Article

Risk Factors for Groin Pain in Male High School Soccer Players Undergoing an Injury Prevention Program: A Cluster Randomized Controlled Trial

Kazuki Fujisaki 1,2, Kiyokazu Akasaka 1,3,*, Takahiro Otsudo 1,3, Hiroshi Hattori 1,3, Yuki Hasebe 1,4, and Toby Hall 5,6

1 Graduate School of Medicine, Saitama Medical University, Saitama 350-0495, Japan; kazuki.0838@gmail.com (K.F.); otsudo@saitama-med.ac.jp (T.O.); hiroshi.hattori1024@gmail.com (H.H.);
yuki.hasebe1216@gmail.com (Y.H.)
2 Department of Physical Therapy, Ota College of Medical Technology, Ota 373-0812, Japan
3 School of Physical Therapy, Saitama Medical University, Saitama 350-0495, Japan
4 Department of Rehabilitation, Saitama Medical Center, Saitama Medical University, Saitama 350-8550, Japan
5 Curtin School of Allied Health, Curtin University, Perth, WA 6845, Australia; halltm@netspace.net.au
6 Manual Concepts, Perth, WA 6007, Australia
*
Correspondence: akasaka-smc@umin.ac.jp; Tel.: +81-49-295-1001

Abstract: Little is known about the risk factors for developing groin pain in high school soccer players. Therefore, the purpose of the study is to investigate the risk factors for developing inguinal pain in high school soccer players who are undergoing an injury prevention program. A cluster randomized controlled trial was conducted on 202 high school soccer players. Players were allocated to either group A (3 schools, 66 players) receiving the Copenhagen adduction exercise (CAE) alone, or group B (2 schools, 73 players) receiving the CAE and Nordic hamstrings exercise, or group C, the control group without any intervention (2 schools, 63 players). Hip range of motion (ROM) and strength measures were assessed prior to a groin injury prevention program and used in univariate and multivariate analysis to predict development of groin pain. Logistic regression analysis identified that hip abduction ROM and eccentric adductor strength of the dominant leg were factors in the development of groin pain. Increased abduction ROM and decreased eccentric adductor muscle strength of the dominant leg were risk factors for the development of groin pain.

Keywords: high school; soccer; player; groin pain; risk factor

1. Introduction

Soccer is a sport that requires high-intensity sprinting, kicking, and rapid high-speed changes in direction [1–4], which can be common causes of injury [5].

Groin pain is common in soccer players and is the most common of all injuries [6–8], with high risk of recurrence [9]. The Doha agreement classifies groin pain into adductor-related, iliopsoas-related, inguinal-related, pubic-related, and hip joint-related pain [10]. The origin of such pain is frequently the adductor muscles [11], with 61% reported as having adductor muscle-related pain [12].

Factors related to the development of groin pain have been reported to include decreased hip abduction range of motion (ROM) [13], decreased adductor muscle strength [14,15], and trunk muscle weakness [16]. This might explain why the Copenhagen adduction exercise (CAE) is effective as a preventive exercise for groin pain, possibly due to increased eccentric adductor muscle strength reported when strengthening the hip adductor muscles [17], which was associated with reduced injury occurrence [18,19]. A benefit of the CAE is that it does not require expensive equipment and can be applied almost anywhere.

In addition to injury prevention through exercise such as the CAE, it is important to identify risk factors which might also be helpful in injury prevention in athletes undergoing...
the CAE. Most research on groin pain is in relation to adult athletes. There is limited research on the implementation of the CAE and factors related to the development of groin pain in male high school soccer players. In addition, there is limited evidence on whether combining the CAE with exercise for other muscle groups, such as the Nordic hamstrings exercise (NHE), is more effective in reducing groin pain development. Functionally the hamstring muscles have an auxiliary effect on the hip adductor muscles [20,21], but it is unclear whether training the hamstring muscles enhances the effect of a CAE program.

The purpose of this research was to identify whether previously reported variables in groin pain evaluation (hip eccentric adductor and abductor strength and ROM of both hip joints) [15–17] could predict injury in high school soccer players undergoing a groin pain injury prevention program. Information gained from this study may improve knowledge on how to prevent groin pain among high school soccer players.

2. Methods
2.1. Study Design and Participants

Participants were male high school students participating in a Japanese under 18 soccer league. Participants were competing at the highest level in the prefecture and national league, and the top teams were targeted for standardization. We contacted 10 schools with teams in this league for potential inclusion. Two high schools did not respond, and another could not start at the right time. Four players were absent from club activities and were excluded. Consent was obtained from the principal and coach from each school. In addition, all parents and players gave written consent for this research. The inclusion criteria were male high school soccer players who had not been injured within the previous month. This study followed the Declaration of Helsinki and was approved by the Ethics Committee at the Saitama Medical University, Saitama, Japan (M-98).

2.2. Randomization

This cluster randomized controlled trial was registered with the University Hospital Medical Information Network at The University of Tokyo Hospital (Registration number 000036863) and was conducted from August 2019 to December 2019. We felt it would be difficult to blind subjects through individual subject randomization, so each high school formed a cluster group which were then randomized using the envelope method. After a team agreed to participate, the principal investigator opened a sealed envelope revealing their group assignment. Group A received only the CAE, Group B received both the CAE and NHE, while Group C was the control group without any intervention.

2.3. Blinding

It was not possible to blind players, coaches, or the principal investigator to group allocation. Recorded data were collected by the principal investigator alone.

2.4. Intervention

The CAE was performed as follows. The athlete lay on their side, their forearm on the ground to stabilize the trunk, while their other arm was placed with their hand on their pelvis. A teammate supported the player’s uppermost leg at the ankle and knee. The athlete was then required to lift their body off the ground, by adducting the upper hip, until the upper leg and trunk were horizontal, following which, they lifted their lower leg off the ground to touch ankles. This was counted as one repetition, each lasting 3 s. (Figure 1) [17,18]. The players performed the exercise on both sides. If pain of greater than 3/10 was provoked during the exercise the player was told to stop.
Figure 1. The Copenhagen adduction exercise. (A) Starting/ending position, (B) The mid position of the adductor muscle strengthening program.

For the NHE, two players formed a pair. The performing athlete began the exercise kneeling with his trunk upright, before slowly lowering himself to the ground. An assistant held both lower legs of the athlete on the ground. The exercise ceased once their hands touched the ground (Figure 2) [22]. Again, if pain of greater than 3/10 was provoked during the exercise the player was told to stop.

Figure 2. The Nordic hamstrings exercise. (A) Starting position, (B) End position of the hamstrings muscle strengthening program.

Subjects in both intervention groups were asked to carry out the exercise program 1–3 times a week for 16 weeks as part of their regular warm-up. The number of repetitions was based on previous research (Table 1) [18,22]. We informed subjects that the exercise had to be conducted under the supervision of a coach or trainer, and that the principal investigator was to be contacted if problems or adverse events occurred during the exercise program. Before the study began, the players and coaches were well trained in how to perform the exercises. The exercises were basically done on the playing field or indoors depending on the weather and team conditions. Subjects exercised in the clothing they wore for soccer.

Exercise compliance was recorded daily by athletes on a recording sheet. To calculate overall compliance, the total number of completed sessions was summed and divided by the number of respondents. Once a week, we contacted managers, trainers, and athlete representatives to keep track of exercise progress. The principal investigator collected recording papers with encrypted numbers.
Table 1. Training protocol for Copenhagen adduction exercise (CAE) and Nordic hamstring exercise (NHE).

| Week | Weekly Sessions | Sets (Per Side) | Repetitions (Per Side) |
|------|----------------|----------------|-----------------------|
| CAE  |                |                |                       |
| 1    | 2              | 1              | 3–5                   |
| 2    | 3              | 1              | 3–5                   |
| 3–4  | 3              | 1              | 7–10                  |
| 5–16 | 3              | 1              | 12–15                 |
| NHE  |                |                |                       |
| 1    | 1              | 2              | 5                     |
| 2    | 2              | 2              | 6                     |
| 3    | 2              | 3              | 6                     |
| 4    | 2              | 3              | 6, 7, 8               |
| 5–16 | 2              | 3              | 8, 9, 10              |

* CAE describes the number and number of sets on one side.

2.5. Risk Factor Screening

Risk factor screening, including hip ROM and strength, were performed prior to the intervention period. Hip ROM measurements included internal and external rotation in supine, internal rotation in prone, abduction in side-lying, and Bent knee Fall Out (BKFO) were taken using previously reported methods (Figure 3) [23,24]. Hip internal and external rotation in supine was measured with a digital goniometer (Easy Angle manufactured by Meloq, Stockholm, Sweden). The average value of two repetitions was recorded. Internal rotation in prone were measured using digital inclinometers (digital level manufactured by FstDgte, Shenzhen, China). For internal rotation in prone, two digital inclinometers were used, the measurement repeated three times, and mean value recorded. For hip abduction, a single inclinometer was used to measure the hip abduction angle with the knee of the limb flexed to 90° in a side lying position. The measurement was repeated three times and the average value was recorded. BKFO was measured once using a tape measure. For this measurement, the subject was supine, with hips bilaterally flexed to 45°, knees at 90° flexion. The distances between the head of the fibula and the bed were measured using a flexible tape measure.

Hip abduction and adduction strength were recorded with reference to previously reported measurement method using a handheld dynamometer (HHD, SAKAIMED Mobi, Tokyo, Japan) [24,25]. Eccentric muscle strength was assessed (Figure 3). The participant exerted a 3 sec isometric maximum voluntary contraction against the HHD following which a 2 sec break was performed by the examiner pushing the leg slowly towards the bed. One mock test and three maximum tests were performed with a break of 30 s between trials. The maximum scores of the three tests were recorded as Nm/kg. All measurements were performed by the principal investigator, and subsequently recorded.

In order to control the quality of the evaluation, all the tests and measurements were performed by the principal investigator alone. The principal investigator was trained for a minimum of 5 h in the measurement method. Good to excellent intraexaminer reliability values (intraclass correlation coefficient = 0.66–0.93) for all ROM and strength tests have been previously reported, along with normal values [24].
2.6. Injury Reporting

Injury was defined as a condition in which pain occurred in the area during sports activities regardless of time loss or treatment needs [26]. Injury data were collected over a 16-week period. The presence or absence of injury was recorded on training or playing days. In addition, injury details were filled out on the injury report form. Details of the injury were provided on the injury report form and completed with the advice of a trainer or physiotherapist whom the principal investigator has trained. The principal investigator explained the Doha classification method to the trainers and physiotherapists of each team and let them determine the type of groin pain for each athlete in pain. Each player was asked to report the presence or absence of groin pain. Injuries were classified into three severity categories according to the time it took until the player was fully fit to take part in all types of organized soccer play: minor (1–7 days), moderate (8–28 days), and major (>28 days).

To calculate exposure time individually, athletes were asked to record daily practice time, match time, and time lost due to injury. Once a week, we contacted managers, trainers, and athlete representatives and worked closely to review the status of the recording and injury report forms. The development of groin pain was conveyed to the athletic trainer or physiotherapist. Injury details were self-reported in an injury statement, with the advice of an athletic trainer or physiotherapist who had been informed of the details by the principal investigator. Reports were collected weekly by the principal investigator. However, overuse injuries for which there was no time lost were also included to incorporate small repeated-strain injuries, as some players still elect to play despite groin discomfort.

2.7. Sample Size

The sample size for logistic regression analysis was determined according to Altman’s formula \( n \geq 10 \times \text{independent variable} \). The number of independent variables was 14 combining the dominant and non-dominant leg, hence the required number of subjects was 140 or more.
2.8. Statistical Analyses

The analysis was performed using an intention-to-treat (ITT) analysis. \( \chi^2 \) tests were performed to compare the number of injuries inducing groin pain among the three groups A, B, and C. Following that, a Bonferroni correction was performed as a post hoc analysis for the items for which a significant difference was found. In addition, in order to clarify the factors related to groin pain, univariate logistic regression analysis (forced injection method) was performed with the dependent variable as the presence or absence of groin pain and the independent hip physical examination variables. After that, logistic regression analysis (variable increase method: likelihood ratio) was performed on the items for which a significant difference was found in the independent variables. In consideration of multicollinearity, items with \( r > 0.8 \) between independent variables were excluded.

The effect size for the medical examination variables was calculated as \( r \), while the effect size of the number of injuries was calculated as \( \phi \). Effect size < 0.1 is rated as small, 0.3 rated medium, and >0.5 rated large [27]. In addition, logistic regression analysis calculated odds ratios and 95% confidence intervals.

3. Results

3.1. Participants

A total of seven high school soccer clubs (202 players) were enrolled in the study. The flow of the players through the phases of the study is shown in Figure 4.

![Figure 4](image-url): Flowchart showing numbers of players participating.

There was a total of 11 dropouts, 4 in Group A, 1 in Group B, and 6 in Group C. The reasons were retirement, injury, and low compliance. Baseline characteristics for players included in the ITT analysis are shown in Table 2.

Table 2. Subject Characteristics (\( n = 202 \)).

|                     | A Group (\( n = 66 \)) | B Group (\( n = 73 \)) | C Group (\( n = 63 \)) | \( p \)-Value |
|---------------------|------------------------|------------------------|------------------------|--------------|
| Age (years) \( ^{a} \) | 16.4 ± 0.9 (15–18)    | 16.0 ± 0.7 (15–18)    | 16.1 ± 0.9 (15–18)    | 0.47         |
| Height (cm) \( ^{a} \) | 170.7 ± 5.7 (156.0–186.3) | 169.2 ± 5.2 (157.2–184.0) | 170.3 ± 5.1 (160.0–180.0) | 0.24         |
| Weight (kg) \( ^{b} \) | 60.2 ± 7.1 (40–83)    | 58.4 ± 7.2 (42–80)    | 58.5 ± 6.5 (45–74)    | 0.22         |
| Dominant foot (players) |                        |                        |                        |              |
Table 2. Cont.

| A Group (n = 66) b | B Group (n = 73) b | C Group (n = 63) b | p-Value |
|------------------|------------------|------------------|--------|
| Field position (players) | Field position (players) | Field position (players) | Field position (players) |
| Right | 55 | 67 | 52 | 0.74 |
| Left | 11 | 6 | 11 | |
| Attackers | 10 | 12 | 11 | |
| Midfielders | 24 | 27 | 23 | |
| Defenders | 26 | 23 | 24 | |
| Goalkeepers | 6 | 11 | 5 | |

a Shows mean and standard deviation. Furthermore, the minimum–maximum is listed. b Group A Copenhagen adduction exercise alone. Group B combined Copenhagen adduction exercise and Nordic hamstrings exercise. Group C continues as usual.

3.2. Injury Occurrence

Table 3 shows the frequency of groin pain in each group over the 16-week period. Groin pain was significantly reduced in group B compared to group C. Groin pain with time lost was significantly reduced in groups A and B compared to group C. When comparing groups A and B, a small effect size was observed in groin pain, although there was no significant difference.

Table 3. Frequency of groin pain by number of groin pain injuries a.

| Variable | Groin Pain (n = 25) | Non-Groin Pain (n = 177) | p-Value | Effect Size (r) |
|----------|---------------------|--------------------------|---------|-----------------|
| Groin pain | 8 (12.1) | 4 (5.5) | 0.01 | 0.16 |
| Time-lost-to-sports | 6 (9.1) | 3 (4.1) | 0.01 | 0.24 |
| Groin pain | 16 (28.6) | 6 (25.4) | 0.01 | 0.02 |

A chi-square test was performed to compare the three groups. The two groups were then compared using the chi-square test or Fisher’s exact test. b Group A intervenes Copenhagen adduction exercise alone. Group B is a combined intervention of Copenhagen adduction exercise and Nordic hamstrings exercise. Group C is a control group. c The significance level is α = 0.05. d The Bonferroni correction was used as a post hoc test.

During the 16-week intervention period of 202 high school soccer players, the total number of injuries was 138. In addition, the total exposure time was 43,008 playing hours. The total incidence of injuries was 3.2 per 1000 athlete hours (95% confidence interval [CI], 2.8–4.8). The total number of groin pain injuries was 30. The incidence of groin pain was 0.7 per 1000 athlete hours (CI 95%, 0.4–0.9). There were 23 injuries on the dominant leg (79.3%) and 6 on the non-dominant leg (20.7%). Of these, 9 were minor injuries (time lost 1–7 days), 15 were moderate injuries (time lost 8–28 days), and 1 was a severe injury (>28 days lost). Groin pain without time loss occurred on five occasions.

3.3. Hip Variable Screening

Table 4 shows a comparison of each variable in the screening process for players with groin pain and those without groin pain. When comparing mean values, a significant difference was found in the items of hip abduction ROM, as well as eccentric abduction and eccentric abduction muscle strength. In these items, there was a significant difference between the dominant leg and the non-dominant leg.

Table 4. Hip range of motion and strength in the presence or absence of groin pain.

| Variable | Groin Pain (n = 25) | Non-Groin Pain (n = 177) | p-Value | Effect Size (r) |
|----------|---------------------|--------------------------|---------|-----------------|
| Hip range of motion | 36.8 ± 7.4 | 36.2 ± 9.6 | 0.79 | 0.02 |
| External rotation (°) | 36.8 ± 7.4 | 36.2 ± 9.6 | 0.79 | 0.02 |
Table 4. Cont.

| Variable                                   | Groin Pain (n = 25) | Non-Groin Pain (n = 177) | p-Value | Effect Size (r) |
|--------------------------------------------|---------------------|----------------------------|---------|-----------------|
| Non-Dominant leg                           | 39.8 ± 7.5          | 38.5 ± 8.6                 | 0.45    | 0.53            |
| Internal rotation (°)                      |                     |                            |         |                 |
| Dominant leg                               | 27.6 ± 6.5          | 27.4 ± 9.1                 | 0.65    | 0.01            |
| Non-Dominant leg                           | 26.7 ± 6.1          | 27.5 ± 8.4                 | 0.40    | 0.03            |
| Abduction (°)                               |                     |                            |         |                 |
| Dominant leg                               | 35.7 ± 7.4          | 33.9 ± 8.3                 | 1.00    | 0.07            |
| Non-Dominant leg                           | 35.3 ± 6.4          | 35.3 ± 7.9                 | 0.59    | 0.01            |
| Internal rotation in the prone position (°)|                     |                            |         |                 |
| Dominant leg                               | 46.1 ± 6.5          | 41.0 ± 5.8                 | <0.001<sup>a</sup>| 0.27            |
| Non-Dominant leg                           | 45.5 ± 6.5          | 41.3 ± 6.2                 | 0.02<sup>a</sup> | 0.21            |
| Bent knee fall out (cm)                    |                     |                            |         |                 |
| Dominant leg                               | 13.3 ± 4.5          | 14.1 ± 4.2                 | 0.37    | 0.06            |
| Non-Dominant leg                           | 13.8 ± 4.0          | 13.9 ± 4.0                 | 0.94    | 0.01            |
| Eccentric muscle strength                  |                     |                            |         |                 |
| Adduction (Nm/Kg)                           |                     |                            |         |                 |
| Dominant leg                               | 2.6 ± 0.3           | 2.9 ± 0.4                  | <0.001<sup>a</sup> | 0.26 |
| Non-Dominant leg                           | 2.5 ± 0.3           | 2.9 ± 0.5                  | <0.001<sup>a</sup> | 0.15 |
| Abduction (Nm/Kg)                           |                     |                            |         |                 |
| Dominant leg                               | 2.0 ± 0.3           | 2.1 ± 0.3                  | 0.04<sup>a</sup> | 0.24 |
| Non-Dominant leg                           | 2.0 ± 0.3           | 2.2 ± 0.3                  | 0.02<sup>a</sup> | 0.17 |

<sup>a</sup> The significance level is α = 0.05.

3.4. Risk Factors for Groin Pain

Results of univariate logistic regression analysis identified hip abduction ROM (dominant leg and non-dominant leg), eccentric adduction muscle strength (dominant leg and non-dominant leg), and eccentric abduction muscle strength (dominant leg and non-dominant leg) at the start of the intervention as predictor variables for the development of groin pain (Table 5). Following this, logistic regression analysis used the items with significant differences as independent variables. Consequently, abduction ROM of the dominant leg and adductor strength of the dominant leg were selected (Table 6).

Table 5. Factors related to the development of groin pain (Single logistic regression analysis).

| Hip range of motion | B<sup>a</sup> | SE<sup>b</sup> | p-Value | Odds | 95% CI of Odds |
|---------------------|---------------|---------------|---------|------|----------------|
| External rotation   |               |               |         |      |                |
| Dominant leg        | 0.006         | 0.023         | 0.79    | 1.01 | 0.96           |
| Non-dominant leg    | 0.019         | 0.025         | 0.45    | 1.02 | 0.97           |
| Internal rotation   |               |               |         |      |                |
| Dominant leg        | 0.003         | 0.024         | 0.90    | 1.00 | 0.96           |
| Non-dominant leg    | −0.012        | 0.027         | 0.64    | 0.99 | 0.94           |
| Internal rotation in prone | | | | | |
| Dominant leg        | 0.027         | 0.026         | 0.31    | 1.03 | 0.98           |
| Non-dominant leg    | 0.001         | 0.028         | 1.00    | 1.03 | 0.95           |
| Abduction           |               |               |         |      |                |
| Dominant leg        | 0.145         | 0.039         | 0.01<sup>d</sup> | 1.13 | 1.05           |
| Non-dominant leg    | 0.106         | 0.035         | 0.01<sup>d</sup> | 1.11 | 1.04           |
| BKFO<sup>c</sup>    |               |               |         |      |                |
| Dominant leg        | −0.047        | 0.052         | 0.37    | 0.96 | 0.86           |
| Non-dominant leg    | −0.004        | 0.054         | 0.94    | 1.00 | 0.90           |

Eccentric muscle strength

| Adduction          |               |               |         |      |                |
| Dominant leg       | −1.991        | 0.568         | 0.01<sup>d</sup> | 0.14 | 0.05           |

<sup>a</sup> The significance level is α = 0.05.
Table 5. Cont.

| Abduction | B  | SE  | p-Value | Odds | 95% CI of Odds |
|-----------|----|-----|---------|------|----------------|
| Non-dominant leg | −1.707 | 0.514 | 0.01 | 0.18 | 0.07 to 0.50 |
| Dominant leg | −1.307 | 0.639 | 0.04 | 0.27 | 0.08 to 0.95 |
| Non-dominant leg | −1.476 | 0.639 | 0.02 | 0.23 | 0.07 to 0.80 |

* B: regression coefficient. b SE: standard error. ^ BKFO: Bent Knee Fall Out. d The significance level is α = 0.05.

Table 6. Factors related to the development of groin pain (Multiple logistic regression analysis).

| Hip Range of Motion | B  | SE  | p-Value | Odds | 95% CI of Odds |
|---------------------|----|-----|---------|------|----------------|
| Abduction | Dominant leg | 0.152 | 0.043 | 0.01 | 1.16 to 1.26 |
| Eccentric Muscle Strength | Dominant leg | −2.123 | 0.601 | 0.01 | 0.12 |
| Adduction | −2.614 | 2.317 | 0.26 | 0.07 | 0.04 to 0.39 |

* likelihood ratio: p-value < 0.01, Hosmer-Lemeshow test: p = 0.39, percentage of correct classifications was 87.6%.

The odds ratio for each item was 1.16 (95% CI: 1.07 to 1.26) for hip abduction ROM and 0.12 (95% CI: 0.04 to 0.39) for eccentric adductor muscle strength. The results of the Hosmer–Lemeshow test in this model were shown to be compatible with p = 0.39, with the percentage of correct classifications being 87.6%.

Following this, logistic regression analysis used the items with significant differences as independent variables. Consequently, abduction ROM of the dominant leg and adductor strength of the dominant leg were selected (Table 6).

The odds ratio for each item was 1.16 (95% CI: 1.07 to 1.26) for hip abduction ROM and 0.12 (95% CI: 0.04 to 0.39) for eccentric adductor muscle strength. The results of the Hosmer–Lemeshow test in this model were shown to be compatible with p = 0.39, with the percentage of correct classifications being 87.6%.

4. Discussion

This study examined high school soccer players’ risk factors for the development of groin pain during a 16-week groin injury prevention program, as well as the effectiveness of the program on groin pain prevention. This is the first study to analyze risk factors for the development of groin pain in high school soccer players. Factors predicting groin pain were decreased strength in hip adduction and an increase in hip abduction ROM at start of the evaluation period.

In this 16-week study, the injury rate for all injuries was 3.3 per 1000 athlete hours. This was comparable to previous studies of high school soccer players [28,29]. The incidence of groin pain injuries was 0.7 per 1000 athlete hours. Groin pain in adult soccer players has been reported to be common [30,31], and is also common in younger players [28,29]. The injury rates obtained in the present study were similar to previous reports indicating that groin pain is common even in high school soccer players.

The CAE has been reported to reduce the incidence of groin pain [18], which is consistent with our findings. In the present study, the combination of CAE and NHE reduced the number of groin pain injuries, and CAE alone reduced the number of cases with time lost to sport as shown in Table 3. This supports the effectiveness of the CAE in preventing groin pain in high school soccer players. The data also show that undertaking a program including the CAE and NHE was effective in preventing the development of more severe groin pain. Comparing intervention groups A and B, the number of groin pain
injuries was lower in group B, although with small effect size. This suggests that although the CAE can influence the risk of injury, based on our data, combining different forms of exercise intervention is more effective. From the above, we suggest that a combination of CAE and NHE exercise is more effective for groin pain prevention.

Hip ROM and adductor muscle strength have been reported to be associated with groin pain [13–16,32]. When comparing hip ROM and strength data between players who developed groin pain and those who did not, significant differences were found in hip abduction ROM, as well as eccentric adductor and abductor muscle strength. In this study, these differences were on the dominant and non-dominant leg. From these results, it would appear logical to screen hip abduction ROM, as well eccentric adductor and abductor muscle strength to identify at risk players.

Previous studies have reported risk factors for developing groin pain in professional soccer players [14]. Lower levels of isometric adductor muscle strength were reported as a factor. Although our study evaluated a different form of muscle function, a reduction in adductor muscle strength was also found to be a factor in groin injury risk. The exact mechanism by which a reduction in adductor strength causes groin pain is not known. It is possible that reduced adductor strength is associated with an increase in stress on soft tissues around the groin region. In addition, during eccentric contraction, muscle activation is required while the muscle and soft tissue are elongated, this could potentially place greater stress on soft tissues in the area, which may reduce the ability to maximally activate the muscle. Muscle damage has been reported to be caused by reduced muscle tightness [33,34], but this study suggests that increased extensibility of the adductor muscles may affect groin pain. It is possible that minor muscle damage may become more severe due to repeated micro failure, and groin function may decline.

Regarding the relationship between increased hip abduction ROM, and the occurrence of groin pain found in this study, increased hip abduction ROM may place additional stress on the adductor muscles, perhaps inducing muscle damage and pain. A previous study of adult soccer players reported that a risk factor for groin pain was a decrease in abduction ROM associated with hip adductor stiffness [8]. However, our study showed that increased hip abduction ROM was a risk factor for the development of groin pain in high school soccer players. This indicates that in high school soccer players, increased extensibility, rather than reduced adductor muscle flexibility, can cause injury to the groin. It has also been suggested that this difference between adult and adolescent players may be related to the fact that high school soccer players do not acquire full body emphasized movements, have lower muscle strength than professional soccer players, and have less stability around the hip joint [35]. Therefore, it should be noted that hip abduction ROM may be excessive in high school soccer players. Furthermore, leg dominance appears important, as eccentric hip adductor muscle strength and hip abduction ROM of the dominant leg were associated with groin pain. In soccer players, it has been reported that the dominant leg is most frequently injured [36], and kicking is the most common injuring movement [5]. As the dominant leg kicks most frequently, it is most likely to be injured. The dominant leg is more frequently used during competition games in junior soccer players [37], which might explain why the dominant leg is more affected by groin pain.

From the above points, it is possible that the CAE may increase eccentric adductor muscle strength and prevent increased hip abduction ROM. Previous studies have reported that strengthening the adductor muscles in professional ice hockey players and semi-professional soccer players reduces groin pain [15,18]. CAE has also been shown to be effective for chronic pubic-related pain [38]. The current study also now provides evidence for this in high school soccer players. The clinical implications of these findings are that a decrease in eccentric adductor muscle strength and an increase in abduction ROM on the dominant side imply screening potential for injury prevention in high school soccer players.

As a limitation of this study, injury data were based on the athlete’s self-report, which may have been under or over reported. In addition, injury investigation in this study was
also self-reported, potentially leading to measurement bias. We only evaluated subjects during the intervention period over 16 weeks. Furthermore, in the definition of groin pain used in this study, it was difficult to distinguish between acute injury and injury due to overuse. A longer follow up period is required to evaluate long-term changes. Furthermore, no intervention effect was observed in group A with respect to the number of groin injuries. Therefore, the CAE alone appears to not have a preventive effect on hip eccentric adduction weakness and hip abduction ROM. In the future, analysis with an increased sample size is required. Finally, as the competition level was limited, extrapolation to all high school soccer players might not be valid.

5. Conclusions

According to a 16-week injury survey and hip screening program in high school soccer players, the risk factors for developing groin pain were dominant leg decreased eccentric hip adductor muscle strength and increased hip abduction ROM. A 16-week CAE program was effective in preventing groin pain, although adding the NHE to this program may enhance the program’s effectiveness.

Author Contributions: Conceptualization, K.F. and K.A.; methodology, K.A.; formal analysis, K.F.; investigation, K.F.; data curation, T.O., H.H., Y.H. and T.H.; writing—original draft preparation, K.F., K.A. and T.H.; writing—review and editing, K.F., K.A., T.O., H.H., Y.H. and T.H.; supervision, K.A.; project administration, K.A. and T.O.; All authors have read and agreed to the published version of the manuscript.

Funding: This research was carried out at the Saitama Medical University Graduate School of Medicine Research Fund for graduate students.

Institutional Review Board Statement: This cluster randomized controlled trial was enrolled in the University Hospital Medical Information Network (UMIN000036863). This study was approved by the Ethics Review Committee, faculty of Health Sciences, Saitama Medical University (M-98).

Informed Consent Statement: Informed consent was obtained from the principals and coaches of each school. All parents and players also agreed in writing to this investigation.

Data Availability Statement: The data presented in this study are openly available in FigShare at https://doi.org/10.6084/m9.figshare.14374616.v1 (accessed on 13 April 2021).

Acknowledgments: The authors thank all players and coaches who participated in the study, as well as the team medical staff.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Brophy, R.H.; Backus, S.I.; Pansy, B.S.; Lyman, S.; Williams, R.J. Lower Extremity Muscle Activation and Alignment during the Soccer Instep and Side-foot Kicks. *J. Orthop. Sports Phys. Ther.* 2007, 37, 260–268. [CrossRef] [PubMed]
2. Judge, J.O.; Davis, B.R.; Ounpuu, S. Step length reductions in advanced age: The role of ankle and hip kinetics. *J. Gerontol. A Biol. Sci. Med. Sci.* 1996, 51, 303–312. [CrossRef] [PubMed]
3. Charnock, B.L.; Lewis, C.L.; Garrett, W.E., Jr.; Queen, R.M. Adductor longus mechanics during the maximal effort soccer kick. *Sports Biomech.* 2009, 8, 223–234. [CrossRef] [PubMed]
4. Chycki, J.; Golas, A.; Halz, M.; Maszczyk, A.; Toborek, M.; Zajac, A. Chronic Ingestion of Sodium and Potassium Bicarbonate, with Potassium, Magnesium and Calcium Citrate Improves Anaerobic Performance in Elite Soccer Players. *Nutrients* 2018, 10, 1610. [CrossRef]
5. Ekstrand, J.; Hägglund, M.; Waldén, M. Epidemiology of Muscle Injuries in Professional Football (Soccer). *Am. J. Sports Med.* 2011, 39, 1226–1232. [CrossRef]
6. Hawkins, R.D.; Fuller, C.W. A prospective epidemiological study of injuries in four English professional football clubs. *Br. J. Sports Med.* 1999, 33, 196–203. [CrossRef]
7. Ekstrand, J.; Gillquist, J. The Avoidability of Soccer Injuries. *Int. J. Sports Med.* 1983, 4, 124–128. [CrossRef]
8. Hägglund, M.; Waldén, M.; Ekstrand, J. Previous injury as a risk factor for injury in elite football: A prospective study over two consecutive seasons. *Br. J. Sports Med.* 2006, 40, 767–772. [CrossRef]
9. Werner, J.; Hagglund, M.; Walden, M.; Ekstrand, J. UEFA injury study: A prospective study of hip and groin injuries in professional football over seven consecutive seasons. *Br. J. Sports Med.* 2009, 43, 1036–1040. [CrossRef]
10. Weir, A.; Brukner, P.D.; Delahunt, E.; Ekstrand, J.; Griffin, D.R.; Khan, K.M.; Lovell, G.; Meyers, W.C.; Muschaweck, U.; Orchard, J.; et al. Doha agreement meeting on terminology and definitions in groin pain in athletes. *Br. J. Sports Med.* 2015, 49, 768–774. [CrossRef]

11. Taylor, R.; Vuckovic, Z.; Mosler, A.; Agricola, R.; Otten, R.; Jacobsen, P.; Holmich, P.; Weir, A. Multidisciplinary Assessment of 100 Athletes with Groin Pain Using the Doha Agreement: High Prevalence of Adductor-Related Groin Pain in Conjunction with Multiple Causes. *Clin. J. Sport Med.* 2018, 28, 364–369. [CrossRef]

12. Mosler, A.B.; Weir, A.; Eirale, C.; Farooq, A.; Thorborg, K.; Whiteley, R.J.; Hölmich, P.; Crossley, K.M. Epidemiology of time loss groin injuries in men’s professional football league: A 2-year prospective study of 17 clubs and 606 players. *Br. J. Sports Med.* 2018, 52, 292–297. [CrossRef]

13. Arnason, A.; Sigurdsson, S.B.; Gudmundsson, A.; Holme, I.; Engerbretsen, L.; Bahr, R. Risk Factors for Injuries in Football. *Am. J. Sports Med.* 2004, 32, 5–16. [CrossRef]

14. Engerbretsen, A.H.; Myklebust, G.; Holme, I.M.K.; Engerbretsen, L.; Bahr, R. Intrinsic Risk Factors for Groin Injuries among Male Soccer Players: A prospective cohort study. *Am. J. Sports Med.* 2010, 38, 2051–2057. [CrossRef]

15. Tyler, T.F.; Nicholas, S.J.; Campbell, R.J.; McHugh, M.P. The Association of Hip Strength and Flexibility with the Incidence of Adductor Muscle Strains in Professional Ice Hockey Players. *Am. J. Sports Med.* 2001, 29, 124–128. [CrossRef]

16. Emery, C.A.; Meeuwisse, W.H. Risk factors for groin injuries in hockey. *Med. Sci. Sports Exerc.* 2001, 33, 1423–1433. [CrossRef]

17. Ishaq, L.; Sørensen, C.N.; Kaae, N.M.; Jørgensen, L.B.; Hölmich, P.; Serner, A. Large eccentric strength increase using the Copenhagen Adduction exercise in football: A randomized controlled trial. *Scand. J. Med. Sci. Sports* 2016, 26, 1334–1342. [CrossRef]

18. Harøy, J.; Clarsen, B.; Wiger, E.G.; Oyen, M.G.; Serner, A.; Thorborg, K.; Hölmich, P.; Andersen, T.E.; Bahr, R. The Adductor Strengthening Program prevents groin problems among male football players: A cluster-randomised controlled trial. *Br. J. Sports Med.* 2019, 53, 145–152. [CrossRef]

19. Polglass, G.; Burrows, A.; Willett, M. Impact of a modified progressive Copenhagen adduction exercise programme on hip adduction strength and postexercise muscle soreness in professional footballers. *BMJ Open Sport Exerc. Med.* 2019, 5, e000570. [CrossRef]

20. Broksli, S.M.; Murthy, N.S.; Krych, A.J.; Obey, M.R.; Collins, M.S. The adductor magnus “mini-hamstring”: MRI appearance and potential pitfalls. *Skelet. Radiol.* 2016, 45, 213–219. [CrossRef]

21. Obey, M.R.; Broksli, S.M.; Spinner, R.J.; Collins, M.S.; Krych, A.J. Anatomy of the Adductor Magnus Origin. Implications for Proximal Hamstring Injuries. *Orthop. J. Sports Med.* 2016, 4, 2325967115625055. [CrossRef] [PubMed]

22. Mjølsnes, R.; Arnason, Å.; Østhagen, T.; Raastad, T.; Bahr, R. A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. *Scand. J. Med. Sci. Sports* 2004, 14, 311–317. [CrossRef] [PubMed]

23. Mosler, A.B.; Crossley, K.M.; Thorborg, K.; Whiteley, R.J.; Weir, A.; Serner, A.; Hölmich, P. Hip strength and range of motion: Normal values from a professional football league. *J. Sci. Med. Sport* 2017, 20, 339–343. [CrossRef] [PubMed]

24. Mosler, A.B.; Agricola, R.; Thorborg, K.; Weir, A.; Whiteley, R.J.; Crossley, K.M.; Hölmich, P. Is Bony Hip Morphology Associated with Range of Motion and Strength in Asymptomatic Male Soccer Players? *J. Orthop. Sports Phys. Ther.* 2018, 48, 250–259. [CrossRef]

25. Thorborg, K.; Couppe, C.; Petersen, J.; Magnusson, S.P.; Holmich, P. Eccentric hip adduction and abduction strength in elite soccer players and matched controls: A cross-sectional study. *Br. J. Sports Med.* 2011, 45, 10–13. [CrossRef]

26. Fuller, C.W.; Ekstrand, J.; Junge, A.; Andersen, T.E.; Bahr, R.; Dvorak, J.; Hägglund, M.; McCrorry, P.; Meeuwisse, W.H. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Br. J. Sports Med.* 2006, 16, 96–106. [CrossRef]

27. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Routledge Academic: New York, NY, USA, 1988.

28. Pfirrmann, D.; Herbst, M.; Ingelfinger, P.; Simon, P.; Tug, S. Analysis of Injury Incidences in Male Professional Adult and Elite Youth Soccer Players: A Systematic Review. *J. Athl. Train.* 2016, 51, 410–424. [CrossRef]

29. Cezarino, L.G.; da Silva Grüniger, B.L.; Silva, R.S. Injury Profile in a Brazilian First-Division Youth Soccer Team: A Prospective Study. *J. Athl. Train.* 2016, 50, 295–302. [CrossRef]

30. Kerbel, Y.E.; Smith, C.M.; Prodromo, J.P.; Nzeogu, M.I.; Mulcahey, M.K. Epidemiology of Hip and Groin Injuries in Collegiate Athletes in the United States. *Orthop. J. Sports Med.* 2018, 6, 1–8. [CrossRef]

31. Attar, W.S.A.A.; Soomro, N.; Pappas, E.; Sinclair, P.J.; Sanders, R.H. Adding a post-training FIFA 11+ exercise program to the pre-training FIFA 11+ injury prevention program reduces injury rates among male amateur soccer players: A cluster-randomised trial. *J. Physiother.* 2017, 63, 235–242. [CrossRef]

32. Tak, I.; Engelaar, L.; Gouttebarge, V.; Barendrecht, M.; Van Den Heuvel, S.; Kerkhoffs, G.; Langhout, R.; Stubbe, J.; Weir, A. Is lower hip range of motion a risk factor for groin pain in athletes? A systematic review with clinical applications. *Br. J. Sports Med.* 2017, 51, 1611–1621. [CrossRef]

33. Rahnama, N.; Reilly, T.; Lees, A.; Graham-Smith, P. Muscle fatigue induced by exercise simulating the work rate of competitive soccer. *J. Sports Sci.* 2003, 21, 933–942. [CrossRef]

34. Ekstrand, J.; Gillquist, J.; Möller, M.; Öberg, B.; Liljedahl, S.-O. Incidence of soccer injuries and their relation to training and team success. *Am. J. Sports Med.* 1983, 11, 63–67. [CrossRef]
35. Price, R.J.; Hawkins, R.D.; Hulse, M.A.; Hodson, A. The Football Association medical research programme: An audit of injuries in academy youth football. Br. J. Sports Med. 2004, 38, 466–471. [CrossRef]

36. Hölmich, P.; Thorborg, K.; Dehlendorff, C.; Krosggaard, K.; Gluud, C. Incidence and clinical presentation of groin injuries in sub-elite male soccer. Br. J. Sports Med. 2014, 48, 1245–1250. [CrossRef]

37. Kearns, C.F.; Isokawa, M.; Abe, T. Architectural characteristics of dominant leg muscles in junior soccer players. Eur. J. Appl. Physiol. 2001, 85, 240–243. [CrossRef]

38. Eberbach, H.; Fürst-Meroth, D.; Kloos, F.; Leible, M.; Bohsung, V.; Bode, L.; Wenning, M.; Hagen, S.; Bode, G. Long-standing pubic-related groin pain in professional academy soccer players: A prospective cohort study on possible risk factors, rehabilitation and return to play. BMC Musculoskelet. Disord. 2021, 22, 958. [CrossRef]