INTRODUCTION

Hip and groin injuries are a considerable problem in male football, accounting for 12%-16% of all injuries per season and resulting in an average absence of 15 days per injury. Adductor-related groin pain (AGP) represents 64%-68% of all groin injuries, with 15% classified as reinjuries. The most frequent mechanisms for groin injuries in football are kicking and changes of direction, as a result of the large eccentric forces when these movements are performed at high speeds.

Footballers with weak hip adductors are at increased risk of groin injury, and adductor strengthening has been shown to reduce this risk. However, the minimal effective dose of strength training to improve hip adductor strength and mitigate the risk of adductor problems remains unknown. The aim of this randomised controlled trial was to investigate the training and detraining effects of a low-dose Copenhagen adduction exercise (CA) intervention in sub-elite male footballers on eccentric hip adduction strength (primary outcome) and peak adductor squeeze strength (secondary outcome). Thirty-nine male footballers were randomised into two groups: The intervention group completed the CA twice weekly during six in-season weeks in addition to normal football training, while the control group continued normal football training. Strength testing was performed at weeks 0, 3, 6 (training period), and weeks 7-9 (detraining period). There was no between-group difference in eccentric strength at week 6 and 9. There was a significant group by time interaction at 6 weeks (0.52 Nm/kg, 95% CI 0.17-0.86) and 9 weeks (0.59 Nm/kg, 95% CI 0.25-0.93) at which the intervention group displayed greater adductor squeeze strength. These results suggest the low-dose CA intervention is insufficient to modify eccentric hip adduction strength but improves peak adductor squeeze strength.

KEYWORDS

Copenhagen adduction exercise, football, hip adduction strength, injury prevention, soccer
adduction exercise (CA) has normalised electromyography activity of 108% of maximal voluntary isometric contraction (MVIC) in the adductor longus of the dominant leg. The CA has been shown to produce eccentric strength gains in several studies and is considered an appropriate exercise with the potential to induce adductor strength adaptations.

The CA has reduced the prevalence of groin problems by 41% in footballers throughout a single season. In this study, the exercise dose was substantially higher in the 6-8 week pre-season (6-45 maximal weekly repetitions per side) compared to the 28-week in-season period (12-15 maximal weekly repetitions per side). The CA has produced an increase in eccentric hip adduction strength of 9% in U19 elite footballers and 36% in U19 sub-elite footballers following an 8-week FIFA 11+ exercise dose (9-45 weekly repetitions per side) and an 8-week high-dose intervention (24-90 weekly repetitions per side). Sub-elite footballers may have reduced opportunities to participate in a pre-season conditioning period before the start of the competitive season, and an in-season intervention may be more relevant in this population. As an example, university-level footballers in the United Kingdom have a limited pre-season and typically have two training sessions and one game each week during the in-season. While previous research has demonstrated large increases in eccentric hip adduction strength can be achieved in sub-elite footballers using a high-dose intervention, low-dose training interventions which have a reduced time burden may be more appropriate for these athletes as this is expected to increase exercise compliance, while still potentially reducing the risk of injury. However, whether improvements in eccentric adduction strength can be achieved in sub-elite footballers with low-dose training protocols and thus augment the eccentric hip adduction strength risk factor is unknown.

Therefore, a low-dose training protocol which can be supervised twice per week during in-season football training sessions appears more feasible and may enhance compliance in university football. Furthermore, any possible detraining effect on hip adduction strength after stopping the CA intervention is also relevant to investigate as compliance with such training programs is reduced during congested football periods and breaks from regular football training.

The current study aimed to investigate the effect of a low-dose six-week CA training intervention (progressive resistance training of 10-30 weekly repetitions per side) on eccentric adduction strength and peak adductor squeeze strength in sub-elite male footballers. Both these measures are associated with the risk of developing groin injuries, can be assessed in a clinic environment, and have implications for injury prevention practices in football. Additionally, the changes in eccentric adduction strength and peak adductor squeeze strength after stopping the CA will also be examined over a 3-week detraining period, as this is a typical mid-season break duration for University-level footballers in the United Kingdom.

It was hypothesised the low-dose CA intervention would increase eccentric adduction strength and peak adductor squeeze strength more in the intervention group (IG) compared to the control group (CG).

2 | METHODS

2.1 | Study design

This assessor-blinded randomised controlled trial with a two-group parallel design (1:1 allocation ratio) investigated the effect of a 6-week supervised CA intervention in male footballers. The trial was registered in the Clinical Trials Protocol Registration and Results System at clinicaltrials.gov (ID: NCT03684200), prior to inclusion of the first participant. In accordance with the Declaration of Helsinki and approved by The Research Ethics Approval Committee for Health at the University of Bath (EP 17/18 166), all participants provided their written informed consent to participate. The reporting adheres to the Consolidated Standards of Reporting Trials (CONSORT).

2.2 | Participants

In September 2018, the University of Bath football club was invited to take part in an in-season randomised controlled trial commencing at the start of the season. All players from three male football teams were assessed for eligibility and enrolled by the principal investigator (JD). Players who were able to perform strength testing during the study period and able to perform strength testing during the study period were considered for inclusion. Exclusion criteria included any specific hip adductor strengthening in the two months before study initiation and hip and groin pain resulting in loss of football training or matches in the two months preceding the study. Strength testing data were collected within a physiotherapy treatment room and indoor athletics track at the University.

2.3 | Randomisation and blinding

Participants were randomised 1:1 into the IG or the CG. A computer-generated randomisation was performed by a person that was blinded to the pre-determined allocation sequence and had no further involvement in the study. After baseline testing, participants were orally informed of their group assignment from the principal investigator (JD). The CG was advised not to perform specific hip adductor strengthening during the study period and to continue with normal football training. One investigator (JW) was blinded.
to group allocation and performed all strength testing. In order to maintain assessor blinding, the principal investigator informed the participants not to reveal their group allocation to the investigator performing the strength testing.

2.4 Intervention procedure

In addition to normal football training, the IG performed six weeks of progressive resistance training of the hip adductors using the CA (Figure 1) from the 1st October to the 9th of November 2018. The intervention duration and exercise dose were chosen to be less than previous studies and were considered a low-dose approach. The low-dose protocol was an adaptation of the program used with elite-level footballers by Harøy et al which included three weekly training sessions consisting of one set of 3-15 repetitions (9-45 weekly repetitions per side). It was decided two weekly training sessions consisting of one set of 5-15 repetitions (10-30 weekly repetitions per side) was an appropriate exercise dose for strength improvements in this population, as well as having external validity and practicality for the training commitments of sub-elite footballers. The intervention took approximately five minutes to complete and was performed on separate days (Monday and Friday) of the week. The exercise intervention is reported according to the CERT checklist and a full description is provided in Appendix 1. The exercise supervisor recorded weekly compliance to the intervention, perceived loading of the adductor muscle group using the Borg CR10 scale and maximal weekly DOMS using the 11-point numeric rating scale.

2.5 Outcomes

The primary outcome measure was eccentric adduction strength (Nm/kg), and the secondary outcome was long-lever peak adductor squeeze strength (Nm/kg). Strength testing

![Participant flow throughout the study](image-url)
was performed at week 0 prior to starting the intervention (baseline), 3 (mid-intervention), 6 (post-intervention), and 7-9 (detraining period) by a single blinded assessor. Before testing, participants were instructed to complete a standardised supervised warm-up of five minutes light running and to avoid stretching which could influence strength testing performance. The strength testing setup included a portable hand-held dynamometer (HHD) (Lafayette Instrument Company), tape measure, pen, and an examination table. The eccentric hip adduction test was performed as a break test in which the examiner gradually overcomes the MVIC of the participant. Conversely, the peak adductor squeeze test was performed as an isometric make test. The two testing procedures have been described previously and have demonstrated good intra-tester, inter-day reliability (eccentric hip adduction strength test: ICC 0.91 (0.70-0.98), SEM = 6.3%, peak adductor squeeze strength test: ICC 0.97 (0.93-0.99), SEM = 2.5%) with no systematic variation between test, and retest. The tests were performed in the same order for each testing week starting with the peak adductor squeeze test followed by the eccentric hip adduction test. Only the dominant leg defined as the preferred kicking leg was tested. This substantially reduced testing time is relevant to injury prevention as the dominant leg is the most frequently injured.

2.6 | Sample size

The sample size calculation was based on the primary outcome, and it was decided 15% was a realistic and relevant between-group difference in eccentric hip adduction strength in sub-elite footballers, given that previous research has demonstrated a 36% improvement in eccentric strength with a weekly exercise dose approximately 2-3 times higher than the present study. The analysis was performed using G*power software (v. 3.1, Heinrich-Heine-Universitat, Dusseldorf, Germany). With an alpha (α) level of 5% and a statistical power of 80%, the priori power calculation revealed that 18 participants were required in each group to detect an expected between-group difference of 0.35 Nm/kg and a standard deviation (SD) of 0.36 Nm/kg, based upon the means and SDs from previous studies.

2.7 | Statistical analyses

A physiotherapist (LI) blinded to group assignment omitted strength testing measures at specific time points due to injuries of the hip, thigh, and groin as these are expected to reduce hip adduction strength. All outcome variables were analysed according to the intention-to-treat (ITT) principle using a linear mixed model. Time (testing week), group (IG vs CG), and group by time interaction were set as fixed factors. Per-protocol analysis was also planned with a compliance limit set at a minimum of 8 out of the 12 planned sessions (67%), as per Harøy et al. The PROC MIXED function of SAS V.9.2 (SAS Institute, Inc) was used. An α level of 5% was considered statistically significant in all analyses, and data from the linear mixed model are presented as least square means ± SD or 95% confidence intervals (CI), as appropriate. Effect sizes were calculated by use of Cohen's d and interpreted as small (d = 0.2), moderate (d = 0.5), and large (d = 0.8).

3 | RESULTS

3.1 | Study flow and characteristics

The flow of participants throughout the study is highlighted in Figure 1. Of the 39 participants randomised to the IG (n = 20) and CG (n = 19) (Table 1), two participants from the CG stopped playing football after the baseline and mid-intervention testing weeks, respectively. In total, 211 of the 234 planned strength tests for each outcome were conducted and included for analyses, which equates to 9.8% of missing data. All players had a compliance of at least 67%, and therefore, the pre-planned per-protocol analysis (excluding players with less than 67% compliance) was not conducted.

3.2 | Primary outcome

There was no significant group by time interaction on eccentric adduction strength, indicating no between-group difference in change (P = .93). The IG significantly increased eccentric strength by 6.7% from 3.04 (±0.51) Nm/kg at

FIGURE 2 The Copenhagen adduction exercise. (A) Start and end position. (B) Mid-position
baseline to 3.24 (±0.51) Nm/kg at week 6 (P = .03), whereas the CG increased eccentric strength by 5.7% from 2.83 (±0.51) Nm/kg at baseline to 2.99 (±0.56) Nm/kg (P = .15) at week 6 (Figure 3). There was no significant between-group difference at week 6 (0.25 Nm/kg, 95% CI, −0.09 to 0.59, d = 0.5, SEM = 0.17) (Table 2). After stopping the intervention, eccentric strength in the IG decreased 4.4% from 3.24 (±0.51) to 3.10 (±0.51) Nm/kg at week 9 (P = .13), whereas the CG decreased 2.7% from 2.99 (±0.56) to 2.91 (±0.54) Nm/kg at week 9 (P = .47) (Figure 3). There was no significant between-group difference at week 9 (0.19 Nm/kg, 95% CI, −0.14 to 0.52, d = 0.4, SEM = 0.17) (Table 2). Individual strength measurements for each participant are highlighted in the supplementary Appendix 2.

### 3.3 Secondary outcome

There was a significant group by time interaction on peak adductor squeeze strength, indicating a significant between-group difference in change (P = .05). In the IG, peak squeeze strength significantly increased by 12.3% from 2.79 (±0.51) Nm/kg at baseline to 3.13 (±0.52) Nm/kg (P < .01) at week 6, whereas the CG increased peak squeeze strength by 1.9% from 2.57 (±0.52) Nm/kg at baseline to 2.61

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**TABLE 1** Baseline characteristics of included participants as group means (SD), (n = 39)

|                      | Intervention group (n = 20) | Control group (n = 19) |
|----------------------|-----------------------------|------------------------|
| Age (years)          | 19.5 (1.2)                  | 19.3 (1.0)             |
| Height (cm)          | 177.0 (5.1)                 | 182.3 (6.4)            |
| Weight (kg)          | 71.14 (6.8)                 | 77.87 (9.1)            |

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**FIGURE 3** Eccentric adduction strength and peak squeeze strength (±95% confidence intervals) registered for both the intervention group (IG) and control group (CG)
(±0.56) Nm/kg at week 6 (P = .66), representing a between-group difference in change of 10.4%. There was a significant between-group difference at week 6 (0.52 Nm/kg, 95% CI, 0.17-0.86, d = 1.1, SEM = 0.17) (Table 2). After stopping the intervention, squeeze strength in the IG decreased 5.6% from 3.13 (±0.52) to 2.95 (±0.51) Nm/kg at week 9 (P = .06) (Figure 3), whereas CG decreased 9.6% from 2.61 (±0.56) to 2.36 (±0.54) Nm/kg at week 9 (P = .03) (Figure 3). There was a significant between-group difference at week 9 (0.59 Nm/kg, 95% CI, 0.25-0.93, d = 1.3, SEM = 0.17) (Table 2). Individual strength measurements for each participant are highlighted in the supplementary Appendix 3.

### 3.4 | Compliance, DOMS and perceived loading

Of the 12 training sessions, the IG completed 11.6 (±1.1) sessions (compliance rate: 96.7%). Information on DOMS and perceived loading is presented in Figures 4 and 5. No injuries or complaints relating to the CA intervention were registered.

### 4 | DISCUSSION

Our main finding of the present study was a low-dose CA intervention did not improve eccentric hip adduction strength during a 6-week training period. However, a between-group difference in the form of a strength increase was observed for peak adductor squeeze strength and this difference was maintained at the end of the detraining period.

#### 4.1 | Eccentric hip adduction strength

Contrary to our hypothesis, no significant between-group difference in eccentric adduction strength was observed after six weeks of progressive strengthening using the CA. This may,
however, be explained by the lower exercise dose performed in this study compared to previous studies. The IG in the present study performed a total of 110 repetitions on each side over six weeks. Conversely, the study by Ishøi et al consisted of two weekly training sessions progressing from two sets of six repetitions to three sets of 15 repetitions on each side (representing a total of 480 repetitions on each side). Moreover, Harøy et al adopted the FIFA 11+ protocol representing an exercise dose of approximately 260 repetitions on each side, depending on the exercise difficulty selected by each participant. Consequently, the eccentric adduction strength changes in these studies appear to represent a dose-response relationship, with increases in eccentric hip adduction strength ranging from approximately 0%, 9%, 14, and 36%, when the repetitions increased from 110, 260, 324, and 480 during a 6-8 week CA intervention. Therefore, the lack of eccentric adduction strength improvements observed in the IG is likely due to the exercise dose being too low in this study and a higher exercise dose is recommended, in order to modify the eccentric adduction strength risk factor.

4.2 Peak adductor squeeze strength

The IG demonstrated a 10.4% greater within-group change compared to the CG for peak adductor squeeze strength after six weeks of adductor strengthening, which is greater than the 6.6% minimal detectable change identified for this test. However, this is not considered a relevant between-group strength difference. The peak squeeze strength decreased by 5.6% in the IG after stopping the exercise for three weeks, compared to a 9.6% decrease in the CG during this period. Decreased isometric adduction strength is present both preceding and during the onset of AGP; therefore, an increase in peak squeeze strength may be a relevant finding in the prevention of groin problems.

4.3 Perceived exercise intensity and DOMS

In the current study, the IG reported an increase in perceived loading and DOMS in the hip adductors when the repetitions increased during the training period. This infers the training protocol was progressive in nature, despite the exercise volume being too low to improve eccentric adduction strength.

4.4 Study limitations

The results of the present study can only be applied to sub-elite male footballers; however, this population presents a large proportion of those actively playing football and has high incidences of muscle strain injuries and re-injuries. Although the intervention protocol augmented the isometric adduction strength of participants, no changes were observed in eccentric adduction strength. In relation to the principles of specificity, the testing setup of the peak squeeze strength test more closely resembles the CA compared to the eccentric strength test. Therefore, it is possible the differences in strength changes between the two testing methods are partly related to improved testing performance as a result of a learning effect.

Exposure to football was not measured in this study, and demands of match play can induce muscle damage and inflammation lasting up to 72 h. However, due to the randomised controlled trial design, such potential confounders are expected to be evenly distributed between groups. Participants with missing data during follow-up strength testing were not excluded as we used the PROC MIXED function of the SAS model which includes all available strength testing data. Thus, multiple imputation was not conducted, which can be a potential limitation; however, as missing strength testing data was only minimal (9.8%), we decided to continue with our pre-planned statistical analyses.
5  |  PERSPECTIVES

Hip adductor strengthening has been recommended in the prevention of groin pain in footballers. However, strength training interventions must provide a sufficient stimulus to induce meaningful improvements in eccentric hip adduction strength, in order to mitigate this identified risk factor for groin problems in footballers. This study provides evidence that a total of 110 repetitions of the CA on each side during a six-week period were not enough to increase eccentric hip adduction strength and therefore this dose may not be sufficient to reduce the risk of groin problems. Previous literature has demonstrated a total of approximately 260 repetitions are adequate to generate improvements in eccentric hip adduction strength, although the minimum exercise dose required to modify the eccentric strength risk factor is unknown. Further research using exercise volumes ranging between 110 and 260 repetitions of the CA is warranted in order to develop an understanding of the minimum effective dose required for groin injury risk factor mitigation.

ACKNOWLEDGEMENTS

The authors would like to thank all of the players and coaches who participated in this study. We would also like to thank Cassie Wilson, PhD, for her support with the research planning. This study was supported by a research grant from the Association of Chartered Physiotherapists in Sports and Exercise Medicine (ACPSERM) in the United Kingdom.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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APPENDIX 1

CA Exercise Intervention

The CA requires a partner and was performed pitch-side in addition to the regular warm-up before football training sessions. All training sessions were supervised by the principle investigator (JD), who is a physiotherapist, to ensure correct technique. The active partner performing the exercise is supported on one forearm on the floor and the upper arm is resting along their side. The supporting partner places their hands under the ankle and the knee of the upper leg. The active partner raises their body from the floor and adducts both legs in a three second movement until the body reaches a straight line. The body is then lowered toward the ground in a three second movement, the foot of the lower leg touches the ground before performing another repetition. There should be no side flexion of the trunk during any part of the exercise and movement from the “start” to the “mid-position” should be achieved through concentric hip adduction of both legs, an isometric hold, followed by eccentric hip adduction of both legs to return to the “end-position” (Figure 2). Each participant performed one set of the exercise on each side before changing roles with their partner. The number of repetitions per set gradually increased over the training period and 5, 5, 8, 10, 12, and 15 repetitions per set were performed during weeks 1-6, respectively.
APPENDIX 2

Eccentric hip adduction strength of the intervention and control group. Circles and lines represent strength measurements for each participant at week 0 (baseline), week 6 (post-intervention), and week 9 (post-detraining period). Only participants with full data sets were included in the figure (n = 30). The bold circles and lines represent the mean for each group and includes participants with missing data (n = 39).
APPENDIX 3
Peak adductor squeeze strength of the intervention and control group. Circles and lines represent strength measurements for each participant at week 0 (baseline), week 6 (post-intervention), and week 9 (post-detraining period). Only participants with full data sets were included in the figure (n = 30). The bold circles and lines represent the mean for each group and includes participants with missing data (n = 39).