

Prevalence of abdominal injuries among team sports athletes: a narrative review**Prevalencia de lesiones abdominales entre atletas de deportes de equipo: una revisión narrativa**

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Abstract. Introduction: Injuries to the core musculature or abdominal musculature, characterized by dysfunction or disruption of the musculoskeletal system between the chest and mid-muscle region, are prevalent in athletic populations. Recognizing the pivotal role of core stability in mitigating such injuries and facilitating coordinated limb movements, core stability training has gained popularity among athletes. Recent research has shed light on the correlation between hip pathology and abdominal muscle injuries, particularly groin injuries, emphasizing the imperative for comprehensive management and prevention strategies. Thus, the aim of this literature review was to investigate the prevalence and impact of abdominal injuries among team sports athletes. Methods: The narrative review was conducted on MEDLINE, CINAHL and Embase using the following keywords, adapted and combined using Boolean operators to build the search string: “Athletes”, “athletic injuries”, “abdominal muscles”, “Sprains and Strains”, and “epidemiology”. After inclusion and exclusion criteria were applied, the articles were independently screened by two authors reading the titles and abstracts or full articles. The quality assessment was conducted using the PEDro scale, the NIH Quality Assessment Tool for observational cohort and cross-sectional studies and MethodologicaI STandards for Epidemiological Research (MASTER). Results: Through databases research 1303 articles were founded. After the screening process, 10 studies were included for qualitative analysis. Quality scores of the selected observational/cross-sectional studies ranged from “fair” to “good” for NIH tool, with 23 points for MASTER score and a PEDro 7 for the included RCT. Conclusion: Abdominal injuries, which are highly prevalent in kinetic-intensive sports such as football, baseball, soccer and hockey, respond with good clinical results, particularly in terms of the intensity of pain reported by the patient, to a multimodal approach given by a combination of passive and active therapies.

Keywords: Athletes, athletic injuries, abdominal muscle injuries, frequency, sprains and strains.

Resumen. Introducción: Las lesiones de la musculatura central o abdominal, caracterizadas por una disfunción o alteración del sistema musculoesquelético entre el tórax y la región muscular media, son frecuentes en las poblaciones atléticas. Reconociendo el papel fundamental de la estabilidad central para mitigar dichas lesiones y facilitar los movimientos coordinados de las extremidades, el entrenamiento de la estabilidad central ha ganado popularidad entre los atletas. Investigaciones recientes han arrojado luz sobre la correlación entre la patología de la cadera y las lesiones musculares abdominales, en particular las lesiones inguinales, haciendo hincapié en la necesidad imperiosa de estrategias integrales de gestión y prevención. Así pues, el objetivo de esta revisión bibliográfica era investigar la prevalencia y el impacto de las lesiones abdominales entre los atletas de deportes de equipo. Métodos: La revisión narrativa se realizó en MEDLINE, CINAHL y Embase utilizando las siguientes palabras clave, adaptadas y combinadas mediante operadores booleanos para construir la cadena de búsqueda: «Athletes», «athletic injuries», «abdominal muscles», «Sprains and Strains» y «epidemiology». Una vez aplicados los criterios de inclusión y exclusión, los artículos fueron revisados de forma independiente por dos autores que leyeron los títulos y los resúmenes o los artículos completos. La evaluación de la calidad se realizó mediante la escala PEDro, la herramienta de evaluación de la calidad de los NIH para estudios observacionales de cohortes y transversales y MethodologicaI STandards for Epidemiological Research (MASTER). Resultados: A través de la búsqueda en bases de datos se encontraron 1303 artículos. Tras el proceso de cribado, se incluyeron 10 estudios para el análisis cualitativo. Las puntuaciones de calidad de los estudios observacionales/transversales seleccionados oscilaron entre «regular» y «buena» para la herramienta NIH, con 23 puntos para la puntuación MASTER y un PEDro 7 para el ECA incluido. Conclusiones: Las lesiones abdominales, muy prevalentes en deportes de gran intensidad cinética como el fútbol, el béisbol, el fútbol americano y el hockey, responden con buenos resultados clínicos, sobre todo en cuanto a la intensidad del dolor referida por el paciente, a un enfoque multimodal dado por una combinación de terapias pasivas y activas.

Palabras clave: Atletas, lesiones atléticas, lesiones musculares abdominales, frecuencia, esguinces y distensiones.

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Introduction

Injuries to the core musculature or abdominal musculature, characterized by dysfunction or disruption of the musculoskeletal system between the chest and mid-muscle region, are prevalent in athletic populations (Gill et al., 2023). This anatomical region, comprising muscles crucial for pelvic stability and trunk movement such as the rectus abdominis (RA) – superficial long, paired muscle located anteriorly on the abdominal wall --and adductor longus (AL) – found in the medial thigh, originated from the pubic tubercle -- assumes pivotal roles in various sporting activities (Firmansyah et al., 2024; Garrett, 1996; Kibler, Press,

& Sciascia, 2006; Sepúlveda et al., 2022), and it is the most commonly implicated region in core muscle injuries because RA and AL have a opposing force vectors and act as antagonists with hip extension and core rotation (Mullen, Hadley, Vopat, & Wolf, 2023). Fibers of the RA attach the periosteum of the pubic boby and the AL origin on the pelvis from the pubic aponeurosis (Larson, 2014). This area, where these muscles insert, functions as a fulcrum for the structures of the aponeurosis, and it is hypothesised that, in cases of AL or RA injury, it may be subject to alterations in the biomechanics of the pelvis and the stability of the pubic symphysis, representing a potential causing factor for onset of pain in the groin area. Notably, groin injuries, a significant subset of these

injuries, prevail in sports characterized by rapid acceleration, deceleration, sudden changes in direction, and repetitive kicking or lateral motion, also associated with injury to the RA aponeurosis and/or AL tendon (Ellsworth, Zolund, & Tyler, 2014).

Musculoskeletal injuries, a comprehensive term encompassing trauma to muscles, bones, tendons, ligaments, and other soft tissues, significantly impair athletes' performance and entail substantial economic burdens (Rojas, Cañon, & Romero, 2023). Recognizing the pivotal role of core stability in mitigating such injuries and facilitating coordinated limb movements, core stability training has gained popularity among athletes. Recent research has shed light on the correlation between hip pathology and abdominal muscle injuries, particularly groin injuries, emphasizing the imperative for comprehensive management and prevention strategies (Araujo, Cancela, Bezerra, Chaves, & Rodrigues, 2021; Castaldo, Ge, Chiarotto, Villafane, & Arendt-Nielsen, 2014; Cruz et al., 2023; Li et al., 2015). Groin injuries alone account for 2-5% of all sports-related injuries, and when combined with lower abdominal injuries, they rank among the most frequent causes of pain and practice time loss in sports (Morelli & Smith, 2001; Orchard, 2015; Whittaker, Small, Maffey, & Emery, 2015). Of notable consideration is the central muscle injury, formerly referred to as sports hernia or athletic pubalgia, characterized by damage to skeletal muscles between the chest and mid-thigh, with a specific focus on musculature originating or inserting into the pubis (Poor, Roedl, Zoga, & Meyers, 2018).

Thus, the aim of this literature review was to investigate the prevalence and impact of abdominal injuries among team sports athletes in order to develop effective strategies for injury management and prevention, ultimately enhancing the quality of medical care and minimizing sports-related injuries.

Methods

This is a narrative review of studies reporting the prevalence of the abdominal injuries among athletes of different levels and investigating the role of physiotherapy in management and prevention. PRISMA guidelines were followed during the design, search, and reporting stages of this narrative review.

Search strategy

The electronic literature search was conducted in the following databases from their inception until September 15, 2023: MEDLINE, CINAHL, and EMBASE. "Athletes", "athletic injuries", "abdominal muscles", "Sprains and Strains", and "epidemiology" were the keywords used in the databases, with the proper adaptation and combined with Boolean operators. Additional records were searched through other sources to complement the database findings (manual search of reference lists). Two authors (F.G. and

A.B.) performed the search and evaluated the abstracts independently for potential eligibility and subsequently full-text publications for eligibility. A third author (J.H.V.) resolved discrepancies (Villafañe, 2022). Each researcher reviewed the title and the abstract of all the articles, selecting the relevant ones according to inclusion and exclusion criteria.

The search strategy was restricted to human research, including randomized controlled trials (RCTs), cohort studies, and cross-sectional studies.

Population, intervention, control, and outcomes

The inclusion criteria restricted the studies' participants to be male or female aged over 18 years old whom practice amateur or elite athletes with abdominal muscles injury, whom undergone conservative management and rehabilitation as the intervention. The selected outcome was the frequency of abdominal injuries among the selected population. Randomised controlled trials, cohort and retrospective studies, cross-sectional studies and case series are the study designs considered within the inclusion criteria.

Studies selection

After the independent titles and abstracts screening of the identified studies by two authors (F.G. and A.B.), full texts of the potentially relevant articles were retrieved. All disagreements between the reviewers were settled with another author (J.H.V.). The manual search of relevant studies' references was applied to retrieve additional articles. Exclusion criteria based on study design were systematic reviews, meta-analyses, letters, case reports, editorials, and comments. The studies that included subjects under 18 years of age or sedentary subjects were excluded.

Data extraction

Two authors (F.G. and A.B.) conducted the extraction independently. A third author (J.H.V.) resolved discrepancies. Reviewers were not blinded to information regarding authors, the journal, or the outcomes for each article reviewed. A standardized form was used to extract data concerning study design, number and mean age of participants, year and country of publication, setting, expectation association with outcome, clinical outcome measures, and reported findings. The form was developed according to the direction of the Cochrane Handbook for Systematic Reviews of Interventions.

Study quality and risk of bias assessment

RCTs' methodological quality was evaluated using the PEDro scale. The PEDro scale is an 11-item scale designed for rating the methodological quality of RCTs. Each item that is satisfied on the scale contributes one point to the total possible score of 10 points. Version 2 of the Cochrane risk-of-bias tool for randomized trials (RoB 2) was used to assess the risk of bias in randomized clinical trials included in the present study. RoB 2 evaluates a set of domains of bias, focussing on different aspects of trial design, conduct, and

reporting.

The NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional studies was used to assess the observational studies included in the present review. It is based on 14 items, each one defined as “cannot determine”, “not applicable”, or “not reported”, followed by an assessment and global scoring of “good” (11-14 points), “fair” (5-10 points) or “poor” (0-4 points). The NIH Quality Assessment tool for Case Series Studies was used to assess the only case series included in this review, with a score of 8 up to 9. MASTER (MethodologicaI STandards for Epidemiological Research) tool was used to assess the descriptive epidemiological study included in the present study.

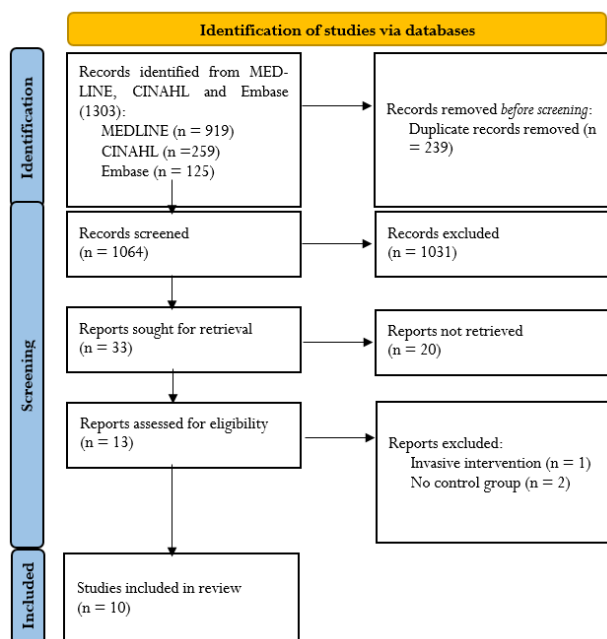


Figure 1. Flowchart of search resources and article selection steps

Results

Study selection

At first, 1303 articles were identified through the database search. Once duplicates were excluded, the titles and abstracts of the remaining unique articles were analyzed. To conclude, full-text articles were analyzed to verify their eligibility for inclusion in this review. Ten studies (Juhan et al., 2021). were finally selected for inclusion in this review. The flow chart of the data selection and extraction process is shown in Figure 1 (PRISMA flow diagram).

Quality assessment

Seven studies were evaluated using the NIH Quality Assessment Tool for observational cohort and cross-sectional studies. The study conducted by Maquirriain, Ghisi, and Kokaly scored 8. The study conducted by Camp et al scored 9. The two studies conducted by Hölmich et al and Delic et al scored 10, while the studies conducted by Juhan et al and Engebretse et al were evaluated with a score of 11. Finally, the study produced by Emery and Meeuwisse received a rating of 12 (Table 2).

Only one study was evaluated using the NIH Quality Assessment Tool for Case Series Studies, the one realized by Balius et al in 2011. The study scored 8 points. The PEDro scale was used to assess the methodological quality of the study conducted by Abouelnaga & Aboelnour in 2019. The study received a score of 7 out of 10, (Table 1).

Risk of Bias within and across the studies

The RoB 2.0 scale was used to assess the study conducted by Abouelnaga & Aboelnour. The study was classified as "low risk." On the other hand, the MASTER scale was used to evaluate the study conducted by Conte et al in 2012. The resulting score was 23 (Table 1).

Table 1. The studies characteristics

Author, years	Study design	Aim of the study	Participants	Outcome measures	Results	Methodological Quality score
(Conte, Thompson, Marks, & Dines, 2012a)	Epidemiological descriptive study	The aim of this study is to characterize these injuries and report on their incidence in baseball over the past 20 years.	N = 393; Male baseball elite players of the MLB (Major League Baseball) injured between 1991 and 2010.	Imaging MRI Ultrasound	At least 92% of these injuries were internal/external oblique or intercostal muscle tears. An upward trend was observed from 1991 to 2010, especially with regard to early season injuries, and the overall injury rate was 22% higher in the 2000s than in the 1990s. 78.1% of pitchers' injuries were contralateral to the dominant arm and 70.3% of position player injuries were contralateral to the dominant batting side.	MASTER result: 23/36
(Camp et al., 2018)	Observational cohort study	The purpose of this study were to (1) describe, compare, and contrast the hip ROM profiles for MLB pitchers and PPs; (2) better understand the injury rates and impact of abdominal musculature and back injuries in professional baseball; and (3) determine how hip ROM is related to these injuries in all players (pitchers and PPs) and upper extremity injuries in pitchers.	N = 258 male; Baseball pro players whom participated at MLB spring training camp. <i>Inclusion criteria</i> No injuries that limited ROM assessment and/or precluded full participation in all baseball-related activities.	ROM Bilateral hip ROM (IR, ER and TROM)	A total of 258 players (129 pitchers and 129 position players) experienced 20 back injuries and 35 abdominal injuries during the period under review. A 5° hip internal rotation deficit correlated with injuries to the core (odds ratio [OR], 1.40; P = 0.024 for pitchers; OR, 1.35; P = 0.026 for position players) and back (OR, 1.160; P = 0.022 for pitchers).	NIH result: 9 "Fair"
Abouelnaga	RCT	This study was designed	N = 40, male.	Pain	After treatment, a decrease in VAS was observed in	PEDro 7/10

and Aboelnour, 2019)	to evaluate the efficacy of active rehabilitation for the management of sports hernias.	Soccer players diagnosed with sports hernia <i>Inclusion criteria</i> - Age: 18–25 yo; - Groin pain for at least two months; - At least three of five clinical findings.	VAS ROM IR and ER	both groups, 80.25% in group A and 41.93% in group B. The difference between the two groups was statistically significant (p=0.0001), while there was no statistical difference in internal and external rotation between the two groups. An improvement in outcome measures was observed in group A compared to group B (p=0.01). Thirteen patients in group A and only three in group B returned to sporting activity without groin pain.	
(Hölmich, Thorborg, Dehlendorff, Krogsgaard, & Glud, 2014)	Cohort study The aims were (1) to describe the occurrence and clinical presentation of groin injuries in this cohort; (2) to examine the characteristics of these injuries.	N = 998, male; <i>Inclusion criteria</i> - Sub-élite soccer players of clubs from Denmark, Copenhagen and Zealand series and series 1-3; - Amateur competitive level; - Training between two and four times a week.	Injuries history Self-administered questionnaire Physical examination Standardised protocol	The total number of injuries (any anatomical part) recorded among the 998 players was 494. The injury incidence was 3.41 injuries/1000h. The injury time was moderate (8-28 days) in 43% and severe (>28 days) in 33%. It was significantly related to the extent adductor- and abdominal-related injuries and their interaction.	NIH result: 10 "Fair"
(Delic, Ross, Blankenbaker, & Woo, 2019)	Retrospective study The objective was to determine the pubic bone fracture incidence and associated injury patterns in patients with core muscle injury.	N = 93; 87 male, 6 female; Mean age: 34.4 [16-66] yo <i>Inclusion criteria</i> Patients with aponeurotic injury;	Pain MRI Imaging - Presence/absence pubic fracture - Associated injuries	The overall incidence of fractures was 18.3 per cent (17/93), including 13 pubic body fatigue fractures and four high cortical fractures/fractures. Athletes can therefore proceed with a gradual return to sport as symptoms allow, with most showing complete healing within 3-5 months.	NIH result: 10 "Fair"
(Juhan et al., 2021)	Prospective cohort study The purpose of this study was to compare the epidemiology of injuries in women's collegiate indoor and beach volleyball per body site and per time lost from sport participation.	N = 161; female. <i>Inclusion criteria</i> - Division I athletes who participated in either beach volleyball or indoor volleyball; - History of injury.	Injuries history Injury rate	The injury rates for beach volleyball vs. indoor volleyball were 1.8 vs. 5.3 injuries per 1000 hours of play (P < .0001). The abdominal muscle injury rate was significantly higher in beach volleyball than in indoor volleyball (11.8% vs. 4.7%; P ≤ .0008).	NIH result: 11 "Good"
(Engebretsen, Myklebust, Holme, Engebretsen, & Bahr, 2010)	Prospective cohort study The aim of this study was to examine potential intrinsic risk factors for acute and overuse groin strain injuries in a prospective cohort study among subelite male soccer players	N = 508, male. <i>Inclusion criteria</i> - Amateur soccer players - Absence of injury at the test for risk factors for groin injuries	Physical ability - Counter-movement jumps - 40-m sprint tests Strength Isometric adductor strength test Clinical presentation - Clinical examination - Questionnaire	The total incidence of groin injuries was 0.6 injuries per 1000 playing hours (95% confidence interval [CI], 0.4-0.7), 0.3 injuries per 1000 training hours (95% CI, 0.2-0.4) and 1.8 injuries per 1000 hours of playing time (95% CI, 1.2-2.5). A previous acute groin injury and clinically determined adductor muscle weakness were significantly associated with an increased risk of groin injury. The analysis based only on acute injuries causing absence from the game revealed the result of the 40-metre sprint test and the functional test of the rectus abdominis muscles as significant risk factors.	NIH result: 11 "Good"
(Balius et al., 2011)	Case series The aim of this study is to illustrate an aspect of handball-related injury which, as is the case with tennis and volleyball, is uncommon and has not been specifically reported to date.	N = 5, male. <i>Inclusion criteria</i> - Élite handball players of Spanish league. - Asymptomatic elite handball players from the Spanish national handball team. Mean age: 14.76 yo	Abdominal injury Sonographic assessment of rectus abdominis	The tear occurred on the contralateral side with respect to the shooter's dominant arm in four of the cases, and all injuries were located at the infraumbilical level.	NIH for Case Series: 8 "Good"
(Maquiraín, Ghisi, & Kokalj, 2007)	Prospective cohort study The purpose of this study is to examine the anatomy of the anterolateral abdominal wall, as well as abdominal activation patterns in relation to tennis stroke biomechanics.	N = 21, 3 male, 18 female. Mean age: 21.3±3 yo. <i>Inclusion criteria</i> - Élite tennis player - Rectus abdominis strain	Imaging Sonography and/or MRI	Clinical grading revealed, 6 minor, 11 moderate and 4 severe injuries. Average time to full return to sport was 4.5 weeks (range 2-8 weeks). No re-injuries had occurred by the time of last follow-up visit (mean follow-up duration was 13 months, range 6-18 months).	NIH result: 8 "Fair"
(Emery & Meeuwisse, 2001)	Prospective cohort study The focus of this study was to examine intrinsic and potentially modifiable risk factors (muscle strength, flexibility, and level of off-season sport specific training) associated with groin and abdominal straining injury in ice hockey.	N = 1292, male. <i>Inclusion criteria</i> - NHL hockey players who attended the training camp	Off-season training Questionnaire Preseason peak hip adductor strength Adapted Nicholas Manual Muscle Tester (NMMT) Preseason flexibility Active hip abduction with universal goniometer. Exposure data - Previous injury - Level of NHL experience - Position of play Injury data Description, date, time loss, previous injury, mechanism, position of play.	During training camp, players who reported fewer than 18 specific training sessions during the off-season had more than three times the risk of injury than those who had more (relative risk (RR); 3.38 95% confidence interval (CI), 1.45-7.92). Players who reported a previous history of this injury had more than double the risk of injury compared to those who did not (RR, 2.88; 95% CI, 1.33-6.26). Peak adductor isometric torque, total flexibility in abduction and skate blade notch measurement were not predictive of injury. In the regular season, sport-specific training was not such a strong risk factor. The reported groin and abdominal muscle strain injuries consisted of 17.31% (95% CI, 8.23-30.31%) of abdominal muscle strain injuries and 82.69% (95% CI, 69.67-91.77%) of groin muscle strain injuries.	NIH result: 12 "Good"

Table 2.
NIH Quality Assessment Tool for observational cohort and cross-sectional studies.

Items	Research question		Study population		Recruiting and eligibility criteria	Sample size	Exposure (exp.)	Sufficient timeframe	Level of exposure	Exp. measures and assessment	Repeated exp. assessment	Outcome measures	Assessors blinding	Follow-up	Statistical analysis	Total score
	1	2	3	4												
Camp et al., (2018)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Nr	Nr	Yes	9
Hölmich et al., (2014)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Nd	Yes	Yes	No	Yes	Nr	Nr	Yes	10
Delic et al., (2019)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Nr	Nr	Yes	10
Juhan et al., (2021)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Nr	Nr	Yes	11
Engelbrechtsen et al., (2010)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Cd	Yes	Yes	No	Yes	Yes	Nr	Yes	11
Maquirriain, Ghisi and Kotalj, (2007)	Yes	Yes	Yes	Yes	No	Yes	Cd	No	No	No	No	Yes	Yes	Yes	No	8
Emery and Meeuwisse, (2001)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Cd	Yes	Yes	No	Yes	Yes	Yes	Yes	12

Data from studies

Below are the data from the ten studies included for this review.

Delic et al. (Delic, Ross, Blankenbaker, & Woo, 2019) conducted a study to determine the occurrence of fractures in the pubic bone and associated injury patterns in patients with core muscle injuries. From June 2007 to August 2017, 93 consecutive patients with core muscle injuries, confirmed by MRI, were independently analyzed by two musculoskeletal radiologists. They assessed pubic bone fractures in a blinded manner and recorded other bone and soft tissue injury characteristics. Pain duration before the MRI and return-to-play time were obtained from clinical records. The overall fracture incidence was 18.3% (17 out of 93 cases), with 13 fatigue fractures of the pubic body and 4 elevated cortical fractures or fragments. After multiple comparisons, no significant association was found between fractures and injury characteristics, pain duration, or return-to-play time. In conclusion, Delic et al.'s study showed that pubic bone fractures, especially fatigue fractures, are common in patients with various core muscle injury patterns. The presence of fractures did not exhibit a strong correlation with injury patterns, pain duration, or return-to-play time. Nevertheless, it may have implications for patient management.

Abouelnaga et al. (Abouelnaga & Aboelnour, 2019) conducted a study to assess the effectiveness of an active rehabilitation program for individuals with sports hernias. The program involved repetitive and challenging muscle contractions, core stability exercises, balance training, progressive resistance exercises, and running. Forty soccer players diagnosed with sports hernia were randomly assigned to two groups: group A underwent the active rehabilitation program (plus heat therapy, massage, transcutaneous electrical nerve stimulation, and mobilization), and group B received conventional treatment. Treatment sessions were conducted three times per week for two months, with evaluations before and after treatment. Results showed that both groups exhibited reduced VAS scores at the end of treatment, with a reduction of 80.25% in group A and 41.93% in group B. The difference between

the groups was statistically significant ($p=0.0001$). However, there were no statistically significant differences in hip internal and external rotation between the groups after treatment ($p>0.05$). In conclusion, the active rehabilitation program was effective in managing sports hernias, as evidenced by reduced pain and successful return to sports activities.

Balius et al. (Balius et al., 2011) investigated five cases of elite handball players experiencing ruptured rectus abdominis. Sonographically, rectus abdominis lesions appeared as disrupted brillar patterns with blood infiltration throughout the lesion. In some cases, ultrasound imaging was supplemented with MRI. A standardized rehabilitation protocol was implemented, and the handball players returned to play within a duration of 16 to 22 days, averaging 18.2 days. Follow-up examinations at 15 months showed no reinjury or persistent discomfort, and all players resumed competing at their highest level. The tears occurred in the contralateral shooting arm in four of the five cases, and all injuries were localized at the infraumbilical level. Additionally, contralateral abdominal hypertrophy in the dominant arm was observed in the context of handball.

In the study by Camp et al., (Camp et al., 2018) hip range of motion (ROM) was evaluated in professional athletes participating in Major League Spring Training over six seasons (2010 to 2015). The study included 258 player-seasons. Among all players, there were 20 reported back injuries and 35 abdominal injuries. Hip ROM did not show a significant correlation with shoulder or elbow injuries. However, a 5-degree deficit in hip internal rotation exhibited a positive correlation with core injuries (odds ratio [OR], 1.40; $P = 0.024$ for pitchers; OR, 1.35; $P = 0.026$ for position players) and back injuries (OR, 1.160; $P=0.022$ for pitchers). Notably, hip internal rotation deficits were predictive of back and abdominal injuries but did not demonstrate a predictive relationship with shoulder or elbow injuries.

Conte et al.'s research, conducted in 2012, explored the prevalence of abdominal muscle strains in Major League Baseball over two decades (from 1991 to 2010) (Conte, Thompson, Marks, & Dines, 2012). The study investigated the characteristics of these injuries, their association with

the dominant arm or batting side, and the required recovery time. The study identified 393 cases of abdominal muscle strains, accounting for 5% of all baseball injuries. The majority of these injuries (at least 92%) were classified as internal/external oblique or intercostal muscle strains, with pitchers accounting for 44% of the cases. The reinjury rate was found to be 12.1%, and an upward trend in the incidence of abdominal muscle strains was observed, particularly in early-season injuries. The overall injury rate in the 2000s was 22% higher than that in the 1990s. In conclusion, the incidence of abdominal muscle strains in baseball has shown an upward trend over the past two decades, particularly early in the season, despite advancements in diagnostic procedures, preventive core strengthening exercises, and rehabilitation techniques. Injuries contralateral to the dominant arm or batting side were more common.

The primary aim of the cohort study conducted by Emery et al. (Emery & Meeuwisse, 2001) was to identify predictive factors for groin or abdominal strain injuries in the National Hockey League (NHL). Players with a history of previous injury had a risk of injury more than two times higher than those without such a history (RR: 2.88; 95% CI: 1.33–6.26). However, peak isometric adductor torque, total abduction flexibility, and skate blade hollow measurement did not emerge as predictive factors for injury. The study also revealed the presence of a dose-response gradient, with the predicted probability of injury decreasing as the level of sport-specific training increased. In the regular season, the association between sport-specific training and injury risk was not as pronounced (RR: 2.32; 95% CI: 1.0–5.39). Low levels of off-season sport-specific training and a history of previous injury were clearly identified as risk factors for groin injuries in elite-level hockey.

Engebretsen et al. (Engebretsen, Myklebust, Holme, Engebretsen, & Bahr, 2010) conducted a cohort study to identify potential risk factors for groin injuries among male soccer players. They analyzed data from 508 players across 31 amateur teams during the 2004 preseason, focusing on previous injuries, reduced function scores, age, clinical examination findings, and low isometric groin strength as potential risk factors. Previous acute groin injury (adjusted odds ratio [OR], 2.60; 95% CI, 1.10-6.11) and clinically determined weak adductor muscles (adjusted OR, 4.28; 95% CI, 1.31-14.0) were significantly associated with an increased risk of groin injuries. In conclusion, a history of acute groin injury and weak adductor muscles were determined to be significant risk factors for new groin injuries.

The aim of the study conducted by Holmich et al. (Hölmich, Thorborg, Dehlendorff, Krosgaard, & Gluud, 2014) was to present a comprehensive analysis of the occurrence and clinical presentation of groin injuries in a sizable cohort of sub-elite soccer players over a complete 10-month season. Adductor-related injuries were the most frequently observed clinical entity among recorded groin injuries, followed by iliopsoas-related and abdominal-related injuries. Groin injuries were significantly more prevalent in the dominant leg. Additionally, the presence of

both adductor and abdominal pain significantly increased injury time compared to injuries without such pain (RIT=4.56, 95% CI 1.91 to 10.91, $p=0.001$). In conclusion, adductor-related groin injuries were the predominant clinical manifestation among male soccer players and were associated with longer injury durations, particularly when combined with abdominal-related injuries.

The objective of the cohort study conducted by Juhan et al. (Juhan et al., 2021) was to conduct a comparative analysis of injury epidemiology and the duration of time lost from participation among female NCAA Division I athletes engaged in indoor and beach volleyball. A total of 161 female NCAA Division I volleyball athletes were included in the study, with 974 injuries documented. The injury rates for beach volleyball versus indoor volleyball were 1.8 versus 5.3 injuries per 1000 hours played ($P<0.0001$). The rate of abdominal muscle injuries was significantly higher in beach volleyball than in indoor volleyball (11.8% vs. 4.7%; $P=0.0008$). In conclusion, indoor volleyball was associated with a higher likelihood of injury compared to beach volleyball. Sport-related concussions and knee injuries were more prevalent in indoor volleyball, while abdominal muscle injuries were more frequent in beach volleyball.

The study conducted by Maquirriain et al. (Maquirriain, Ghisi, & Kokalj, 2007) investigated the structure of the front and side abdominal wall, as well as the activation patterns of abdominal muscles during tennis strokes. The study presents a practical guide for rehabilitating tennis players, with a specific focus on the importance of eccentric-plyometric strengthening for comprehensive recovery and the prevention of future injuries. This guide is tailored specifically for tennis players, and it underscores the significance of eccentric-plyometric exercises in achieving a complete recovery.

Discussion

The aim of this literature review was to analyse the prevalence of abdominal injuries in the population of team sports athletes. The included studies presented, in addition to the epidemiological data on this problem moderately represented among sports injuries, clinically relevant reports on the rehabilitation approach adopted in the conservative management of these problems, their correlation with any associated injuries (such as bone fractures), and the possible correlation, for predictive and preventive purposes, with physical factors (strength, articularity, etc.).

Conte et al and Juhan et al. (Conte et al., 2012; Juhan et al., 2021) investigated the prevalence of groin lesions in professional baseball and NCAA college volleyball players, respectively. Due to the prospective nature of the study over a period of almost 20 years, Conte et al. provided very detailed epidemiological results regarding injury frequency, injury site, injury mechanism, etc., however, severely limiting the transferability of their findings to other sports. In line with the data provided by this narrative review are

the epidemiological data provided by Kopschik et al. (Kopschik, Crisman, Lomasney, Smith, & Jadidi, s.d.) in a recent literature review, which indicate a 90% male prevalence of cases of groin pain (referred to by its synonym 'sports hernia' in the aforementioned article) and a higher frequency within football, also accompanied by other high physical intensity sports such as football, hockey, baseball and rugby, even at the non-elite activity level (Negrini, Imperio, Villafañe, Negrini, & Zaina, 2013).

Two of the included studies (Abouelnaga & Aboelnour, 2019; Balius et al., 2011) tested the conservative approach in the management of groin pain following groin injuries occurring during sporting activity. Both highlighted the importance of an early active approach in the management of groin pain, but with two different focuses: on abdominal injuries in the case of Balius and abdominal/adductor insertional injuries in the case of Abouelnaga, adapting the focus of exercise and manual therapy respectively to the abdominal level in the first case and to the proximal lower limb in the second. This result is in line with the data reported in a recent systematic review by Lahuerta-Martín et al. (Lahuerta-Martín et al., 2023), who showed that in the management of patients with groin pain, a combined approach of passive therapy (muscle heat, electrotherapy, manual therapy, transverse friction massage, stretching techniques) and therapeutic exercise (predominantly hip strengthening programmes) or exercise alone has a positive effect on pain intensity, with greater pain reduction in the short term in the case of exercise therapy than passive physical therapy plus exercise therapy (Pillastrini et al., 2015; Rainoldi, Zaina, Villafañe, Donzelli, & Negrini, 2015).

Focusing on core muscle injuries, this review, aligned with the review of Mullen et al. (Mullen, Hadley, Vopat, & Wolf, 2023) underlined the lack of evidence regarding the optimal rehabilitation plan and the outcome of nonsurgical care. Unlike the included studies, Mullen et al. suggested the combination of rest, NSAIDs, physical therapy and injections; in particular, in addition to a hip-strengthening programme (Mulry, Rodenhouse, & Busconi, 2021) and gradual, non-aggressive mobilisation of the hip and spine – the authors indicated the need for a proprioceptive programme to enhance hip and pelvic movement patterns, directing athletes toward sport-specific activity once the pain of day-to-day activity had resolved, approximately 4 weeks of rehabilitation (Ellsworth et al., 2014; Larson, 2014; Mullen et al., 2023).

In the context of a limited body of evidence in the area of abdominal injuries from a groin-related symptom perspective, this review attempted to provide a broader view by extrapolating both abdominal injury data and abdominal-adductor related groin pain data, again highlighting the central role that abdominal-adductor imbalance may play in the onset of a substantial proportion of groin pain cases (Mullens, Zoga, Morrison, & Meyers, 2012; Preskitt, 2011; Sheen et al., 2014; Villafañe, 2023).

The correlation with possible predictive factors in the

occurrence of groin lesions was analysed in 4 of the studies included in this review (Camp et al., 2018; Emery & Meeuwisse, 2001; Engebretsen et al., 2010; Hölmich et al., 2014). Although the athletes involved came from different sports (hockey, baseball and soccer), in 3 of the 4 papers the evaluation of strength, articularity and injury-related history was overlapping, increasing the relevance of the aggregated results; only Engebretsen and colleagues added, in addition to the clinical evaluation in line with the other 3 studies, an evaluation with dynamic functional tests, bringing the analysis of the predictive factors of injury in the groin area very close to the actual sports practice.

Limitations

The taxonomic heterogeneity that is strongly present in dealing with the vast topic of Groin Pain to date, although the 'Doha agreement meeting on terminology and definitions in groin pain in athletes' has created greater clarity in the research field, represents a limitation to the generalisation of the results obtained in this review. Another limitation is represented by the variability in the level of the athletes involved in the various studies included, which, although they involved different sports with a high kinetic load on the core and lower limbs - thus making the results referable to a larger sports population - may lower their reliability.

Conclusion

The management of abdominal injuries in non-elite and elite athletes may represent an important clinical challenge for health professionals in light of its possible role as a factor in the onset of groin pain. Abdominal injuries, which are highly prevalent in kinetic-intensive sports such as football, baseball, soccer and hockey, respond with good clinical results, particularly in terms of the intensity of pain reported by the patient, to a multimodal approach given by a combination of passive and active therapies. To date, more research is needed in the area of abdominal injuries and more generally in the area of groin pain in order to gain a better understanding of these highly complex problems.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest

The authors declare no conflict of interest.

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