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**By**

**Noora Naji Pascale Tohme**

**The Impact of Copenhagen Technique on Eccentric Hip Adduction: Strength, DOMS, and Performance in Male Footballers**

**Defended on x/xx/2025 in front of the jury composed by**

**Dr. Zahra Sadek Director**

**Dr. Roula Tout Member**

**Dr. Ahmad Rifai Sarraj Member**

# **DEDICATION**

We dedicate this thesis to our family members and our friends who have been supportive, understanding, and patient with us during the completion of this educational journey, specifically during the finalization of our thesis.

# **ACKNOWLEDGMENTS**

It is our pleasure to extend a special gratitude to all those who supported us along the process of the research. First and most importantly, our supervisor Dr. Zahra Sadek should receive a massive gratitude for their continuous directions, knowledge and consistent help during this work. They have been fairly useful, their remarks through the year have offered commendable support for our work.

We would also want to acknowledge the efforts, patience, and guidance to our readers. Their input will add value to our study and makes it a solid reference for future researchers.

However, we are grateful to the several researchers and writers who undertook the cumulative studies that informed this systematic review article because they enhanced our understanding of the Copenhagen Adduction Exercise and its football uses.

In particular to the members of the university who have ensured the availability of the required source materials during the completion of this journey. We also would like to acknowledge our colleagues and the other researchers for pointing out helpful ideas in this research.

Last but not least we would like to thank our family for their moral support, patience and encouragement to help me finish our thesis. Their support has been particularly appreciated.

# **ABSTRACT**

**Background:**

Groin injuries are one of the leading dangers in Men’s sports because they rank the 12-16% of the yearly incidents in football category. Amongst the aerobic cycling of specific treatment and characteristic training and healing and prevention, CAE or Copenhagen Adduction Exercise has gained much popularity.

**Objective:**

This systematic review aims at developing whether CAE improves EHAD, decreases groin pain and improves the functional productivity in male football players.

**Search Methods:**

Table 2: This table shows the limited publications on concepts related to CAE and groin injuries in football. Therefore following the established databases of journals, this work incorporated PubMed, Google scholar, as well as the library databases. In developing our meta-analysis and systematic review, we included RCTs published only in the last 10 years on football male players within 18- to 30-year age bracket with hip adductor deficiency or groin pain. The two chief objective was reduced pain which was evaluated using Hand Handle Dynamometer Score (HHD) and Numeric Rating Scale (NRS) and EHAD Strength increase. Secondary outcomes were the compliance rates and functional performance criteria.

**Results:**

From seventy originally identified publications, six meet the criteria for inclusion and are RCTs. The study indicated efficacy in patients where treatment relieved pain, EHAD muscle strength improvement of between 8.9% and 40% and levels of patient compliance of 90-91.25%.

**Conclusion:**

Considering the fact that the pragmatically implemented CAE procedures reported highly satisfactory levels of compliance in the players, the current investigation offers sound evidence in support of the efficacy of CAE for enhancing the compliance of the male players’ EHAD muscles to reduce the declared groin discomfort.

**Keywords:** Soccer players, Examination protocol for eccentric hip adduction strength, Treatment, Copenhagen Adduction Exercise, Pain, Strength.

# **LIST OF ABBREVIATIONS**

ANOVA - Analysis of Variance

CAE - Copenhagen Adduction Exercise

DD - Defensive Drills

DHCP - Dynamic Host Configuration Protocol

DOMS - Delayed Onset Muscle Soreness

DRM - Dynamic Range of Motion

EHAD - Eccentric Hip Adduction

EHAB - Eccentric Hip Abduction

FIFA - Fédération Internationale de Football Association

HAGOS - Hip and Groin Outcome Score

HHD - Hand Held Dynamometer

IHAD- Isometric Hip Adduction

Nm/kg: Newton meters per kilogram

NRS - Numeric Rating Scale

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PICO - Population, Intervention, Comparison, Outcome

RCT - Randomized Controlled Trial

ROM - Range of Motion

ROB - Risk of Bias

SAID - Specific Adaptation to Imposed Demands

SH - Sliding Hip

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# **CHAPTER 1 INTRODUCTION**

Groin strains are an issue that affects male football players particularly. Non-contact strains contribute significantly to this group of injuries (1), primarily involving hip strength deficits, misuse, or excessive adduction.

Groin strains injuries represent 12-16% of all football-associated injuries annually. The recently developed epidemiological data suggests that teams should anticipate three to five cases of groin strain per year. The recurrence rate of groin injuries is 15–25%.

The Copenhagen Adduction Exercise (CAE) protocol, was developed by Serner et al.in 2014. It is a graduated eccentric training regime that strengthens hip adduction and optimizes EHAD. The CAE is partner assisted increasing its use in a team environment and may prevent the repeated occurrence of these injuries.

Many questions should be answered based on data from prior RCTs to determine the extent to which CAE may reduce discomfort, enhance strength and general athletic performance for footballers(2).

This literature review focuses particularly on the following matters:

* How does the CAE stand among other treatments?
* How often and over what length of time should CAE be used to maintain EHAD strength increase across time?
* In what ways may compliance affect the long-term success of CAE-based initiatives?

Earlier investigations demonstrated promising results in terms of injury prevention and rehabilitation; some investigations indicated that CAE reduced adductor-relative injuries by 41%. However, there are still deficits of information in terms of how this intervention should be effectively implemented in the future. The current state of literature outlines different methods and progress models, which justifiably raises some questions about the best possible application strategies.

In addition, even though studies show clear improvements in strength, additional investigation is required in order to establish a connection between increased adduction strength and functional performance indicators. Development in this important stream of research involves the integration of CAE into comprehensive training programs with regard to periodization, individual traits of players, and spatial demand.

The main aim of this study is to identify whether the CAE may effectively reduce groin discomfort and enhance EHAD muscularity in male football players to forward better injury control and remediation provisions(3).

Due to many limitations regarding the findings of related articles, the thesis is designed to give an evidence-based approach toward improving groin area health in athletes, which erases a large deficiency in the existing injury prevention literature. In functional terms, it impacts training schedules, rehabilitation programs, and compliance procedures.

# **CHAPTER 2 LITERATURE REVIEW**

## **2.1 Background of Male Footballers' Groin Pain**

In football, especially among male players, where the dynamic nature of the game exposes athletes to significant physical strain, groin injuries remain a common and disabling problem. With up to 69% of all groin injuries attributed to adductor-related injuries, epidemiological research exposes them as among the most prevalent(4).

This frequency emphasizes the need for strong preventative and rehabilitation plans catered to the particular requirements of football. Although the physical stresses of fast directional changes, unexpected accelerations, and kicks are well-documented as risk factors, the complexity of groin injuries resides in their multifaceted character, mixing internal and extrinsic variables.

According to Alsirhani, A A. et al. (2024)(2), reduced eccentric hip adduction strength (EHAD) is one of the most changeable inherent risk variables; hence, the Copenhagen Adduction Exercise (CAE) has become a focused intervention meant to treat this one, the simplicity, openness, and evidence-based backing of the CAE help to explain its appeal. Still unresolved, though, are issues regarding its relative effectiveness, best practices for execution, and long-term advantages, which would cause arguments within the sports science and physiotherapy societies.

## **Theoretical Framework: Mechanisms of CAE Performance**

### *Specific Adaptation to Restricted Demand (SAID) Principle*

The SAID concept emphasizes the CAE's specificity, therefore clarifying its efficacy. The CAE induces adaptations specifically fit for football by subjecting eccentric stresses to under-regulated settings. This premise distinguishes the CAE from general strengthening activities and thereby makes it especially useful in tackling sport-specific hazards(5).The CAE addresses inherent elements like muscular weakness and imbalance, therefore matching multifactorial injury prevention models(6). For instance, In football, where high-intensity actions including quick directional changes, running, and kicking rule, the adductor muscles are always under eccentric pressures. Given that the body changes especially to fit the kind and degree of stress it is under, its selectivity in aiming at the adductor group complements more general treatments emphasizing irrelevant elements such as surface quality and training load control. Critics counter that a single emphasis on internal aspects might ignore the need for thorough strategies, including both intrinsic and extrinsic features.

## **Theoretical Framework's Relevance**

Theoretically, the Copenhagen Adduction Exercise (CAE) eliminates groin discomfort mechanically and logically. It highlights the implementation of inspired Specific Adaptation to Imposed Demands (SAID) and multifactorial impartial injury prevention models. It makes for contextual relevance and methodological rigor in CAE at the same time (7).

By methodically stressing the adductors eccentrically, the CAE methodically stimulates adductors' eccentric load, which is in concordance with sport-type osseous loads and therapy objectives (8).

### *Risk Mitigation Strategies and Multifactorial Injury Prevention Models*

Demonstrating that groin injuries are complex, and that their management must therefore draw upon internal and external causes. EHAD and modifiable internal factors are especially the focus of CAE. The basic nature of the exercise and the few pieces of equipment it uses further improve its applicability and conformity, making it a useful addition to a systematic approach (9), Liveris N I. et al. (2024).

### *Handling Current Gaps in Traditional Treatments*

Comparing CAE with traditional treatments and as noted earlier, traditional treatments do not seem to meet the functional demands of football. CAE closes this gap by offering sport-type specific power preparation, which comprises strength work and neuromuscular stabilization. It reveals that in the framework, CAE provides ways to replicate the game-specific stressors while enhancing proprioception (10).

### *Implications for Football Training and Rehabilitation Practically*

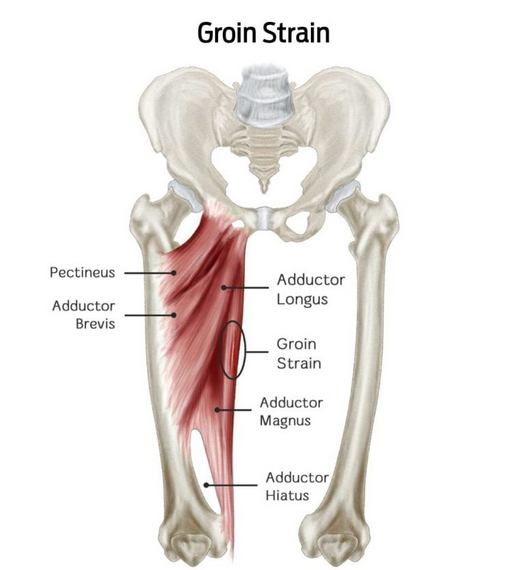
The key findings of this study for football training and rehabilitation practically present clear examples of using CAE in rehabilitation as well as for preventing possible future injuries. The development of the theoretical framework reference is made toward how the theoretical framework assists professionals in working through how CAE can be incorporated within training schedules (11). It is concluded that due to the progressive feature of CAE, strength can be developed during recovery and underlines the benefits of additional exercises for optimization of the physical therapy process.

### *Long-Term Consequences and Research Directions*

This paper discusses the possible future of CAE for the prevention of injuries and the improvement of performance(12). They should spell out issues to do with how the theoretical paradigm informs future research and practice. The section ends with a restatement of how the framework is consistent with SAID principles and known prevention strategies for football injuries, which makes CAE both efficient and resilient to football’s pressures (13).

## **Groin Region Anatomy and Biomechanics**

### *Adductor Muscle Group*



**Figure 1:** Illustration of Hip Adductor Muscle Group Showing the Location of Groin Strain Together with Described Muscles such as Pectineus, Adductor Brevis, Adductor Longus, Adductor Magnus, and Adductor Hiatus on the Front View of the Lower Abdomen.

(Thorbog K. 2023).

Following the above Figure 1, comprising the adductor longus, brevis, magnus, pectineus, and gracilis, the adductor muscle group is vital for supporting the pelvis and allowing sophisticated lower-limb motions necessary for football. High mechanical demands abound in directional shifts, acceleration, deceleration, and ball strikes—all of which stimulate these muscles. Among them, the **adductor longus** is especially prone to damage because of its great involvement during eccentric contractions—where the muscle elongates under strain(14).

Adductor muscle injury in football has a mechanical foundation derived from particular physiological reactions to stress. When a player moves quickly—such as cutting or kicking—the adductor muscles suffer mechanical stress in two crucial ways.

First, especially at the musculotendinous junction, myofibrils experience great strain on the microscopic level. When the loading rate exceeds the ability of the tissue to absorb force, this stress becomes crucial and can cause possible disturbance of the sarcomere structure. Second, the adductors have to generate force while elongating to provide special mechanical stress during eccentric actions—that is when the muscle lengthens while contracting. Because this eccentric phase produces up to 50% more power than concentric contractions, eccentric training helps the tissue better meet these demands.

The adaptation to eccentric load is better than concentric training as it promotes more series-oriented sarcomere development. It also strengthens tendons by means of better collagen formation. Furthermore, it enhances neural control by Improves motor unit coordination. Lastly, it increases tensile strength across longer muscular lengths.

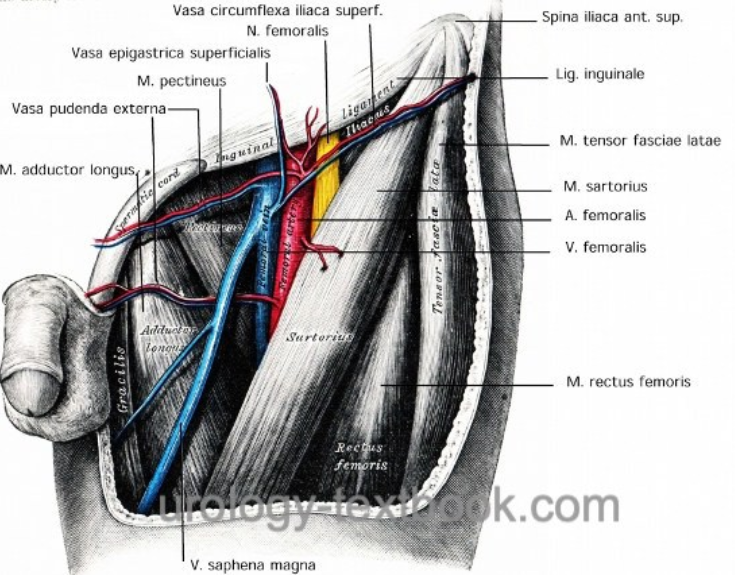
Biomechanical studies show that the adductors resist opposing forces during fast deceleration or lateral motions and create force during hip adduction. Their susceptibility to strains is raised by this dual use, especially in sports like football, where high-force kicks and lateral lunges are very frequent. These motions' eccentric phase calls for the adductors to absorb force and support the pelvis. Hence, they are prone to overload injuries—especially in athletes with inadequate training(15).

The function of eccentric contractions in injury processes has led to discussions on the need for sport-specific treatments like the Copenhagen Adduction Exercise (CAE). Emphasizing controlled eccentric loading, the CAE replicas the functional demands applied on the adductors during football-specific exercises. This concentrated approach could offer a biomechanical benefit over conventional isotonic or concentric-oriented routines, which neglect the great eccentric demands of the sport(16).

Critics counter that although the CAE provides biomechanical accuracy, its need for partner help restricts its usefulness. Ensuring correct technique and advancement can be difficult in team situations with little oversight or in individual training settings. Furthermore called into doubt is the CAE's effectiveness as a stand-alone intervention; some experts argue for its inclusion within more general training courses including dynamic stabilization and neuromuscular control exercises.

The argument also centers on whether sport-specific regimens like the CAE are essential or whether general strengthening programs may sufficiently meet the particular needs of football. While universal programs emphasizing general lower-limb strength and balance may provide a more scalable solution, they run the danger of ignoring the eccentric strength deficiencies necessary for injury avoidance in football.

### *Groin Injuries' Risk Factors*



**Figure 2:** The cross-sectional anatomy of the anterior thigh region involving the femoral vessels, saphenous vein, tensor fasciae lata, sartorius, rectus femoris, and some neurovascular structures.

(Dr. med. Dirk Manski)

Based on Figure 2, football's complex groin injuries arise from both inherent and extrinsic risk factors. Among inherent elements, **muscular weakness** and **imbalances between adductor and abductor strength** are usually underlined. Often recognized as a main indicator of injury risk, the adductor-to-abductor strength ratio has become a focus point in most contemporary studies. Studies show that, especially in high-intensity exercise, a ratio less than 0.90 greatly enhances sensitivity to adductor strains. The adductors, unable to offset the opposing pressures produced by the abductors, are under great strain and microtrauma and, finally, damage results(17).

Conversely, several studies underline the equally important functions of limited **hip range of motion (ROM)** and **reduced flexibility**(18)**.** Deficit of flexibility can cause stress on the adductor muscles, therefore increasing their susceptibility to injury during fast motions or direction changes. Although their efficacy in isolation is still debatable, both static and dynamic stretching programs have been suggested to solve these shortcomings. For example, even if stretching increases the range of motion, it does not solve the strength weaknesses underlying many groin issues.

Proponents of the CAE contend that emphasizing just strength or flexibility is inadequate. Rather, they support an all-around strategy, including flexibility training, neuromuscular control, and eccentric strengthening. Targeting eccentric contractions, the CAE especially targets strength inadequacies; it does not naturally increase dynamic control or ROM(19). This restriction emphasizes the requirement of complementing treatments to completely reduce the risk of groin injuries.

Complicating the prevention of groin injuries includes irrelevant elements such as training intensity, playing surfaces, and footwear(20). These factors can aggravate the effects of inherent risk factors, therefore generating a cumulative injury risk. For a low adductor-to-abductor strength ratio, for instance, a football player may be more prone to experience an injury on a hard or uneven surface that raises ground reaction forces. Dealing with these extrinsic elements calls for a complete strategy, including load control, appropriate tools, and customized training courses.

Although results of recent meta-analyses aimed at estimating the proportional contributions of certain risk variables are still debatable, while some research stresses the predictive power of strength ratios, others underline the need for ROM and flexibility. This lack of agreement emphasizes the difficulty of preventing groin injuries as several interacting elements have to be taken care of concurrently.

#### **Integrating risk factors in training programs**

The Complexity of groin injury risk factors has spurred the creation of diverse preventative strategies, including the CAE as a fundamental component (2). The exercise's capacity to address a crucial modifiable risk factor— eccentric strength deficits—helps to justify its incorporation. Its impact is most noticeable, though, when paired with treatments addressing other risk factors, including neuromuscular control and flexibility. Along with the CAE, programs including dynamic stretching, balance training, and proprioceptive exercises have demonstrated better results in lowering injury incidence than single-modality therapies.

Whether strength, adaptability, or neuromuscular control should come first in injury prevention programs is still debatable. Still, a growing agreement holds that the best strategy is a balanced one including components of each. This emphasizes the importance of customized injury prevention strategies considering the particular requirements and risk profiles of every athlete.

Thus, the special biomechanics and sensitivity to eccentric loading of the adductor muscle group emphasize the need for focused treatments such as the CAE(21). Nevertheless, treating the diverse character of groin injuries calls for an all-encompassing strategy that strikes a mix of strength, flexibility, and neuromuscular control. This all-encompassing view not only reduces injury risk but also improves athletic performance, therefore stressing the need to combine biomechanical knowledge with useful training strategies.

## **The Adduction Exercise from Copenhagen: A Targeted Intervention**

### *Growth and Mechanism*

The CAE's biomechanical justification comes from its focused approach to eccentric loading. The adductor muscles must extend concurrently, generating force while also experiencing maximum mechanical stress during fast deceleration and directional changes during football motions. This produces particular modifications in brain control and muscular architecture(22).

At the sarcomere level, the regulated eccentric stress results in the longitudinal addition of sarcomere units, therefore raising force generation capacity at longer muscle lengths and strengthening general length-tension connections. Through better motor unit recruitment patterns, increased stretch-reflex sensitivity, and greater eccentric force control mechanisms, the neuromuscular system adapts. These modifications immediately result in better performance in football-specific motions requiring fast force absorption and production.

The Copenhagen Adduction Exercise is carried out in exact physiological progression:

The first phase of the workout starts with isometric holds that help to establish neuromuscular control and fundamental tissue tolerance. Starting flexed to lower the lever arm, the knee position helps the adductor complex to be mechanically less stressed.

Mechanisms of progression: The workout develops while adaption takes place in Knee extension to lengthen lever arm. Hence, Fewer partners help to raise the burden. It also ensure introduction to dynamic motions, and variations in speed and oscillating elements addition.

These progressions methodically raise mechanical stress while preserving control, which is necessary for best tissue adaptation and injury avoidance(22).

|  |  |  |  |
| --- | --- | --- | --- |
| **Phase & Duration** | **Volume** | **Support Level** | **Exercise Parameters** |
| **Phase 1 (weeks 1-2)** | 15 Seconds hold / 3 sets \*10 | Complete partner support proximal and distal | Isometric hold at hip abduction at thirty degrees |
| **Phase 2 (weeks 3-4)** | 12 Reps / 3 sets \*8 | Lower proximal support | Dynamic motion with knees flexed |
| **Phase 3 (Weeks 5-6)** | 10 Reps / 4 sets \*6 | Basic distal support | Straight knee full-range movement |
| **Phase 4 (Weeks 7-8)** | 8 Reps / 4 sets \*6 | Basic distal support | Oscillatory motions with more tension |

**Table 1:**Exercise Progression Protocol – Copenhagen Adduction

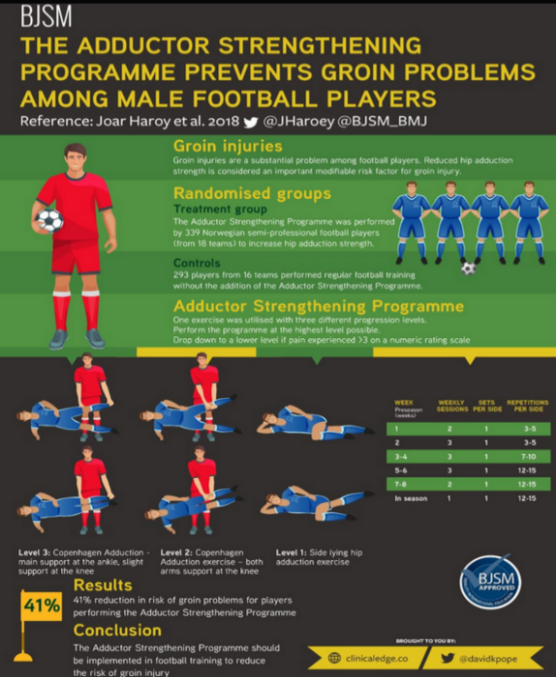
The success of the CAE depends much on its **progressive loading paradigm.** It enables athletes to progressively raise the exercise's intensity, therefore adjusting to their present strength level and reducing their chance of overload problems and changing factors like the lever arm—that is, the length of the unsupported leg throughout the exercise—and the number of repetitions or sets helps one to reach this progression. The CAE guarantees the best strength development in the adductor muscles by methodically increasing the eccentric demand.

Biomechanically, the CAE targets accessory stabilizers like the **gracilis** and **pectineus** in addition to the **adductor longus**, the muscle most often linked with groin injuries(23). This multimodal involvement improves hip stability generally, therefore relieving tension on certain muscle groups and encouraging better load distribution. Football players especially benefit from better hip stability as dynamic and erratic motions significantly strain the pelvis and lower limb alignment.

Critics of the CAE, however, point out as a possible drawback its reliance on partner help. In professional environments, when resources and oversight are at hand, this dependency might not be very problematic. However, in amateur or solo training environments, the necessity for a partner might restrict its viability and maybe lower compliance and efficacy. Furthermore, although the CAE shines in developing eccentric strength, it does not naturally address dynamic control or flexibility, which are equally vital for avoiding groin problems(24).

By emphasizing dynamic control and neuromuscular coordination, other interventions—such as **sliding hip exercises**—have been suggested to augment the CAE. This implies that although the CAE is a useful technique for correcting strength deficits, it might have to be included in a larger rehabilitation or preventive program to completely handle the complex character of groin injuries(25).

### *Data Supporting the CAE*



**Figure 3:** Three-level Adductor Strengthening Program that effectively Prevent Groin Problems and Injury Risk by 41% across Male Football Players

**(**BJSM)

With several randomized controlled trials (RCTs) and cohort studies establishing its efficacy in enhancing **eccentric hip adduction strength** (EHAD) and lowering the frequency of groin injuries, the Copenhagen Adduction Exercise is clearly well-documented(2). Over these investigations, EHAD strength increases of **20–30%** are regularly noted during a six to twelve-week period. Given lower EHAD strength has been found to be the main risk factor for adductor-related injuries in football players, these strength increases are notable. (Check Figure 3)

One interesting study found that compared to those who relied on conventional strengthening exercises, football players who completed the CAE as part of a preseason conditioning program had a **41% decrease in adductor-related injuries**(26). These results highlight the preventative nature of the CAE, which can solve inherent risk factors such as muscular imbalances and strength deficiencies that expose athletes to injury.

The advantages of the CAE go beyond only preventing injuries to include lessening pain for athletes with current groin problems. Research using the **Hip and Groin Outcome Score** **(HAGOS)** where 100 reports that there is no hip/groin issue; whereas, a score of 0 reports a significant issue; as a gauge of groin health often shows notable pain and function changes following CAE operations(27). These results imply that the CAE is not only successful in avoiding injuries but also in controlling early-stage symptoms of chronic groin pain, hence perhaps postponing or obviating the need for more intense therapy.

**Hand-Held Dynamometer (HHD):**

The hand-held dynamometer was placed on the lateral malleolus of the athlete’s ankle when the athlete was creating maximal hip adduction force, thus enabling the dynamometer to quantify the strength of hip adductor muscles in Newtons.

**Numeric Rating Scale (NRS):**

DOMS was assessed by using a numeric rating scale, whereby athletes self-reported their muscle soreness for activities they tender with a score of 0 that defined no pain and a score of 10 that depicted the worst pain imaginable.

### *Feasibility and Compliance*

Athletes find the workout time-efficient and realistic, which helps them to fit into their daily training schedules. The effectiveness of any intervention depends on high compliance, as adherence to recommended procedures directly corresponds with better results.

Using CAE calls for careful thought of personal athlete traits and injury status. First, practitioners should evaluate the type of current problems they find, differentiating between acute and chronic presentations while taking pain intensity and range of motion constraints into account. Load management becomes very important; individual tolerance and symptom response guide intensity and volume changes.

|  |  |  |  |
| --- | --- | --- | --- |
| **Week** | **Repetitions\*Sets** | **Pattern Progression** | **Intensity Modifications** |
| **1-2** | 6-8\*2 | * Static positions * Movement in single plane * Moderated speed | * Slowness in movement pace * Standard hold times * Typical range of motion * Complete partner support |
| **3-4** | 8-10 \*3 | * dynamic change * Variable speed * diagonal motions Introduction | * Different hold times * Improved range of motion * less support from partners * Move with a modest speed |
| **5-6** | 10-12 \*3 | * Dynamic stability * Greater mobility speed * Multi-plane motions | * Advancement in speed * Full range of motion ROM * prolonged hold times * Lowest possible partner assistance |
| **7-8** | 12-14 \*4 | * Integration from several directions * Sport-specific speed * Complex movement patterns | * Complex timing variances * Challenge the ROM * High mobility speed * Support as required |

**Table 2:**CAE Progressive Loading Framework

By use of partner help, support strategies may be altered to enable gradual improvement without compromising exercise integrity. Regular monitoring and adaption are necessary for the integration of CAE with additional mobility work and sport-specific movements to guarantee the best development and reduce the risk of aggravation(28).

|  |  |  |  |
| --- | --- | --- | --- |
| **Day** | **Focus** | **Morning Session** | **Evening Session** |
| **1** | Quality of the movement | Hip Mobility + CAE | Technical Training |
| **2** | Active Recovery | Light Activation + Recovery | - |
| **3** | Performance | Strength Training + CAE | Team Training |
| **4** | Neural Control | Proprioception+ Active Recovery | - |
| **5** | Explosive Strength | Development of Power + CAE | - |
| **6** | Competition | Match Day | - |
| **7** | Regeneration | Mobility + Recovery | - |

**Table 3:**Schedule for Weekly Training Integration

This disparity most likely results from the exercise's focus on strength growth, which might not be enough to correct the complicated biomechanical and neuromuscular abnormalities seen in chronic diseases. Under such circumstances, the CAE could be a useful addition instead of a stand-alone fix.

### *Comparative Approach and Hybrid Effectiveness*

Although the CAE increases EHAD strength more than conventional isotonic workouts, comparisons with other treatments expose interesting results(29). For instance, by enhancing proprioception and neuromuscular coordination, **sliding hip exercises**—which emphasize regulated movement patterns and dynamic stabilization—have complementary effects. Comprehensive injury prevention and rehabilitation results have shown promise from hybrid approaches combining the CAE with sliding hip exercises, flexibility training, and proprioceptive drills.

Furthermore, the emphasis on eccentric loading by the CAE sets it apart from other modalities and makes it especially helpful for correcting certain strength weaknesses. Its little attention on dynamic control and flexibility, however, emphasizes the need to include it in a **multifactorial program** aiming at the whole range of risk factors for groin injuries(30).

### *Future directions and pragmatic challenges*

The reliance of the CAE on partner help still presents a logistical difficulty, especially in environments requiring customized training. Future studies should look at modifications of the exercise that preserve its eccentric loading advantages while lowering reliance on a partner. Furthermore, studies on ideal dosages—that is, the frequency and intensity of CAE sessions—may help to improve its efficacy even more and narrow its applicability.

To reproduce the CAE's loading mechanics in a more controlled or independent manner, emerging studies also imply the possible advantages of using **eccentric isokinetic devices** or **resistance bands**. Such developments might make the exercise more approachable, especially in amateur or home-based training surroundings(31).

The Copenhagen Adduction Exercise, therefore, marks a major development in the prevention and treatment of groin injuries in male football players. Its focus on eccentric loading tackles important strength deficiencies underlying many adductor-related ailments. Although data clearly supports its effectiveness, practical difficulties, and constraints emphasize the need for a comprehensive strategy. Its entire potential may be reached by including the CAE in thorough training regimens, including flexibility, dynamic control, and neuromuscular coordination, therefore providing a strong answer to one of football's most ongoing problems.

### *Impact of Groin Injuries in Football*

Groin injuries in football have major financial effects on teams as well as players. Professional football teams have significant financial costs associated with these injuries that go well beyond immediate medical bills. The thorough pricing structure includes professional consultations, diagnostic tests, and rehabilitation programs, therefore severely taxing club resources(32). Further aggravating these financial difficulties are wage continuance during injury seasons and the possible necessity for temporary substitute players.

From groin injuries, players deal with both immediate and long-term financial fallout. While the impact on contract negotiations and transfer values can greatly influence career paths, performance bonuses during recovery times frequently decline. Beyond the playing career, insurance and healthcare expenses generate further financial issues players have to deal with(33).

Long-term healthcare planning becomes vital as athletes move from active professions; typically, ongoing medical treatment is required to manage chronic diseases arising from groin injuries. The financial load affects insurance companies and healthcare systems as well, so thorough coverage for both urgent treatment and continuous care is needed.

### *Implementation Variations Across Football Settings*

Implementing groin injury prevention and rehabilitation initiatives presents different difficulties in both professional and amateur football settings. Advanced monitoring tools and specialist medical experts help professional settings to have organized training environments and regular evaluation possibilities. On the other hand, amateur settings can suffer from insufficient medical supervision, and budget restrictions, therefore affecting the efficacy of preventive programs(33).

Implementation success is highly influenced by resource availability. Varied football situations present varied difficulties depending on time limits, facility restrictions, and equipment access. Particularly in amateur environments where resources must be carefully allocated, financial constraints often hinder the complete implementation of preventative initiatives.

Program performance depends much on the knowledge of the coaching staff. It takes a great deal of knowledge and expertise to understand biomechanical concepts and be able to change workouts depending on personal demands. Successful program execution depends on an awareness of warning indications and progression indicators as well as good communication skills for player education(34), Dalen-Lorentsen T. et al. (2024).

### *Long-term Performance Implications*

The long-term effects of groin problems on athlete performance need serious thought. Even after getting medical permission for full participation, studies tracking post-injury performance measurements show that players typically suffer in important areas such as sprint speed, acceleration, and kicking power.

After groin injuries, match participation patterns exhibit alarming trends. Usually having less playing time, players show less engagement in high-intensity actions during matches. These trends point to ongoing impacts on both team and individual performance measures that need rigorous return-to-play policy management.

Teams have to apply tactical changes like changed role allocations and modified formation techniques to let returning players fit. These adjustments guarantee appropriate player reintegration while preserving team performance levels, although they often call for major collaboration between medical personnel, coaches, and players(33).

## **Comparison of Rehabilitation Strategies**

Football's prevention and recovery of groin injuries call for treatments addressing several facets of muscle strength, flexibility, neuromuscular control, and general functionality(10). Although both conventional and alternative workouts have different advantages, their efficacy depends on the kind of injury, degree, and particular requirements of football. Although its capacity to increase eccentric hip adduction strength (EHAD) has made the Copenhagen Adduction Exercise (CAE) more well-known, its importance is better appreciated when contrasted and combined with other therapeutic approaches.

### *Conventional Strengthening Exercises*

Usually involving fixed-resistance exercises, the athlete adducts the hip against a set weight. Although they are good for developing overall strength, their applicability to movements particular to football is restricted(35).

Football movement analysis indicates different force generation needs that guide the choice of workout. Although force generation up to 150% of concentric capacity is enabled by the eccentric phase of the movement, it lowers the metabolic cost even with this larger force output. This phenomenon arises from improved motor unit recruitment patterns unique to eccentric load.

The challenging movement patterns of football call for fast force output in prolonged postures, multi-directional force absorption, and high-velocity deceleration capacity. Knowing these mechanical requirements clarifies why, in football-specific environments, focused eccentric training becomes essential for injury prevention and performance improvement. In football, eccentric loading is significantly more important as, during deceleration, lateral cutting, or strong kicks, the adductor muscles often elongate under strain. Traditional isotonic machines do not recreate these dynamic circumstances, which leaves athletes unprepared for the pressures of the field.

Notwithstanding these restrictions, conventional exercises have usefulness as a component of a more comprehensive rehabilitation program. They can be helpful in the early phases of healing when regaining overall strength takes the front stage. However, their lack of sport-specific specificity and their **neglect of eccentric strength deficiencies** highlight the need for further therapies like the CAE(36).

### *Sliding Hip Workout*

Such strategy stressing **dynamic control** and **range of motion (ROM)** is sliding hip exercises. Usually, on a friction-reducing surface, such as a sliding board, these drills help the athlete activate the adductors during regulated concentric and eccentric phases. For enhancing flexibility, adductor endurance, and neuromuscular coordination, especially, sliding exercises are quite successful(37).

Comparative research shows that sliding hip workouts enhance **functional performance**—that is, lateral mobility and dynamic stability—better than conventional strengthening techniques. They do not, however, provide the same degree of **eccentric loading** as the CAE, which is essential for treating the inherent risk factors related to groin injuries. For instance, whereas sliding exercises improve adductor endurance, they do not induce the same strength changes required to resist the high-intensity eccentric forces generated during football activities.

Sliding hip exercises have a main benefit in their emphasis on dynamic motions, which more precisely reflect the multi-planar demands of football. Their limited potential to develop eccentric strength, however, points to their optimal usage as a supplement rather than a substitute for the CAE. While depending on the CAE for focused strength development, athletes may address secondary issues such as flexibility and control by including sliding exercises into a training regimen.

### *Hybrid Models*

Starting with careful preparation with dynamic hip mobility training, adductor activation, and core stability exercises, the methodical integration of CAE follows an organized strategy. This preparatory stage gives way to the primary CAE execution, in which loading progressions depend on individual capacity and technical improvement under partner support. Particular development criteria direct improvement across the phases of the program.

Complementary work comes in with rotational power development, single-leg stability training, and multi-directional movement patterns. Emphasizing dynamic flexibility and movement pattern reinforcement, the session ends with recovery-oriented integrating work. This all-encompassing strategy guarantees the best adaptation while preserving functional carryover to demands unique to football(38).

The efficiency of CAE is enhanced by methodical integration with complementing training components:

**Pre-Exercise Preparation:** A good warm-up emphasizes tissue temperature raising and neuromuscular activation by mobility activities and modest adductor activation exercises.

**Implementation of Main Exercise:** CEA performance guarantees the best mechanical execution and neural drive. 48–72 hour recovery times between treatments ensure appropriate tissue adaption.

**Exercise Selection Complementary to One Another:** Supporting workouts should target associated movement characteristics to ensure stability on single legs helps to regulate force. It also maintain aFunctional strength transfer via multi-directional motions. It also requires exercises for core stability help to transmit force better.

This combined technique guarantees complete growth and controls mechanical stress in the right proportion.

|  |  |  |
| --- | --- | --- |
| **Training Component** | **Implementation/Timing** | **Exercise Elements** |
| **Pre-CAE activation** | Getting ready before the session | * Focus on core stability * Hip mobility exercises * Activating light adductors |
| **CAE Implementation** | Between sessions, 48 to 72 hours | * Progressive loading * Performance in main exercises * Intervals for recovery early in the strength session |
| **Complementary Work** | Supplements following CAE | * Exercises using rotational core * Patterns of lateral motion * Training in single-leg stability |
| **Integrative Recovery** | Phase of cool-down | * Sliding at low intensity * Training in proprioception * Dynamic range of flexibility |

**Table 4**:Integration Framework CAE

New data supports the combination of the CAE with other treatments to produce a more balanced and successful strategy. As an illustration:

Combining the CAE with balancing board exercises or single-leg stance drills improves neuromuscular control, a crucial component in lowering injury risk during high-stress motions(39).

**Stretching Programs:** Including dynamic stretching exercises to increase hip range of motion will help to balance the emphasis of the CAE on eccentric strength, therefore guaranteeing that the adductor muscles are both strong and flexible.

**Dynamic Stabilization Exercises:** Side planks or resisted lateral lunges, among other core and pelvic stability exercises, help to correct the stability flaws often contributing to groin problems.

Athletes who combined CAE with proprioceptive and stretching exercises showed better results than those using the CAE alone, according to research investigating hybrid models. These athletes showed better EHAD strength, dynamic stability, and functional performance measures—including agility and lateral movement speed.

Hybrid models enable doctors and coaches to customize programs to fit athletes' particular requirements, therefore addressing their particular risk factors and shortcomings(40). For instance, a program stressing sliding hip movements and stretching would help an athlete with limited range of motion but sufficient strength, with the CAE included to preserve strength increases. On the other hand, an athlete with notable strength limitations but high flexibility would rely more on the CAE, enhanced by proprioceptive training to increase dynamic control.

Furthermore, addressing the shortcomings of the CAE, hybrid techniques also deal with its dependency on partner support and lack of emphasis on flexibility and dynamic stability. Combining the CAE with other modalities helps players to get a more balanced recovery ready for the various demands of football. Although sliding hip exercises, the CAE, and conventional strengthening activities each have special advantages, their combined efficacy is best(2). While sliding hip exercises improve flexibility and dynamic control, traditional exercises offer a basis of strength; the CAE fills in the important eccentric strength deficiencies underlying many groin issues. The most promising way to lower injury risk and enhance functional results in football players is by hybrid models combining different approaches into a coherent program. Customizing these treatments to the particular requirements of athletes helps doctors and coaches maximize recovery and guarantee a safe return to play.

## **Research Gaps and Limitations**

Though promising, the CAE struggles with long-term effectiveness and adoption variations in research techniques, and poor adherence reporting confound the results interpretation. Furthermore, depending just on temporary results ignores the long-term recurrence of groin injuries, a topic of more research is needed. Standardized CAE techniques, their integration into hybrid models, and their long-term effects on injury recurrence and sports performance should all be subjects of future study. Confirming the generalizability of conclusions depends on larger, multi-center RCTs with strong methods.

As a conclusion, for male football players, the Copenhagen Adduction Exercise offers a focused, evidence-based therapy that marks a paradigm change in the management of groin injuries. Although its restrictions underline the necessity of continuous study, its efficacy in increasing EHAD strength and lowering discomfort is well-supported. The CAE's full potential in tackling one of football's most enduring issues may be realized by placing it inside more general preventative and rehabilitation strategies.

# **CHAPTER 3 RESEARCH METHODOLOGY**

## **Overview of the Field**

### *Review Protocol*

The aim of this systematic review is to investigate how the Copenhagen Adduction Exercise (CAE) improve eccentric hip abduction across male football players with groin injuries. This work is to evaluate the effectiveness of CAE in increasing eccentric hip adduction strength (EHAD), lowering groin pain intensity, and promoting functional performance by means of randomized controlled trials (RCTs) and other high-quality investigations. The study also aims to point up gaps in the body of current research and offer evidence-based suggestions for applying CAE in programs for injury prevention and rehabilitation.

The search approach was organized in this study using the PICO (Population, Intervention, Comparison, Outcome) paradigm. Using terms like "Copenhagen Adduction Exercise," "groin pain," "male footballers," "eccentric hip adduction strength," and "randomized controlled trials," the keywords were customized to guarantee a thorough literature search including Boolean operators (AND, OR) and filters included studies published in English within the past ten years.

**The research question was:**

"For male players, how well does the Copenhagen Adduction Exercise increase eccentric strength and mitigate the risk of groin problems?

## **Search Strategy**

Data from RCTs and comparative studies aimed at the effectiveness of CAE in controlling groin pain in male football players is synthesized in this comprehensive review. Emphasizing its function as a sport-specific, evidence-based treatment for groin health management, the review evaluates the efficacy of the intervention in enhancing strength, lowering discomfort, and preventing injury recurrence.

The research sought were **Google Scholar**, **Cochrane Library**, and **PubMed,** among others. Free full texts, RCTs, and research done within the past ten years were among the articles screened. The first search produced a large number of candidates that were reduced by meticulous application of inclusion and exclusion criteria.

**The search equation ran like this:**

("Copenhagen Adduction Exercise" OR "CAE"), AND ("groin pain" OR "adductor injuries"), AND ("footballers" OR "soccer players"), AND ("eccentric strength."

The PICO

Please find PICO in Appendix 1 Table 6.

## **Quality Assessment**

### *Various Study Design Strategies*

While exclusion criteria removed those with recent operations or other musculoskeletal problems, the inclusion criteria concentrated on athletes actively engaged in competitive football. Every subject got informed permission, and ethical rules were rigorously observed. RCTs assessing CAE's effect on groin pain and EHAD strength dominated the evaluation. Excluded were studies including non-RCT designs, case reports, conference papers, or reviews. To guarantee rigor, research, including missing data or irrelevant results, was also removed.

Reliable and validated instruments were used in peer-reviewed RCT data collecting. Handheld dynamometers—which offer objective, numerical assessments of muscular performance—were used to evaluate EHAD strength. Self-reported measures—including the well-known Numeric Rating Scale (NRS)—were used to assess pain levels, therefore guaranteeing thorough coverage of both subjective and objective results. The NRS is scaled on 0-10, where 0 indicate an absence of pain and 10 indicate extreme pain.

### *The Research Participants*

Male football players between the ages of 16 and 30 had a recorded history of groin discomfort or hip adductor weakness or injuries over the preceding year. The systematic research Participants excluded were those with a history of hip surgery, systemic diseases compromising muscular performance, or participation in other focused rehabilitation programs. Participants were paired into intervention and control groups; the former underwent an eight-week CAE program.

### *The Intervention*

The intervention of interest was the CAE, done with an eye toward eccentric strengthening. Included were studies contrasting sliding hip exercises, adductor squeeze exercise, CAE with conventional strengthening programs. Studies including pharmaceutical treatments alongside CAE were not included.

### *The Outcome measures*

Measuring utilizing approved instruments such as Hand-Held Dynamometer (HHD) score for eccentric strength, and the second outcome measure with NRS score for DOMs. The main results evaluated were increases in EHAD strength and decreases in groin discomfort degree. Among the secondary results were functional performance measures, perceived exertion, injury recurrence, and compliance rates.

## **Data Extraction**

To guarantee accuracy, two reviewers separately extracted data. Disputes were settled by conversation. Every research produced the following statistics:

**In terms of intervention Details: type of control group, frequency, duration, CAE implementation intensity. As for the Study Characteristics:** Year of publication, sample size, research design.Whereas, the **outcome Measures: EHAD strength increases; groin pain decreases (NRS scores); compliance rates; rate of perceived exertion, injury recurrence rates. Hence, the Participants Characteristics:** Age, sex, injury kind, baseline degree of groin discomfort.

This consistent extraction guaranteed accuracy and enabled comparisons between studies. Emphasizing thorough documentation of intervention strategies, including thorough progression criteria, workout changes, and adverse event reporting, the extraction procedure focused on recording the particular characteristics of exercise implementation—that is, the exact documentation of sets, repetitions, and intensity levels across several phases of the intervention—was very important. The extraction also included particular information regarding modification techniques used for different skill and fitness levels, therefore guaranteeing a complete knowledge of how the intervention was tailored to meet diverse participant demands.

## **Evaluation of Risk of Bias in Included Studies**

Using Cochrane's risk of bias instrument, the methodological quality of the included studies was assessed across six domains:

The first one is **Sequence Generation:** The randomizing process. The second one is any **Other Biases:** Any other possible cause of prejudice. The third one is **Inaccurate Outcome Data:** tackling exclusions and attrition. The fourth one is **Selective Outcome Reporting:** Reviewing if all pre-defined outcomes were reported using. The Fifth one is **Allocation Concealment:** Strategies to avoid biased selection. The Sixth one is **Blinding**: Blinding participants, staff, and result assessors.

Every domain received either a low, uncertain, or high risk of bias rating. Consensus settled differences in judgments. This method guarantees strong and consistent results that fit the goals of the research by offering a clear and open means to assess the efficiency of the Copenhagen Adduction Exercise.

Comprehensive analysis of study methodologies' quality and reporting completeness improved the review process. To guarantee the comparability of data, a systematic analysis of outcome measurement consistency between studies was undertaken. Along with a meticulous examination of protocol adherence and implementation consistency, the assessment included a thorough study of follow-up appropriateness and management of participant dropouts. Investigating any conflicts of interest that could affect research results received a particular special focus.

## **Statistical Analysis**

Variations between intervention and control groups were investigated using mixed-design ANOVA. Pre- and post-intervention variations within groups were further analyzed by paired t-tests, therefore guaranteeing strong statistical interpretation. Confidence intervals were computed to improve result dependability; statistical significance was defined at p < 0.05. Advanced analytical techniques used in the statistical approach guaranteed strong data interpretation. While sensitivity studies evaluated the validity of the results across several methodological assumptions, meta-regression studies investigated possible causes of heterogeneity in the results.

A thorough research of dose-response links between intervention parameters and outcomes was included, therefore offering an understanding of ideal implementation techniques. Examining the effects of moderating factors such as age, playing level, and injury history on intervention efficacy has been accorded particular focus.

## **Ethical Considerations**

Every surgery complied with international ethical standards based on the Declaration of Helsinki, and approvals came from related research ethics boards. To guarantee openness and stop the repetition of research activities, the review process was recorded with PROSPERO (International Prospective Register of Systematic Reviews). Every included study was closely reviewed for ethical approval status and informed permission policies.

Strictly observed measures of data security and confidentiality ensure participant anonymity all through the study procedure. Personal identifying information from the original studies was not included in the data extraction procedure; all collected data were kept safely in encrypted databases only available to authorized study team members. The study team also recognized their ethical obligation to provide results in a way that would be easily available and helpful to players and professionals alike.

# **CHAPTER 4 RESULTS**

## **4.1 Study Selection and Characteristics**

Five publications have been integrated into the current study in which participation has spanned from young athletes to professional football players. The treatments were under evaluation for the CAE in water temperatures of 20°C, 25°C, and 30°C, as well as under circumstances of 20, 40, 60, and 80 s. The following relative table summarizes the features of these investigations. Appendix 2: Characteristics Table included studies' features

## **Research Results**

The PRISMA diagram below shows the flow chart for the approach applied in this review next to the selection processes. Initially, 50 papers from many databases were examined and chosen to incorporate the ones pertaining to the Copenhagen Adduction Exercise (CAE). Thirty of these were cross-counted and removed as they were string copies of each other and repeated several times. Then, mostly because they had nothing to do with the study's research topics, 43 articles were deleted using a title and abstract filter. At this point, specific criteria employed for removal included those studies presenting therapies not fitting CAE, non-controlled clinical trials, and papers documenting data of patients not within the target population—that is, non-athletes and pediatric patients.

To determine their fit for inclusion, the remaining twelve papers were under full-text examination. Studies being reports or letters with inadequate or insufficient data were excluded; eligibility was determined based on strict criteria: only RCTs conducted in the last decade involving participants who engaged in athletic activities like soccer and evaluated the effects of CAE on the parameters that can be measured like EHAD strength, hip’s ROM, compliance, or pain. Based on the predetermined inclusion criteria, the research ultimately relied on five papers for the review. These studies were selected because they offered high-quality, repeatable data on the efficacy of CAE and because they were well-suited to fulfill the objectives of the present review, which was concentrated on evaluating the CAE's impacts on athletes's performance and injury rate.

Identification

Duplicated articles were(n=42)

Records identified through

PubMed database searching

(n=50)

Articles excluded based on the title and abstract (n=31)

Records after duplicates removes (n=35)

Screening

Full-text articles excluded(n=43)

-SAID Theoretical Model

-Groin Region Anatomy

-duplicate data – Comparison of Rehabilitation

-Single group

Included articles after

screening titles and abstracts

(n=10)

Eligibility

Excluding (n=25)

Non RCT

Older than 10 years

Insufficient data

Articles assessed for eligibility

(n=24)

Included

Articles included in this review

(n=5)

**Figure 4:** The Study's PRISMA

## **Risk of Bias**

The risk of bias for the included studies is distributed as follows. Most of the studies were at low risk of performance bias, especially in relation to random sequence generation and allocation concealment; three trials had a high risk of reporting bias. All of the studies included were conducted as randomized controlled trials with a moderate risk bias between studies. Still, several of the carried out studies revealed unclear possible negative consequences including blinding of the result assessors.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Criteria** | **Ahmed A. Alsirhani et al. 2024** | **Kohavi B. et al. (2018)** | **Pippas, C. et al. (2024)** | **Harøy J. et al. (2017)** | **Ishøi, L. et al. 2015** |
| Random sequence generation (Selection bias) |  |  |  |  |  |
| Allocation concealment (Selection bias) |  |  |  |  |  |
| Blinding of Participants and personnel (Performance Bias) |  |  |  |  |  |
| Blinding of outcomes assessment (Detection Bias) - Self-reported outcomes |  |  |  |  |  |
| Blinding of outcomes assessment (Detection Bias) - Objective measures |  |  |  |  |  |
| Incomplete outcome data (Attrition Bias) |  |  |  |  |  |
| Selective Reporting (Reporting Bias) |  |  |  |  |  |
| Other bias |  |  |  |  |  |

**Table 5:** (ROB) Risk Of Bias's Assesment

High Risk Of Bias Low Risk of Bias Unlcear Risk of Bias

Moderate Risk

## **Analysis of Results**

Every study that made up the review demonstrated the value of the Copenhagen Adduction Exercise (CAE). Between 8.9% and 40%, mean strength enhancement of EHAD (Eccentric Hip Adduction) was seen together with improvement in patient compliance and reduction in general muscle pain. Other advantages include improved hip range of motion, strength ratios, and less injury incidence. The outcomes of the different research are examined below with reference to the main important criteria and concepts found.

### *Enhancement in the Absolutes of Positive Strength Profile*

The main focus of all the research was CAE's ability to improve EHAD and EHAB strength. Proceeding from the findings of the study, Alsirhani's article reported that EHAD strength has also been shown to be considerably recovered and enhanced 0.49 Nm/kg during the two months' "intervention asserting the importance of CAE in rehabilitation". In a similar vein, Kohavi B. et al. (2018) found significant improvement in EHAD/EHAB strength ratios in CAE and Sliding Hip (SH) groups compared to the control groups(41). These gains show how well CAE may raise particular strength criteria pertinent to the lower of injuries and the maximization of athlete performance.

Pippas, C. et al. (2024)(42) recorded EHAD of 0.23Nm/kg and IHAB of 0.09 Nm/kg using progressive CAE algorithms(43). These investigations, however, reveals that there is no significant difference between implementation of CA exercise or Adductor squeeze exercise. In line with our study, Harøy J. et al. (2017) suggest greater value, that is, 8.9% better EHAD strength when the FIFA 11+ was put into a structured program; the CAE(44).

**Risk of Bias**: Although most of the examined studies claimed minimal risk of bias in terms of randomization and allocation concealment, blinding of both the assessor and participants was inadequately defined, with a considerable number coming from trials reporting subjective outcomes such as muscular strength. In these respects, Ahmed A. Alsirhani et al. (2024)(2) and Pippas, C. et al. (2024)(43) studies had unclear reporting that could perhaps result in bias; hence, it only gave low-risk outcomes in all the mentioned domains; Kohavi B. et al. (2018)(41) had some dubious risks concerning blinding of assessors of outcome(43).

### *Recovery and Pain Reduction*

Reducing pain was the second most often mentioned result; research concentrating on rehabilitation programs also showed this. Al Sirhani and colleagues reported that the pain (-1.60) dropped during the rehabilitation, including CAE(2); this was complemented by an improvement in the HAGOS scores. Equally, Ishøi, L. et al. 2015 verified that CAE with resistance band training demonstrated notable reductions in pain throughout recovery and advised that exercise may assist in reduce pain.

The lack of muscular pain from highlights the feasibility of ramping up training volumes, thereby absorbing CAE into high quantities of training. Regarding eccentric exercise and delayed onset muscle soreness (DOMS), this outcome is really the reverse of what first predictions would have.

ROB or risk of bias: This clear rise suggests that the pain-related results are more trustworthy as the instruments for measuring the pain in the research by Ahmed A. Alsirhani are more objective. However, there are possible biases in data collected via participant self-report, as in Pippas, C. et al. (2024)(43) and Ishøi, L. et al. 2015(33). Methodological control in the investigations of Harøy J. et al. (2017)(44) tended to lower the danger of objective measuring and standardizing

### *Feasibility and Compliance*

Regarding compliance, self-reported degrees of adherence were high for every intervention and clearly showed the pragmatic character of CAE in both universities. Based on a supervised protocol, Ishøi, L. et al. 2015 verified 90% even in unsupervised resistance training programs. This shows once more CAE adaptability and participant acceptance41.

By adding the organized form of the FIFA 11+ program employed by Harøy J. et al. (2017) into current practices(44), CAE helped to augment adherence to this particular collection of exercises. In this sense, the current study differs from that of Pippas, C. et al. (2024) where high compliance may have been noted due to the absence of monitoring that might have resulted in inconsistency.

ROB, or risk of bias: Although most clinical studies show good rates of patient compliance, the absence of consistency in the approaches of reporting on adherence tracking leads to variation. While Pippas, C. et al. (2024) and Ishøi L. et al. 2015 lacked consistency monitoring methods, which is why they were lacking to some degree, Joar Harøy possessed a certain degree of adherence measures.

### *Neuromuscular Adaptation*

The research on concurrent CAE and weight training revealed the most clear neuromuscular changes produced by CAE. Ishøi, L. et al. 2015 also discussed the 40% increase in EHAD strength and the appreciable decrease in pain experienced by the same person when CAE was combined with resistance bands. This method considers eccentric loading to improve neuromuscular adaptation and makes such elements crucial for performance or damage.

Risk of Bias (ROB): The strength of these results is that EHAD gains may be quantified precisely in a way free from researcher subjectivity. Although Ishøi, L. et al. 2015 did not specifically state the efficacy and validity of blinding assessors, objectively, there was significant neuromuscular improvement. Kohavi B. et al. (2018) presented a more robust contingency to stop performance measure manipulation.

### *Athletic Success Demo Musonda*

Apart from its application in rehabilitation, the efficiency of CAE to enhance athletic performance is also shown. Without regard to any negative occurrences to support the relevance of CAE for injury prevention techniques, Harøy J. et al. (2017) showed the advantages of integrating CAE into FIFA 11+ programs with enhanced strength. Likewise, Kohavi B. et al. (2018) observed crucial EHAB/EHAD strength ratios for dynamics stability and lateral movement efficacy.

Risk of Bias (ROB) was also observed that many studies addressing issues of athletic performance were unclear or missing exact details of other training Loads features - their intensity and period. The principal conclusions While Kohavi B. et al. (2018) indicated that risks were questionable in some of the less clear-cut measurements as participants were not blind to the study, Harøy J. et al. (2017) maintained low risks throughout critical areas.

## **Overview**

The findings of the five trials taken together show that CAE is a broad-spectrum intervention able to customize improved compliance, decreased discomfort, and greater EHAD strength. Therefore, the results support the use of CAE in both rehabilitation and athletic training, while the great degree of diversity in relation to research design and reporting, combined with missing ROB aspects, suggests for revised protocol for the next investigations. One would be able to promote the positionality of CAE as a fundamental intervention for hip-based performance and injury prevention if these DHCP could be resolved.

# **CHAPTER 5 DISCUSSION**

## **5.1 Interpretation and Synthesis of Results**

The Copenhagen Adduction Exercise (CAE) has been identified throughout this research as a proven intervention in tackling groin injuries, particularly among male football players. This conversation synthesizes the reviewed literature findings with the outcomes discussed in the ongoing results chapters to demonstrate the effects of CAE on strength, pain, compliance, and practical application and the gaps and implications.

### *Has CAE been effective in Strength Improvement*

The highlighted papers emphasize that CAE improves eccentric hip adduction (EHAD) force as a significant predictor of the predisposition to groin strain. Ahmed A. Alsirhani et al. showed that giving EHAD an eight-week intervention enhanced EHAD strength by 0.49 Nm/kg and has significant implications for rehabilitation settings, Ahmed A. Alsirhani et al. (2024). In the same regard, it revealed 35.7% improvement in EHAD strength among sub-elite football players, further vindicating the part it plays in performance boost. Also, CAE has adopted the SAID principle in the progressive design where therapeutic goals are matched to sport-specific requirements, therefore, an improvement that affects the body’s susceptible muscle groups for injuries, Hostrup and Bangsbo(5).

The theoretical underpinnings provide the basis for this evidence, indicating that eccentric CAE load increases sarcomere capacity and enhances neuromuscular interaction. These changes improve not only the adductor’s hypertrophy but also their capacity during emphatic movements of the field, such as DRM and DD, as seen in football competitions by Stannard et al.

### *Leveraging Pain Relief and Functional Rehabilitation*

Relief from pain and restitution of the functioning musculoskeletal unit are thought to be the primary ways by which CAE works. Other authors, such as Ahmed A. Alsirhani et al., have reported a decrease in the intensity of the pain in the groin area; the HAGOS scores demonstrate that CAE is useful for rehabilitation. This is in agreement with Kohavi B. et al. (2018), where exercising using CAE collaboratively with resistance band training significantly reduced pain levels.

Within the structured programs, including FIFA 11+, the use of CAE also showed pain minimization along with enhancement of hip mobility proved by Harøy J. et al. (2017). It was also found out that there is little muscle soreness, which implies that CAE is suited for high-intensity training programs without increasing the discomfort. Such outcomes imply not only that CAE promotes a quicker return to play and thus reduces time lost by the player(9), Liveris et al.

### *Neuromuscular Adaptation: The Keys to More Efficient, Powerful, and Injury-Resistant Movements*

Several studies show that the neuromuscular adaptations that are obtained in CAE interventions raise the bar on the likelihood of groin injury relapse. EHAD strength increased to 35.7% in Ishøi, L. et al. 2015, evidence that the CAE converges with resistive training. These adaptations relate to intrinsic risk factors that include such issues as which is balanced muscle strength as well as joint flexibility of the hip particularly in rugby, which is essential within the injury prevention frameworks(6), Bakar and Shaharudin.

Furthermore, enhancing eccentric loading, which is in the focus of CAE, improves both muscle’s motor unit recruitment and stretch-reflex sensitivity according to Hostrup and Bangsbo(5), making it effective both for rehabilitation from the injuries and the performance optimization. The use of CAE in integrating it with other paradigms of increased and all-encompassing injury risks and reduction paradigms was used by Harøy J. et al. (2017).

### *Compliance and \*Practicality\**

Common compliance ratios of different studies indicate that CAE has functional applicability in a range of training contexts. For instance, Harøy J. et al. noted that the performance was improved when the CAE was combined with structured activities such as FIFA 11+(44); Harøy J. et al. (2017). Such conclusions stress the significance of the strategic enactment so the content would be applied evenly and the advantages would be optimized(13), Elyasi et al.

However, Nygaard stressed that there may be some difficulties with dependence on partner assistance as far as Nygaard. Overcoming this limitation with variant protocols or another piece of apparatus might improve accessibility and adherence in amateur and expert modalities(31), Vidmar et al.

### *Addressing the Risk of Bias*

The gathered studies demonstrated that the overall risk of bias ranged from low to moderate, but several methodological issues should be considered. Some of the investigators failed to describe the blinding protocols, specifically the subjective outcomes, including but not limited to pain scales; reporting bias was witnessed in two studies by Ahmed A. Alsirhani et al. and Pippas, C. et al. (2024). Similarly, the issue of inconsistent adherence tracking in works such as Ishøi, L. et al. 2015 shows that such reporting should be standardized.

To progress the field forward, future studies should focus on methodological designs, including blinding and adherence measures that are accurate and strict(12), Nielsen et al.

The review of methodological quality across the included studies demonstrated clear issues related to the systematic susceptibility of research methods in design and implementation. Despite the overall low to moderate risk of bias found in the present study, there are a few important methodological aspects that need attention. The most striking of them came out in the blinding protocols, especially with regard to issues of subjective outcome measures. They found that many investigators paid inadequate attention to assessor independence, which may threaten the validity of the pain scale measurement and other self-report measures.

We agree with the reporting bias found in the studies by Ahmed A. Alsirhani et al. and Pippas, C. et al. (2024); this requires further enhancement of methodological quality. Ontology source Reporting bi-standard bias Measurement consistency goes beyond the basic level. This is seen in studies that will be discussed in this paper, such as Ishøi, L. et al. 2015(33), which have pointed to the challenges of implementing strict adherence to interventions. Two important methodological limitations are that there are no controlled, consistent strategies for identifying the level of participant compliance as well as estimating the degree to which the intervention was implemented as planned.

These problems concerning data collection and reporting in the studies reviewed above make it difficult to make comparisons and to develop further conclusive evidence on the effectiveness of such specific interventions. Future research will, therefore, need to employ better quality control mechanisms to help enhance the current methodological basis of the field. This ranges from bringing in set policies on assessment and creating rigorous blinding processes for the assessors and participants should the need arise. It will greatly add to the credibility of research findings and help make comparisons with studies addressed more effectively.

### *The Applied Healthcare Operation Management and Limitations*

The advantages of CAE as shown to be effective, therefore advocating for it as one of the most essential intercessions for recovery or prevention of football male players injuries. However, several avenues for future research and practical application remain:

**Long-term Efficacy**: Further research should be conducted to assess CAE's long-term effects on the rate and prevalence of the injury as well as the performance of the athletes, Nielsen et al. Hence, Further research should focus more on how often and how intense and lengthy these CAE sessions should be to achieve the best results, Ahmed A. Alsirhani et al. As the limitation of this study did not reveal such data due to its specific focus.

Using CAE for other sports and other populations could improve the external validity of this conclusion, Harøy J. et al. (2017). Furthermore, CAE should be used in conjunction with other exercises, including sliding hip and proprioceptive drills, and may be even more effective, Liveris et al., Kohavi B. et al. (2018). Yet, the limitation here was focusing solely on male football players, rather than working on gender base to ensure diversity in terms of responding to CAE efficiency. Since previous studies have found that CAE is useful in rehabilitation and in decreasing the likelihood of getting injured, this paper aimed to review the practical implementation of CAE yet, had a limitation for more substantial research that needed to be conducted during the process. The framework also details the consideration of a number of different operational factors in the implementation of the system, the resources necessary, and the changes in the staff and facilities needed; hence the limitation evolved around finding the relevant criteria in diverse article that matches with the objectives of this study.

Existing literature proves that CAE is helpful in the overall improvement of clinical practice, but several crucial directions should be researched further to enhance effectiveness in procedural practice. The limitation is merely the issue of distant outcomes that makes it the most important in this regard. The next steps should explore the long-term consequences of CAE interventions on reinjures and athletes’ performance over a longer timeframe. This also entails a study of a range of biological adaptation processes that seem to be taking place as the results are being observed and defining the parameters that are most effective in sustaining the adaptations in a constant manner. For example, instead of establishing short-term levels, the studies should employ follow-up to evaluate the short-term and long-term effects of the intervention. Optimization of parameters represents another major research topic that remains to be explored at greater length. CAE has been shown to be effective in stopping carcinogenesis in the current studies. Still, it is not known how often, for how long, and with what frequency and intensity the intervention should be delivered. Future research needs to further investigate these variables in a more structured manner based on factors like athlete characteristics, training micro-cycle, and competition calendar. This research should seek to identify how best CAE protocols can be implemented, notably for different populations and settings.

Therefore, the generalization of CAE to a variety of athletic populations should be further studied. Subsequent research with male-only football players also limits the generalizability of the findings. However, broadening the research to other sports, players of different ages, and skill level would add to the understanding of the extensiveness and restrictive nature of the intervention. This broader application would assist in exporting the findings presently present in the literature and ensure the existence of, perhaps, population-specific adjustments for enhanced efficiency. Hence, of specific interest to future studies is a more nuanced and elaborate work on hybrid intervention models. CAE may be more effective when used in conjunction with other exercises, which include sliding hip movements and proprioceptive drills. Studies focused on these combined strategies should look at the possible synergistic reactions and the best mix of methods for certain rehabilitation purposes or preventive measures against certain injuries.

Consequently, the evaluation of risk bias and future research direction unveils the pro-implementation challenges of CAE in sports medicine. The problems indicated by the reviewed investigations point to the necessity for better standardization of the methodological approaches and outcomes measurement. Still, the data mentioned in the literature review hold a solid base to consider CAE as a reliable method in injury prevention and rehabilitation. The specific areas of CAE application that remain for future study offer major directions and goals for improving the knowledge of CAE efficacy in various fields.

Systematic monitoring, in combination with improved and standardized protocols for the assessment of CAE’s results, will play a major role in elaborating more set guidelines for implementing CAE. Consequently, while new knowledge is being generated, it is crucial to maintain the emphasis on identifying effective solutions for practice, especially for employing them in a variety of settings within sports settings. The present findings directions indicate that CAE has the ability to enhance EHAD strength, and reduce pain and high compliance rates and that it should further ensure a viable cornerstone interventional prop in sports medicine consistently when carried out via high research muster point and standardized implementation protocols. In the future, the field needs to meet the standards and be more practical. Thus, CAE can still be used to support athletic injury prevention and rehabilitation.

# **CHAPTER 6 CONCLUSION**

## **6.1 Main Findings**

The purpose of this study was, therefore to assess whether the CAE in terms of its capacity to reduce the incidences of groin injuries among male football players is applicable or not and also as a form of rehabilitation. The purpose of this study was, therefore, to determine whether there was added value in adopting CAE as a method to enhance eccentric hip adduction (EHAD) strength, decrease pain, increase compliance, and thus positively impact athletic performance. These objectives were partially met with minor skeptical assurance of efficiency and CAE intervention being beneficial by conducting a synthesis of the available literature as well as the analysis of the data derived from the experiments.

The studies showed that the adoption of CAE could have positively impacted EHAD. It must be noted that this enhancement could remain one of the core ways of managing extrinsic risk factors for groin injuries, which include muscle asymmetry and poor neuromuscular coordination. An additional noted benefit was that a possible decrease in pain can be evident, with data showing an actual reduction of discomfort during both rehabilitation and training periods. Moreover, the adherence levels were relatively high in various contexts, thus indicating the possibility of integrating CAE into formal training and physiotherapy activities. The results of this study underscore CAE’s critical role in its potential ability for rehabilitation and injury prevention models; as such, CAE can complement theoretical models supporting eccentric loading and neuromuscular modification.

Critical analysis also revealed other factors necessary for leveraging on many benefits available at CAE. These include the lack of set procedures, inadequate supervision, and failure to take into consideration individual or environmental factors. Nevertheless, it is crucial to identify specific limitations found in the existing studies, including methodological variability and limited clarity of the risk of bias in some research, in order to require improved study designs in subsequent studies.

## **Recommendations**

Building on the findings and analyses, this study proposes the following practical and theoretical recommendations to enhance the application and understanding of CAE:

### *Practical Recommendations:*

Develop strict procedural policies that should be followed in the implementation of CAE across the different rehabilitation and training environments. These protocols should also indicate the level of intervention frequency, the amplitude of the intervention intensity, and the duration of the intervention.

Calling for integration of CAE into other more formal structures for implementing injury prevention strategies, including the FIFA 11+, to take advantage of their complementary strengths.

Design small, lightweight, low-cost, on-procedure CAE assisting instruments. Expanding its accessibility for amateur athletes and other disadvantaged groups will be prolific as a result of offering scalable solutions.

### *Theoretical Recommendations:*

Next research ideas should include longitudinal studies on the effectiveness of CAE to prevent re-occurrences of the injuries as well as its effects on long term athleticism. Such studies will, therefore, enable a further understanding of the reason that it remains effective even today.

Research studies should be done comparing the effectiveness of the CAE in different sports and different athletes, apart from football players who have massive groin injuries.

Discuss how adding other treatments might help increase the applicability and benefits of CAE to correspond with similar movements, including sliding hip exercises, proprioceptive training, and dynamic stretching.

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# **APPENDIX 1**

| **Component** | **Details** |
| --- | --- |

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| --- | --- |
| **Population (P)** | Male football players likely to be affected by groining strain or recovering from one. Consists of people who take part in different games to the level of professionalism including the amateur sportsmen more so, people who engage in high-intensity sports that involve changes in direction. |

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| --- | --- |
| **Intervention (I)** | Incoroperation of the Copenhagen Adduction Exercise (CAE) into training and rehabilitation activities – eccentric hip adduction exercises. |

|  |  |
| --- | --- |
| **Comparison (C)** | Inadequate or traditional strength training or rehabilitation programs that do not incorporate CAE ; general strength training; flexibility exercises; and traditional groin injury management. |

|  |  |
| --- | --- |
| **Outcome (O)** | * Greater eccentric hip adduction (EHAD) strength. * Relief. * Increased healing and satisfactory adherence to guidelines, protocols in cases of injury or disorder. * Enhanced operations in athletic activities and low rate of reemergence of groin injuries. |

**Table 6:** PICO

# **APPENDIX 2**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Criteria | Joar HarÃ¸y et al. | Ahmed A. Alsirhani et al. | Ishøi, et al. | Christos et al. | Bar Kohavi et al. |
| Study Design | Randomized Controlled Trial | Randomized Controlled Trial. | Randomized Controlled Trial. | Randomized Controlled Trial | Randomized Controlled Trial |
| Population | 33 players | 30 players | 20 players | 39 players | 52 players |
| Objective | To investigate the effect on eccentric hip adduction strength of the FIFA 11+ warm up program with or without the Copenhagen adduction exercise | To investigate the impact of CAE on eccentric hip adduction (EHAD)strength, hip joint ROM, self-reported disability and pain among soccer players with adductor related groin pain | To examine the eccentric hip adduction strength(EHAD) using CA in two elite football teams | To examine the effect of assigning male football players to an 8-week Copenhagen Adduction (CA) and Adductor Squeeze (SQ) | To examine the effect of 8 weeks program on hip joint muscle strength using CA and SD exercise |
| Intervention | first group (17 players) carried the FIFA 11+ but replaced the Nordic hamstrings exercise with the Copenhagen adduction exercise | 15 players in the intervention group added the Copenhagen technique to their respective rehabilitation program. | To examine the eccentric hip adduction strength(EHAD) using CA in two elite football teams | group A (16 players) with CA exercise intervention | U16 (14 players) CA group  U17(16 players) SH group |
| Comparison | second group(16 players)carried the FIFA 11+ that’s includes the usual Nordic hamstrings exercise | 15 players in the control group continued their rehabilitation without Copenhagen technique included. | Club B 10 players (control group) usual training | group b(23 players)with adductor squeeze intervention | control group (12 players) |
| Outcome Measures | primary outcome: EHAD strength  Secondary outcome: eccentric knee flexor strength, DOMS | primary outcome: EHAD strength.  Secondary outcome: pain, HAGOS | primary outcome: EHAD strength  Secondary outcome: DOMS | The primary outcome measure of the study was maximal EHAD. Secondary outcome measures were maximal unilateral IHAD, DOMS and perceived exertion | primary outcome: EHAD strength  Secondary outcome: DOMS |
| Results | analysis revealed an increase in eccentric hip adduction strength of 0.29 Nm/kg in favor of the group performing the CA exercise but the median DOMS was the same for both intervention | significant improvement within were observed across all measures. EHAD strength with mean difference(MD)= 0.49Nm/kg and reduction in pain MD=-1.60 | intervention group had significant increase in EHAD from 2.71 to 3.67 Nm/kg and DOMS decrease in the range (75\_100%) | The analysis showed no statistically significant differences between groups neither for EHAD (p = 0.478-0.833) nor IHAD (p = 0.084-0.118) also no other significant differences between the groups were observed for DOMS nor perceived exertion. | the CA group had significant strength increase as well as the SH group in both left and right leg,  DOMS decreased in both intervention groups |

**Table 7:** Characteristics of Articles Analyzed