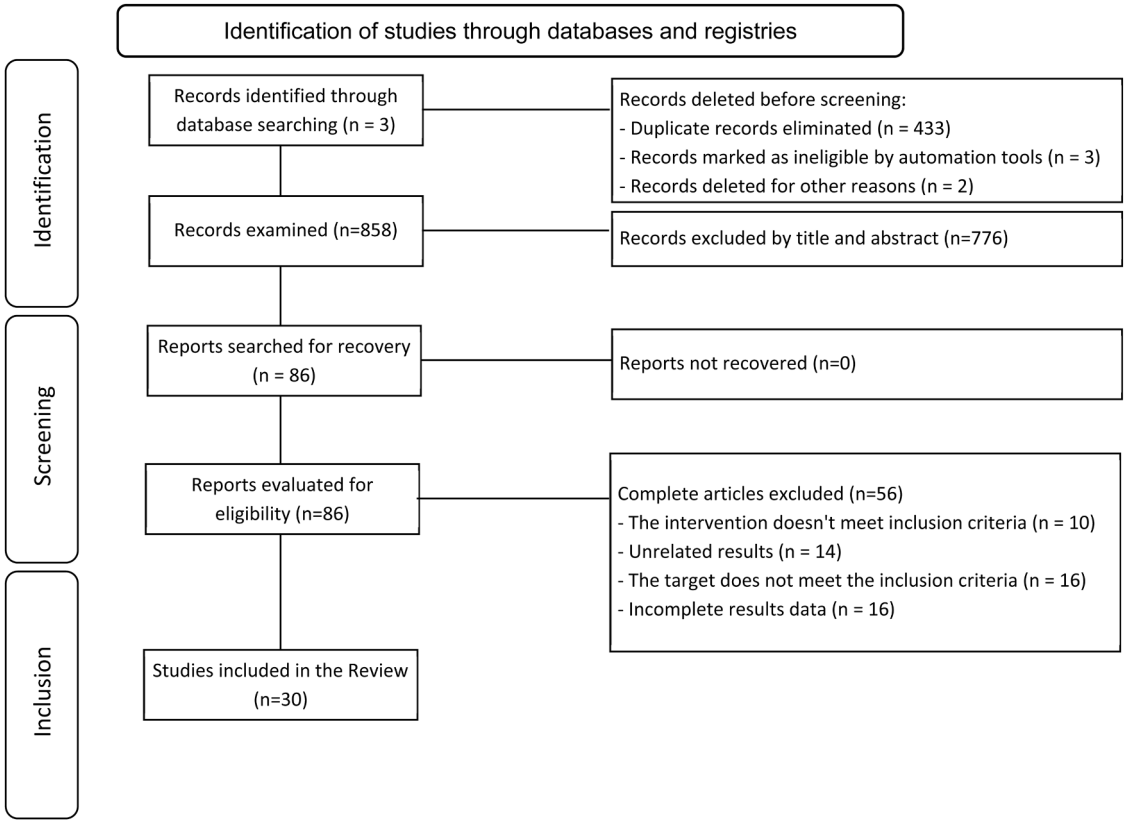

Fig. 1. PRISMA flowchart of the study selection for the review.

Table 1
Record of the characteristics of the studies included in the systematic review.

Study	Number of Athletes	Follow-up (Months)	Sport Practiced	Location of the study	Injury Site	Treatment	Effect
Sansone et al.[29]	32	72	Football, Hockey, Athletics	Mölndal, Sweden	Adductor longus and rectus abdominis	Adductor tenotomy, rectus abdominis tenotomy, or both	Long-term satisfactory result, ¾ athletes able to return
Schilders et al.[30]	43	40	Football, Rugby	London, UK	Adductor dysfunction	Partial selective release of the long adductor	Forty-two out of forty-three athletes returned to their pre-injury level after an average of 9.21 weeks.
Mei-Dan et al.[31]	155	4	Football	Aurora, USA	Adductor dysfunction	Adductor tenotomy (96) and combined adductor tenotomy with hernioplasty (59)	80 % good or excellent results. Surgical intervention allows return to sports at the same level in professional football players after non-surgical treatments have failed.
Sheen et al.[32]	65	3	n/a	Manchester, UK	Unspecified pubalgia	Minimally invasive open repair with suturing and total extraperitoneal repair	Both procedures were equally effective in treating chronic pain.
Paajanen H et al.[33]	60	12	Various	Kuopio, Finland	Adductor dysfunction	Fully extraperitoneal repair with a mesh behind the symphysis	Endoscopic placement of a retropubic mesh was more efficient than conservative therapy.
Schöberl et al.[34]	143	12	Football	Regensburg, Germany	Unspecified pubalgia	Shockwave therapy	Significantly reduced pain, allowing return to football within 3 months of trauma.
Weir et al.[35]	54	24	Football, Hockey, Rugby, Athletics	Leidschendam, Netherlands	Adductor dysfunction	Manual therapy or exercise therapy	Significant decrease in pain scores during sports in 4 months. Manual therapy group returned to sports significantly faster than the exercise therapy group.
Yousefzadeh et al.[36]	15	10	Various	Tehran, Iran	Adductor tendons and/or their insertion into the pubic bone	Modified Hölmich therapeutic exercise protocol	Could be safer and more effective than the Hölmich protocol in athletes to promote their return to sports.
Harr et al.[37]	22	2	Frisbee, Football, Athletics	Washington, USA.	Rectus and adductor tendons	Fascial release of the rectus abdominis and adductor tenotomy	Tenotomies along with herniorrhaphy may improve outcomes.
Mazbouh et al.[38]	10	2.5	Various	Tehran, Iran	Long adductor dysfunction	Modified Hölmich therapeutic exercise protocol	Significant improvements in all clinical measures with all participants in 10 weeks.
Ahumada et al.[39]	12	4	Athletics, Basketball, Football, American Football, Baseball	Birmingham, USA	Unspecified Pubalgia	Open inguinal repair reinforced with mesh	Open approach using mesh relieves pain and restores activity.
Canonico et al.[40]	16	3	Football	Naples, Italy	Inguinal Pain-Related Pubalgia	Lichtenstein Suture technique and human fibrin glue for mesh fixation	Confirms the effectiveness of suture, tension-free hernia repair with human fibrin glue in treating footballers with pubalgia.
Schilders et al.[41]	24	12	Various	Bradford, UK	Long Adductor Dysfunction	Single injection in the pubic cleft of local anesthetic and steroid at the adductor enthesis	Provides at least one year of relief from adductor-related inguinal pain in a competitive athlete with normal MRI findings.
Van Veen et al.[42]	38	3	Football, Triathlon, Athletics, Tennis, Cycling, Baseball, Ice Skating	Rotterdam, Netherlands	Unspecified Pubalgia	Endoscopic mesh placement after reducing a possible hernia	All athletes returned to their normal sports level within 3 months after the operation.
Verrall et al.[43]	27	3	Australian Football	Adelaide, Australia	Pubic Bone Stress Injury	3 months complete rest from active weight-bearing activities	Excellent outcome when evaluated according to the return-to-sport criterion.
Brown et al.[44]	98	72	Hockey	Montreal, Canada	Unspecified Pubalgia	Repair of an external oblique muscle tear and fascia reinforced with a mesh	Resulted in resolution of refractory inguinal pain and return to play in elite hockey player.
de Queiroz et al.[45]	30	36	Football	São Paulo, Brazil	Unspecified Pubalgia	Partial bilateral long adductor tenotomy with trapezial resection of the pubic symphysis	Excellent treatment option for refractory cases and allowing return to sports, especially

(*continued on next page*)

Table 1 (*continued*)

Study	Number of Athletes	Follow-up (Months)	Sport Practiced	Location of the study	Injury Site	Treatment	Effect
							among professional football players.
Garvey et al.[46]	100	6	Football	Sydney, Australia	Rectus Abdominis, Joint Tendinopathy, Inguinal Disruption, Classic Hernia, Traumatic Pubic Osteitis, Pubic Bone Avulsion Fracture	Inguinal reconstruction, open hernia repair with or without mesh, sports hernia repair, laparoscopic repair, conjoint tendon repair, adductor tenotomy.	Aim to strengthen anterior pelvic soft tissues supporting and stabilizing the pubic symphysis. Combined success rate for conservative treatment and surgery was 94 %.
Economopoulos et al.[47]	28	6/12	Various	Charlottesville, USA	Unspecified Pubalgia	Suturing of the transversus abdominis muscle aponeurosis to the sloping edge of the inguinal ligament	Minimal repair technique allows athletes with sports hernias to return to play faster than those treated with modified Bassini method.
Comin et al.48	36	6	Various	Melbourne, Australia	Unspecified Pubalgia	Pulsed radiofrequency (PRF)	Results suggest symptoms can be eliminated with pharmacological or radiofrequency treatment, which is safe and effective, at least in the short term, and superior to anesthetic/steroid injection.
Messaoudi et al.[49]	18	48	Football	Deurne, Belgium	Unspecified Pubalgia	Open surgical repair of combined hernia with long adductor tenotomy	Conservative management often fails. Open surgical repair of combined hernia with long adductor tenotomy relieves symptoms and restores activity in 95 % of athletes.
Maffulli et al.[50]	29	36	Various	London, UK	Long Adductor Dysfunction	Bilateral adductor tenotomy	Minimally invasive bilateral adductor tenotomy may be an effective treatment for inguinal pain associated with refractory long adductor tendinopathy.
Dojcinovic et al.[51]	99	72	Various	Zagreb, Croacia	Long Adductor Dysfunction	Adductor tenotomy	Adductor tendinosis may be present in many cases and is isolated from cases with chronic groin pain and should be treated by tenotomy.
Robertson et al.[52]	109	26	Various	Dublin, Ireland	Long Adductor Dysfunction	Adductor tenotomy	Adductor tenotomy in athletes with severely disabling pain that does not respond to conservative treatment offers the best chance of returning to competitive sports.
Muschaweck et al.[53]	129	12	Various	München, Germany	Unspecified Pubalgia	Open repair with "Minimal Repair" sutures	Minimal Repair technique is an effective and safe way to treat athlete's groin.
Schlegel et al.[54]	19	2	American Football	Greenwood Village, USA	Complete Proximal Adductor Rupture	Physiotherapy (14). Surgical repair using suture anchors (5)	Non-surgical treatment of complete proximal adductor tendon rupture results in statistically significantly faster return to play than surgical treatment in NFL athletes.
Mann et al.[55]	73	3	Various	Leicester, UK	Unspecified Pubalgia	Laparoscopic inguinal release	Laparoscopic inguinal release procedure may be effective in treating a subset of athletes with groin pain.
Jansen et al.[56]	21	14	Various	Rotterdam, Netherlands	Unspecified Pubalgia	Physiotherapy	Significant overall decrease in self-reported sports restriction after intervention for this group of athletes.
Atkinson et al.[57]	48	25	Various	London, UK	Unspecified Pubalgia	Percutaneous adductor tenotomy	Adductor tenotomy provides good symptomatic and functional improvement in chronic adductor-related groin pain refractory to conservative treatment.
Topol et al.[58]	75	3	Football, Rugby	Rosario, Argentina	Unspecified Pubalgia	Monthly injections of dextrose and lidocaine in the abdomen and adductors	Athletes returned to their full elite performance timely and sustainably after undergoing regenerative injection therapy using dextrose.

of research studies in the health field and is applicable to both randomized controlled trials (RCTs) and non-randomized trials. The scale consists of questions and criteria that assess various aspects of the study methodology, such as design, random allocation, blinding, statistical analysis, and presentation of results. Each item is scored based on whether the criterion is met or not in the study. The sum of the scores provides an assessment of the study's quality, where a higher score indicates higher methodological quality. The scale aids in identifying biases and weaknesses in studies, facilitates comparisons between them, and supports decision-making in systematic reviews and meta-analyses.[28] Applying the Downs and Black checklist, eighteen studies were classified as high quality, scoring above 16 points,[30–36,40,42–44,46,49–51,53,55,58] while another 12 were classified as low quality, scoring below 16 points.[29,37–39,41,45,47,48,52,54,56,57] The mean final score was 16.6 (SD = 5.6) (Table 2).

Discussion

This systematic review aimed to study the comparison of available treatment options for groin injuries in athletes and their impact on success rates and injury recurrence. Additionally, the analysis also took into consideration the type of treatment, follow-up duration, site of participants' injuries, and sports specialization. Key findings revealed a trend towards surgical intervention in cases of persistent groin pain, with a notable success rate reported for procedures such as adductor tenotomy combined with hernioplasty. Conservative treatments, including shockwave therapy, manual therapy, and exercise, demonstrated promising results in facilitating a quicker return to sports activity. Notably, the success of treatment varied based on individual response and the severity of the injury. These findings underscore the importance of tailored treatment approaches and further research to establish evidence-based recommendations for the management of athletic groin pain.

The wide variety of treatment approaches, etiology, and the location of the injury for groin injuries in athletes reflects the complexity of this condition. From surgical interventions to conservative therapies, each approach provides a pathway to recovery and return to sports. The results of this systematic review emphasize the importance of carefully considering the most appropriate treatment approach for each athlete based on their specific condition and recovery needs.

Firstly, it is observed that the review covered a total of 30 studies,[29–58] in which a total of 1931 athletes participated. The breadth of this sample provides a robust foundation for analysis and drawing conclusions, despite the high heterogeneity regarding injury sites and different athletes in relation to treatment options for groin injuries. The follow-up period varied among studies, with an average of 19.19 months, allowing for a long-term assessment of treatment effectiveness.

The main findings of this review were observed with a higher prevalence of adductor injuries in sports such as football and athletics. Various treatment strategies, both surgical and conservative, were identified. Surgeries included adductor tenotomies, selective partial release of the long adductor, and repairs with endoscopic mesh.[29–33,37,38,42] These procedures showed success rates in return to sports of around 75–80 %. Conservative therapies, such as shock wave therapy, manual therapy, and exercise, also proved effective in accelerating the return to sports activity.[34–36] The effectiveness of the "Modified Hölmich Therapeutic Exercise Protocol" in improving clinical measures in 10 weeks was highlighted.[38]

However, it is important to note that 13 studies did not specify the type of pubalgia that was studied. This lack of specificity could hinder a comprehensive understanding of the different types of groin injuries and their associated treatments. The broad diversity of injuries impacting the pubic region, in conjunction with the various classifications described, poses some of the main challenges that this clinical condition faces, as evidenced by Weir et al.[5] and Serner et al.[6] It is crucial for future research to address this issue more clearly to establish conclusions between types of injuries and treatment options.

Furthermore, the presence of other injury sites such as adductor tendons, insertion into the pubic bone, long adductor, and proximal adductor rupture adds an additional layer of complexity to the landscape of groin injuries.[59] These findings suggest that injuries can be multifactorial and affect various structures in the inguinal region. Ellsworth

Table 2
Evaluation of studies using the downs and black scale.

Study	Information	External Validity	Internal Validity	Power	Total	Quality
Sansone et al.[29]	6	2	4	1	11	Low
Schilders et al.[30]	10	3	8	5	24	High
Mei-Dan et al.[31]	8	3	10	5	24	High
Sheen et al.[32]	10	3	11	1	25	High
Paajanen et al.[33]	9	3	11	1	25	High
Schöberl et al.[34]	7	3	10	1	21	High
Weir et al.[35]	10	3	9	2	24	High
Yousefzadeh et al.[36]	8	2	10	0	21	High
Harr et al.[37]	3	3	2	0	8	Low
Mazbouh et al.[38]	6	2	3	0	11	Low
Ahumada et al.[39]	3	1	2	0	6	Low
Canonico et al.[40]	8	3	5	3	19	High
Schilders et al.[41]	4	3	5	1	13	Low
Van Veen et al.[42]	10	3	6	1	20	High
Verrall et al.[43]	8	2	5	1	16	High
Brown et al.[44]	8	2	8	2	20	High
de Queiroz et al.[45]	1	3	3	1	8	Low
Garvey et al.[46]	10	3	9	1	24	High
Economopoulos et al.[47]	6	2	3	1	12	Low
Comin et al.[48]	8	2	3	1	14	Low
Messaoudi et al.[49]	7	2	7	2	18	High
Maffulli et al.[50]	8	3	5	1	17	High
Dojcinovic et al.[51]	6	3	7	1	17	High
Robertson et al.[52]	4	2	4	1	11	Low
Muschaweck et al.[53]	6	3	6	1	16	High
Schlegel et al.[54]	5	2	1	2	10	Low
Mann et al.[55]	8	3	8	1	20	High
Jansen et al.[56]	5	3	4	2	14	Low
Atkinson et al.[57]	4	3	5	1	13	Low
Topol et al.[58]	6	5	4	1	16	High

et al.[60] discuss the relevance of accurate assessment and more precise diagnosis to identify and distinguish between athletic pubalgia and other inguinal disruptions, for example. This allows for an improved rehabilitation care plan and advances in recovery therapies such as shockwave therapy, manual therapy, and targeted exercise regimens.

Research in the field of surgeries for groin pain in athletes has yielded promising results in terms of recovery and return to the previous sports level. This review has explored various surgical techniques, such as "Adductor Tenotomy" and "Rectus Abdominis Tenotomy," as well as their combination. These interventions have shown long-term success, as evidenced by Sansone et al.[29] and Harr et al.[37] with approximately 75 % of athletes successfully returning to their previous sports level after undergoing these surgeries. This finding is relevant and supports the effectiveness of these techniques in athlete rehabilitation and performance restoration.

A particularly interesting approach has been the "Selective Partial Release of the Long Adductor," as highlighted by Schilders et al.[30] This technique has presented even more impressive recovery rates, with research indicating that 42 out of 43 athletes were able to return to their previous sports level after undergoing this technique, equating to a success rate close to 98 %. Furthermore, these results were achieved in an average period of 9.21 weeks, emphasizing the speed at which athletes can return to competing at the highest level with this technique according to this study. These findings are consistent with previous research by Boykin et al.[61] which also emphasized the effectiveness of "Selective Partial Release of the Long Adductor" in athlete rehabilitation and their successful return to competition but with an association with femoroacetabular diseases.

Regarding the technique of Adductor Tenotomy combined with hernioplasty for the treatment of groin pain, primarily addressing adductor dysfunction, Mei-Dan et al.[31] reveal that it has achieved success rates, with 80 % of cases reporting good or excellent results. These findings highlight the effectiveness of surgery in addressing specific injuries and restoring desired functionality in athletes according to the authors.

Comparing these findings with previous studies by Machotka et al.[21] and Almeida et al.[22] in the field of sports medicine, a significant advancement in the approach to athlete injuries and rehabilitation is evident. Earlier research may have underestimated the ability of surgery to achieve such positive outcomes in terms of recovery and return to activity.[1,14]

From the "Placement of an endoscopic mesh after reducing a possible hernia" to "Open repair with sutures of 'Minimal Repair,'" diverse approaches have been developed to address groin pain as well. These procedures have provided a pathway to recovery, enabling athletes to return to physical activity with the least discomfort and downtime possible according to the authors.[42,53] The placement of an endoscopic mesh proposed by Van Veen et al.[42] has solidified as an effective technique in inguinal hernia repair. The study involved 38 athletes from various sports such as football, triathlon, athletics, tennis, cycling, baseball, and speed skating over a 3-month follow-up. The results indicate that this technique has achieved significant success rates in reducing and stabilizing hernias, allowing athletes to recover more efficiently.

On the other hand, open repair with sutures of minimal repair by Muschaweck et al.[53] has also proven to be a valuable alternative in the treatment of groin injuries in various sports. This approach focuses on suturing the affected tissues, minimizing surgical invasion, and reducing the risk of complications. When comparing this procedure with previous studies by Ahumada et al. [39] and supporting more invasive approaches, the shift in technique toward less aggressive yet equally effective approaches is highlighted.[39,53] The current trend towards less invasive procedures, such as Muschaweck et al.'s[53] minimal repair with sutures, suggests a greater consideration for faster and more comfortable long-term recovery for athletes, thus highlighting what appears to be the most effective option thus far.

Beyond surgical interventions, this review has explored conservative approaches that have also yielded encouraging results. Shockwave therapy, for example, proposed by Schöberl et al.,[34] has emerged as a viable option to reduce pain and facilitate the return to sports. This non-invasive form of therapy presents promising potential and could represent an effective and preferred alternative to surgical interventions, according to the author. Shockwave therapy stimulates healing by increasing blood flow, promoting cell repair, reducing pain, and can also break down calcified deposits. These metabolic alterations allowed for a significant reduction in pain, enabling a return to football within 3 months following the trauma.[34]

Manual therapy and exercise therapy have also proven their worth in the recovery of sports injuries, according to Weir et al.[35] This controlled and randomized clinical trial demonstrated that manual manipulation therapy is a safe and effective treatment for athletes with chronic groin pain related to the adductors, compared to an exercise therapy program. After 4 months, both groups showed a significant decrease in pain scores on the Visual Analog Scale (VAS) during sports activities. Moreover, athletes in the manual therapy group who fully returned to sports did so significantly faster than those who underwent the exercise therapy program. This suggests an advancement in our understanding of how physical manipulation can influence the recovery and functioning of injured athletes.[35]

Building on existing evidence for manual and exercise therapies, incorporating insights into stretching and multifactorial prevention strategies could enhance rehabilitation and injury prevention for athletes with core muscle injuries. Stretching's role in groin pain rehabilitation remains debated, with literature gaps in its isolated impact. Afonso et al.[62] reviewed studies on stretching within multimodal recovery but found no trials assessing its effectiveness as a standalone intervention, highlighting the need for further research.[62] Similarly, Zilles et al.[63] emphasized the multifactorial nature of groin pain risk and prevention, supporting factors like previous groin pain, hip adductor strength, and the FIFA 11+ Kids program. These findings suggest that while stretching may contribute to broader prevention strategies, its specific role requires further investigation to guide evidence-based interventions.[63]

Regarding the modified Hölmich Therapeutic Exercise Protocol, which has shown promising results in the rehabilitation of athletes with groin pain by Mazbouh et al.,[38] this protocol has been able to generate significant improvements in all clinical measures over a period of 10 weeks, suggesting its effectiveness in addressing this specific injury. Comparing these results with previous research by Yousefzadeh et al.,[36] there is an advancement in optimizing exercise protocols with the modification of exercises in the protocol. This indicates progress in our understanding of how to design specific exercise programs for groin injuries as initial treatment in athletes. The "Modified Hölmich Therapeutic Exercise Protocol" could represent an efficient approach tailored to the needs of athletes in recovery.

However, it is important to consider the individuality of each patient and the variability in response to exercise protocols. What works for one athlete may not be equally effective for another. Additionally, it is crucial to evaluate how this protocol compares to other therapeutic alternatives, such as conservative therapies like "Shockwave Therapy" and "Manual Therapy," as well as surgical interventions. Integrating these approaches into a comprehensive treatment plan could provide a more holistic and effective perspective for addressing groin injuries.

In addressing groin and adductor injuries, the conclusion drawn from the results suggests a stepped treatment strategy. It is recommended to start with conservative approaches such as shockwave therapy, manual therapy, and exercise therapy, aiming to alleviate pain and improve symptoms. Most studies indicate a time window of 3 to 6 months to assess the evolution of symptoms before considering surgical options.[30,34,35,42,43]

In cases where conservative treatment fails to achieve satisfactory improvement, surgical intervention emerges as an effective alternative.

Various surgical procedures, such as adductor tenotomy, selective partial release of the long adductor, and other repair approaches, have shown encouraging results in athletes returning to their sports activities. The choice between these approaches should be based on an individual assessment of the severity of the injury and the patient's response to conservative treatment. Ultimately, the goal is to facilitate complete and safe recovery, allowing athletes to resume their sports activities under optimal conditions.[42,43]

The concept of success in the recovery of sports injuries, as emphasized by Mei-Dan et al.,[31] is closely linked to the athlete's ability to return to their pre-injury performance level, encompassing not only resuming participation in the sport but also returning to their usual training and competition activities with a comparable level of effectiveness.[34,35] However, it's important to consider the potential influence of publication bias (RoBias) on understanding of recovery success. Studies reporting positive outcomes, such as athletes returning to pre-injury performance levels without recurrent symptoms, may be more likely to be published than studies with less favorable outcomes, potentially skewing the perceived success rates of different therapeutic approaches. Nonetheless, successful recovery also necessitates the absence of recurrent symptoms such as pain and dysfunction, ensuring that athletes can perform movements and exercises without significant physical limitations. The variety of therapeutic approaches mentioned, from surgical interventions to conservative therapies, illustrates the complexity of the recovery process. However, success in recovery ultimately extends beyond merely curing the ailment, encompassing the restoration of athletic performance and the athlete's overall quality of life (Chart 1).

Intervention algorithms

Recommendations for future studies

To advance the understanding and treatment of groin and adductor region injuries, it is suggested to focus on various areas of research. It is

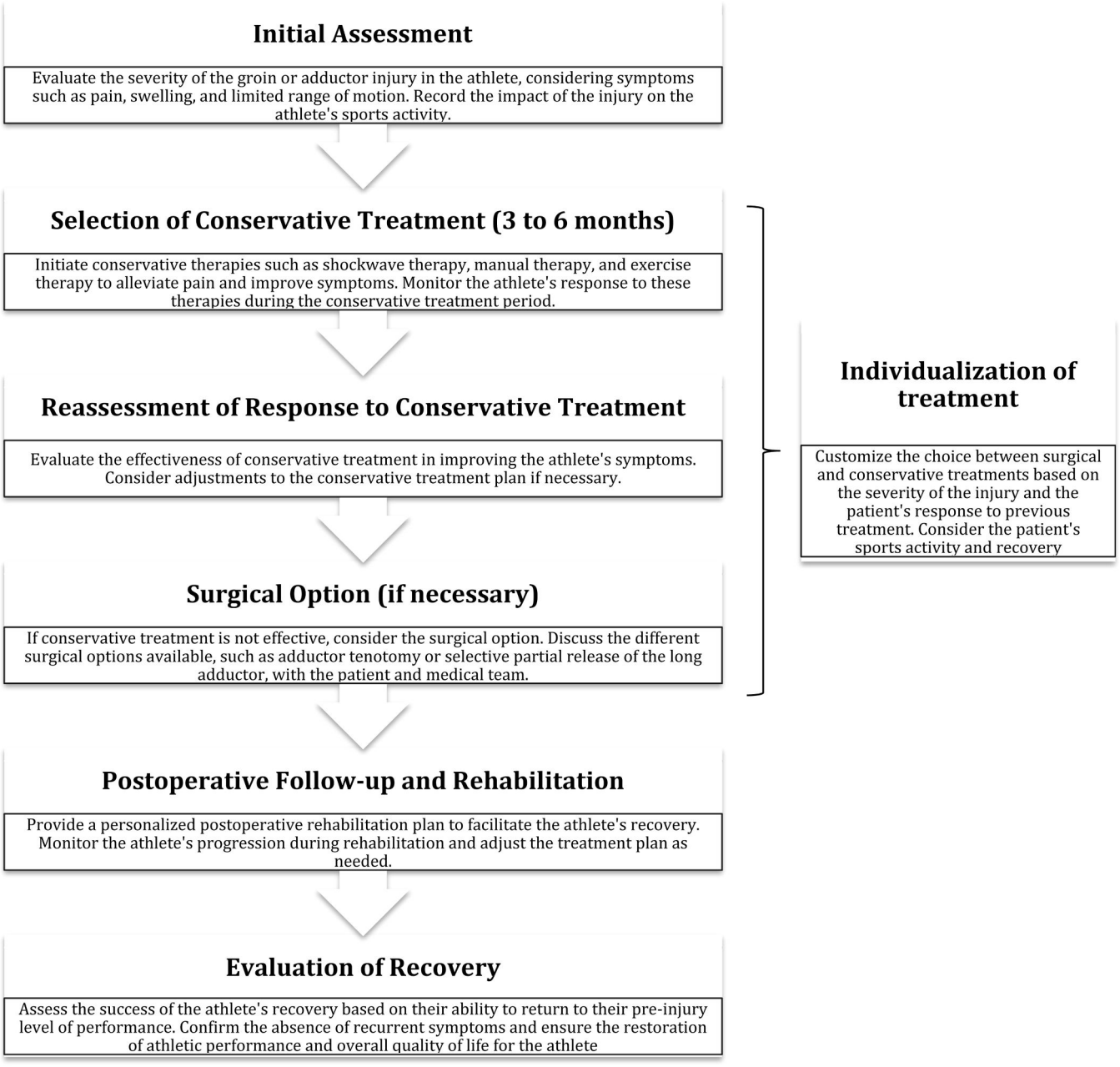

Chart 1. Proposed intervention algorithm for monitoring groin pain.

proposed to investigate the effectiveness of multidisciplinary approaches that combine conservative therapies to expedite athletes' recovery. Additionally, conducting detailed comparisons between different surgical procedures, such as adductor tenotomy and selective partial release of the long adductor, would help identify which approach yields the best results. Exploring therapeutic exercise protocols and conducting long-term follow-ups would aid in understanding the durability of improvements and symptom recurrence. Researching predictive factors for treatment response and conducting comparative studies with control groups would allow for a better assessment of treatment effectiveness. Lastly, exploring preventive strategies, such as warm-up programs and strengthening exercises, to reduce the risk of injuries in athletes is recommended. Addressing these areas could enhance available treatments and the quality of life for athletes affected by these conditions. Furthermore, long-term follow-up studies are also necessary to assess the effectiveness of intervention success over time and potential relapses.

Strengths and limitations of the study

This study provides valuable insights into the management of groin injuries, emphasizing a stepped care strategy from conservative therapies to surgery for persistent cases. Key findings include the success of adductor tenotomy and selective release procedures in facilitating athletes' return to sports. The application of the Downs and Black[28] checklist to evaluate the quality of selected studies adds robustness to the analysis. However, limitations include the inclusion of low-quality research, the absence of controlled prospective studies, and heterogeneity among studies due to variations in injury types and athlete characteristics. The potential for publication bias and lack of standardization in reporting also limit the conclusions. Despite these drawbacks, the study offers a solid foundation for treatment strategies and underscores the importance of individualized care in clinical decision-making.

Conclusion

Treating groin and adductor injuries requires personalized approaches based on individual responses to treatments. Conservative options like shockwave therapy, manual therapy, and exercise regimens are effective, with shockwave therapy providing quick pain relief and faster return to sports. If these methods fail after 3 to 6 months, surgery becomes an effective option, with procedures such as adductor tenotomy combined with hernioplasty showing excellent results. Open repair with sutures offers minimally invasive alternatives. The treatment choice depends on injury severity and previous response, aiming for a safe and complete recovery for athletes to return to optimal sports performance.

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Patient involvement consent

Not applicable

Study design

Systematic review

Prospero approval

A systematic review was conducted following the recommendations of the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA[3] The study was pre-registered in the International Prospective Register of Systematic Reviews (PROSPERO: CRD42023430694)

CRediT authorship contribution statement

João Vitor de Castro Fernandes: Conceptualization, Visualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Andre Pedrinelli:** Conceptualization, Visualization, Data curation, Formal analysis, Writing – review & editing. **Jacobo Ángel Rubio-Arias:** Conceptualization, Visualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing.

Conflicts of interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest.

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