Harøy, J., Thorborg, K., Serner, A., Bjørkheim, A., Rolstad-Martinez, L. E., Hölmich, P., Bahr, R, Andersen, T. E. (2017). Including the Copenhagen Adduction Exercise in the FIFA 11+ Provides Missing Eccentric Hip Adduction Strength Effect in Male Soccer Players: A Randomized Controlled Trial. *American Journal of Sports Medicine, 45*, 3052-3059.

INCLUDING THE COPENHAGEN ADDUCTION EXERCISE IN THE FIFA 11+ PROVIDES MISSING ECCENTRIC HIP ADDUCTION STRENGTH EFFECT IN MALE SOCCER PLAYERS: A RANDOMIZED CONTROLLED TRIAL

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Word count: 5153 (including references)

ABSTRACT

Background: The FIFA 11+ was developed as a complete warm-up program to prevent injuries in soccer players. Although reduced hip adduction strength is associated with groin injuries, none of the exercises included in the FIFA 11+ seem to specifically target hip adduction strength.

Purpose: To investigate the effect on eccentric hip adduction strength of the FIFA 11+ warm-up program with or without the Copenhagen Adduction exercise.

Study Design: Randomized Controlled Clinical Trial

Methods: We recruited 45 eligible players from two U19 elite male soccer teams. Players were randomized into two groups; one group carried out the standard FIFA 11+ program, while the other carried out the FIFA 11+, but replaced the Nordic Hamstring exercise with the Copenhagen Adduction exercise. Both groups performed the intervention three times weekly for 8 weeks. Players completed eccentric strength and sprint testing before and after the intervention. Per-protocol analyses were performed, with 12 players excluded due to low compliance (<67% of sessions completed).

Main Outcome: Eccentric hip adduction strength (Nm/kg).

Results: Between-group analyses showed that there was a significant greater increase in eccentric hip adduction strength of 0.29 Nm/kg (8.9%, p=0.01) in favor of the group performing the Copenhagen Adduction exercise, while there was no within-group change in the group that used the standard FIFA 11+ program (-0.02 Nm/kg (-0.7%), p=0.69).

Conclusion: Including the Copenhagen Adduction exercise in the FIFA 11+ program increases eccentric hip adduction strength, while the standard FIFA 11+ program does not.

Keywords: FIFA 11+, hip adduction strength, groin problems, injury prevention, soccer

What is known about the subject?

- Adductor-related groin pain is the most common groin injury among soccer players
- Low hip adductor strength has been shown to represent a risk factor for groin injury in soccer
- None of the exercises included in the FIFA 11+ seem to target hip adduction strength specifically

What this study adds to existing knowledge:

- The standard FIFA 11+ program does not increase hip adductor strength
- Including the Copenhagen Adduction exercise to the FIFA 11+ program increases hip adduction strength

BACKGROUND

The FIFA 11+ was developed as a complete warm-up program to prevent injuries in youth and amateur soccer players.[2,29] Large randomized controlled trials (RCT), both on female and male players, have confirmed that the program prevents non-contact injuries in soccer.[22,28,29] Of these, two reported data on groin injuries and with conflicting results, showing no reduction in young female footballers,[29] but a significant reduction among male collegiate players.[28]

Although adductor-related groin pain is the most common groin injury among soccer players[9,11,14,27] and low hip adductor strength has been shown to represent a risk factor for groin injury in soccer,[10] none of the exercises included in the FIFA 11+ seem to target hip adduction strength specifically. The apparent absence of adductor strengthening exercises might therefore represent a limitation of the 11+

A recent study examining the EMG activation patterns of 8 strength exercises showed that the Copenhagen Adduction (CA) exercise targets the hip adductors, suggesting that it may be suitable for groin injury prevention and rehabilitation.[26] CA is a simple eccentric partner exercise requiring no equipment. Therefore, like the Nordic Hamstring (NH) exercise, it can easily be used as a high-intensity exercise on the field, before or after, soccer activity. The NH exercise has been documented to prevent hamstring injuries effectively, both as an isolated exercise[1,24,31] and as a part of a warm-up program.[28]

In soccer, kicking is the most frequent injury mechanism for acute groin injuries.[27] Improving the length-tension relationship using an exercise that includes heavy eccentric loading therefore seems relevant to prevent adductor injuries. In under-19 sub-elite soccer players performing an intensive protocol of the CA exercise for 8 weeks, a 36% increase in eccentric hip adduction strength was

achieved.[16] However, we do not know the strength effect of the CA exercise, using an exercise prescription matching that of the NH exercise in the FIFA 11+ program.

Thus, the purpose of this randomized controlled trial was to investigate the effect on eccentric hip adduction strength of the FIFA 11+ warm-up program with or without the Copenhagen Adduction exercise. We hypothesized that eccentric hip adduction strength would increase in players randomized to replace the NH exercise in the FIFA 11+ program with a similar CA exercise protocol.

MATERIALS AND METHODS

Study design and participants

We invited 45 players from two elite male U19 soccer teams in the Oslo region to take part in an 8-week randomized controlled trial during pre-season (January-March 2016). Included players had to be healthy and able to perform strength and performance testing prior to the intervention period.

Randomization and blinding

We randomized players individually into two different training groups, the Nordic Hamstring group (NH group) or Copenhagen Adduction group (CA group). A neutral, blinded person who had no further involvement in the study, made a computer-generated list which was used to randomize players stratified according to team belonging. After baseline testing, players received a sealed envelope, from the principal investigator with their group assignment. All testers were blinded to group allocation during pre- and post-testing. The physiotherapists instructing the team warm-up sessions were not blinded to group assignment.

Intervention procedures

Players in the NH group were asked to carry out the FIFA 11+ warm-up program as described previously,[29] including the NH exercise, while players in the CA group were asked to carry out the FIFA 11+, but to replace the NH exercise with the CA exercise. The exercise prescription for the CA exercise was the same as described for NH in the FIFA 11+ program, however, performed separately on each side (table 1).[29] We assigned a physiotherapist to each team (AB and LER), to ensure adequate instructions on how to perform the exercise programs, and to supervise every training session. Players on the same team completed the FIFA 11+ together during warm-up, except for the NH and CA exercise, where they split up according to group assignment.

Table 1 Exercise prescription for the NH and CA exercise.[29]

Level	Frequency (training sessions per week)	Number of sets	Number of repetitions
Beginner	3	1	3-5
Intermediate			7-10
Advanced			12-15

The Copenhagen Adduction exercise

The CA exercise is a partner exercise where the player lies on the side with one forearm as support on the floor and the other arm placed along the body.[26] The upper leg is held at approximately hip height of the partner, who holds the leg with one arm supporting the ankle and the other supporting the knee (position A in figure 1). The player then raises the body from the field and the lower leg is adducted so that the feet touch each other and the body is in a straight line (position B in figure 1). The body is then lowered halfway to the ground while the foot of the lower leg is lowered so that it just touches the floor without using it for support.[26] The exercise is performed on both sides. Video of the CA exercise is available as an online supplementary appendix.

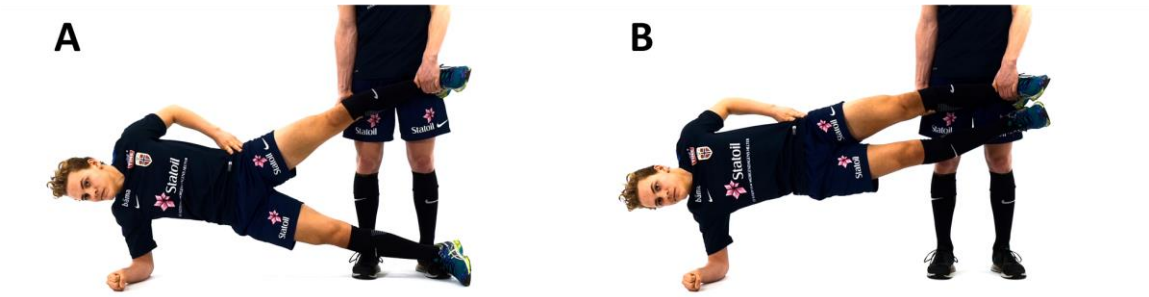

Figure 1 *The Copenhagen Adduction exercise. A start/end-position. B mid-position.*

Strength and performance testing

All tests were performed four days prior to the first training session in the intervention period (January 2016) and within four days after completion of the last training session (March 2016). The players performed eccentric strength tests and a 20 m sprint test. The players were not permitted to play matches during the last two days prior to testing, but were allowed to participate in regular soccer training sessions.

The players completed a form with personal and demographic information and were weighed prior to testing. All players performed a warm-up of 15 min light running (11 km/h) on a treadmill (PRO, Woodway, Waukesha, Wisconsin, USA). Strength and performance tests were performed in the same order pre- and post-intervention, starting with the eccentric hip adduction strength test, 20 m sprint test and finishing with the eccentric knee flexor strength test.

Eccentric hip adduction strength test

The test set-up included a portable hand-held dynamometer (Hoggan microFET2, Hoggan Scientific, Salt Lake City, Utah, USA) and an examination table. A physiotherapist (MVH), with 80 h of testing experience, performed both pre- and post-testing. The dominant and non-dominant leg were tested on all players, the left leg first. Eccentric hip adduction strength was measured in a break test with

the player in a side-lying position with the leg being tested in a straight position, as described by Thorborg et al.[30] (figure 2). The physiotherapist placed the hand-held dynamometer 5 cm proximal of the most prominent part of the medial malleolus and the player exerted a 3-5 s isometric maximum voluntary contraction against the dynamometer before the physiotherapist performed a break of the contraction to measure the eccentric hip adduction strenght.[30] This testing method has been used in several studies examining hip adductor strength in soccer players.[4,16,17,20,23,30] The intra-tester reliability it has been reported with an intraclass correlation coefficient (ICC) of 0.91 and standard error of measurement (SEM) of 6.3%.[30] The player was asked to complete one practice trial before performing three maximal tests and the best result was retained. The players had a 30-s rest period between each trial. The rest period was introduced to avoid a decline in strength across trials due to fatigue. The standardized command by the examiner was "go ahead-push-push-push-push-push".

Leg length was measured in the supine position from the most prominent point of the anterior superior iliac spine to 5 cm proximal to the most prominent point of the medial malleolus. Leg length was used to calculate torque, and adjusted to body-mass (Nm/kg).

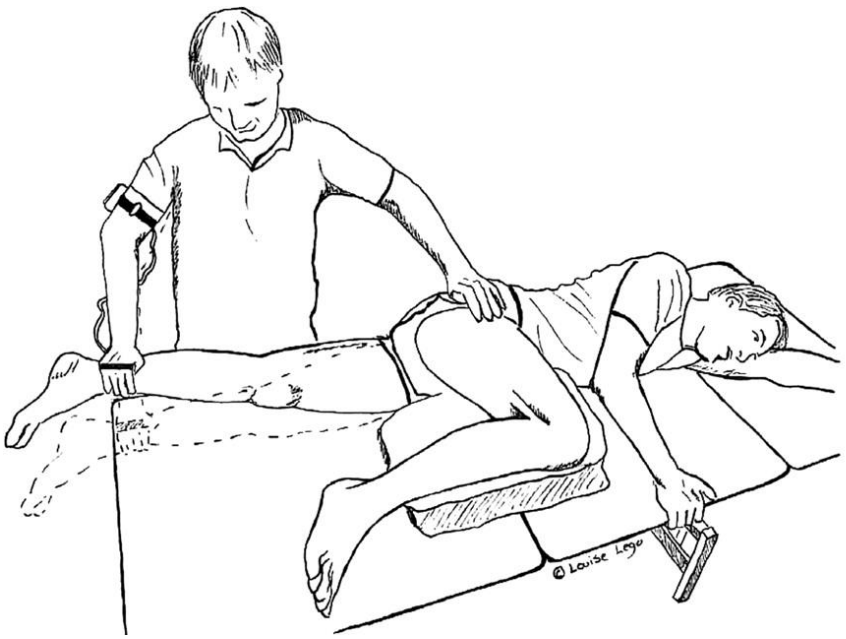

Figure 2 *Testing set-up for eccentric hip adduction strength (with permission from Thorborg et al.[30]). Shaded leg shows end-position of the test.*

Eccentric knee flexor strength test

The same two physiotherapists (AB and LER) performed the pre- and post-testing. Eccentric knee flexor strength was measured using a NordBord (VALD Performance, Brisbane, Australia), as described by Opar et al.[21] For test-retest reliability an ICC of 0.83 to 0.90, typical error of 5.6% to 7.4% and MDC of 15.6% to 20.5% has been reported.[21] The player was asked to perform one practice trial before performing one set of three maximal repetitions. All force values were body-mass adjusted (N/kg). The best of three maximal trials was retained. The standardized command by the examiner was "go ahead-hold-hold-hold ". The investigator monitored the performance of all repetitions visually, and a repetition was rejected if the NH was not performed as instructed.

20-m sprint test

The 20-m sprint tests were performed on an indoor 8-mm Mondotrack FTS surface (Mondo, Conshohocken, Pennsylvania, USA) using a Newtest Powertimer portable system (Ele-Products Oy, Tyrnävä, Finland) using infrared photocells (Model 300s) mounted on the sprint running track and connected to a computer that measures time to the nearest 0.001 s. The same experienced tester (MM) performed both the pre- and post-testing. Players performed two sub-maximal 20 m sprints before maximal sprint testing. Maximum running speed (s) was tested by sprinting 3 x 20 m with 4-6 min of recovery between trials. The time was measured for every 5 m and the best results (0-5 m, 0-10 m, 0-15 m and 0-20 m) were retained for analyses.

Outcome measures

The primary outcome was eccentric hip adduction strength (Nm/kg). Secondary outcomes were eccentric knee flexor strength (N/kg) and 0-5 m, 0-10 m, 0-15 m and 0-20 m sprint times (s).

The physiotherapist assigned to each team registered weekly compliance with the warm-up program for each player, soccer training and match exposure, weekly maximal delayed-onset muscle soreness (DOMS) in the adductor and hamstring muscle groups using a 11-point Numeric Rating Scale (NRS) (0-10).[12]

Sample size

The sample size calculation was based on a previous study examining eccentric hip adduction strength effects of the CA.[16] For a 10% increase in eccentric hip adductor strength, the expected between group difference was set at 0.28 Nm/kg and a standard deviation (SD) of 0.32 Nm/kg. With a power of 80% and a significance level (α) of 0.05, we needed 20 players in each group.

Statistical analyses

All outcome variables were analyzed according to the per-protocol principle, conducted with a minimum compliance limit set at 16 training sessions (67%). Intention-to-treat analyses were not performed, since we were interested in the potential efficacy of the exercise, and therefore only in participants who complied with the specific intervention as planned.[13] Players in both groups were excluded from the analyses if they performed any individual hamstring or hip adductor-specific training in addition to the intervention during the study period. Moreover, players were excluded from the analyses if they were unable to perform either strength or performance testing at baseline or after the intervention period due to injury or illness. The per-protocol exclusion criteria were determined a priori.

Between group difference in baseline characteristics and exposure were assed using an independent t-test or Fisher's exact test, as appropriate. Between-group differences in strength and performance tests were assessed using a repeated measures analysis of covariance (ANCOVA), using pre-test as a covariate.[32] Within-group differences from pre- to post-test were assessed using paired t-tests. We

included both legs in these analyses to obtain robust variance estimations, but incorporated player as a cluster variable in the models. Effect sizes were calculated using Cohen's *d* and interpreted as small (*d*=0.2), moderate (*d*=0.5) and large (*d*=0.8).[7] We performed all analyses using SPSS Statistics for Windows, version 24.0 (SPSS Inc., Chicago, Ill., USA) and STATA (StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP). An α level of ≤0.05 was considered significant. Data are presented as mean values with their SD or 95% confidence interval (CI), as appropriate.

Ethics

In accordance with The Declaration of Helsinki and approved by the Regional Committees for Medical Research Ethics (2015/1921/REK) South East and the Norwegian Social Science and Data Service (45393/3/LT/LR), all participants received written and oral information about the purposes and procedures of the project before providing their written consent to participate in the study. The trial was registered in the International Standard Randomised Controlled Trial Number registry (ISRCTN13731446). This report is prepared according to the Consort Statement recommendations for reporting randomized trials.[19]

RESULTS

Study flow

The flow of participants throughout the study is shown in figure 3. Of the 45 eligible players invited and tested at baseline, one player in the CA group suffered a knee injury and one player in the NH group suffered a groin injury during the intervention period and were unable to complete post-testing. A total of 8 players were excluded from the per-protocol analyses due to a compliance ≤67%. Of these, two players attended training with the clubs senior squad for >4 weeks, two goalkeepers had individual warm-up, and four players had long periods with illness or injury (3-7 weeks). Another

two players, one in each group, were excluded from the analyses due to intensive hip adductor rehabilitation of groin injury suffered during the study period.

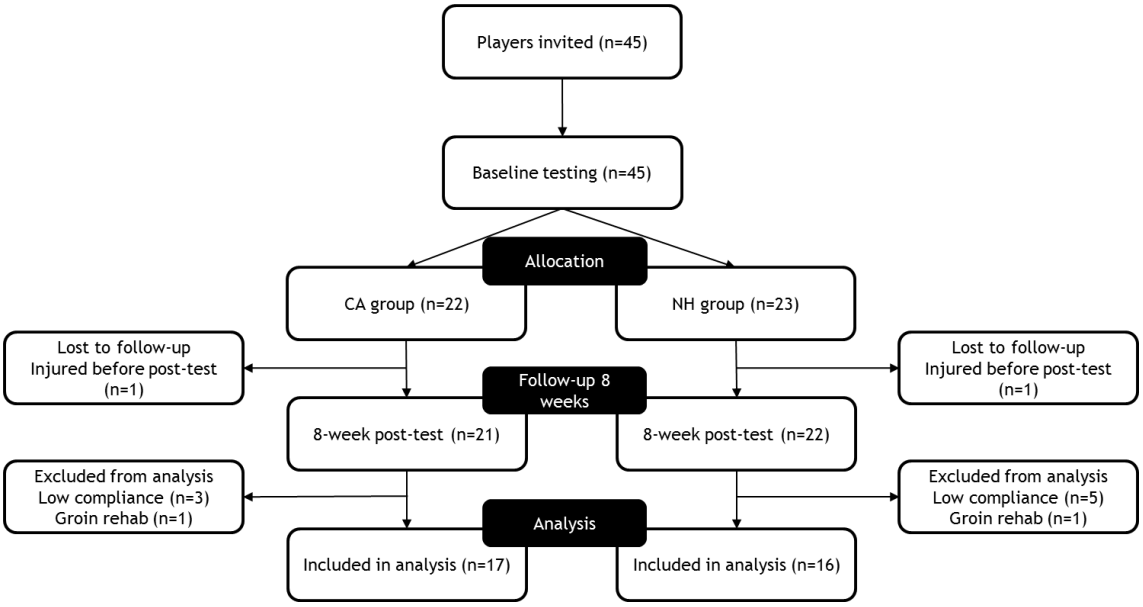

Figure 3 *Flow of participants throughout the intervention.*

Statistical analyses revealed no differences in baseline characteristics or exposure between the two groups (table 2).

Table 2 Baseline characteristics and weekly exposure during the intervention period for the 33 players included in the per-protocol analyses. Data are shown as group means or percentages, as appropriate.

	NH group (n=16)	CA group (n=17)	P
Age (years)	16.9 (1.0)	16.7 (0.9)	0.61
Height (cm)	177.8 (6.0)	179.8 (8.0)	0.37
Weight (kg)	67.6 (10.0)	67.8 (8.9)	0.90
Leg dominance (%)			
Left side	2 (12.5)	2 (11.8)	1.00
Right side	14 (87.5)	15 (88.2)	1.00
Exposure			
Weekly soccer training (h)	7.4 (1.8)	8.1 (2.2)	0.35
Weekly individual training (h)	2.2 (1.7)	1.6 (1.1)	0.38
Weekly match exposure (min)	40 (16)	45 (19)	0.23

Of the 24 training sessions planned, the average compliance was 21.5±1.9 sessions (90% of planned sessions) in the CA group and 21.0±1.6 (88% of planned sessions) in the NH group.

Primary outcome: eccentric hip adduction strength

Eccentric hip adduction strength increased in the group performing the CA exercise and between-group analyses revealed that there was a significant group effect (table 3). The between group effect size calculation suggested a moderate to large (*d*=0.60) strength effect. Within-group analyses showed that there was an increase in eccentric hip adduction strength in the CA group.

Table 3 *Test results. Baseline results and change from test 1 to test 2 within the CA and NH group, as well as between-group differences in the change from test 1 to test 2. Positive values denote increased strength and slower sprint time from test 1 to test 2 and in the CA group vs the NH group. Values are reported as the mean with SD or 95% CI, as shown.*

	CA group (n=17)					NH group (n=16)					Between group difference		
	Test 1	**Test 2**	**Test 2-Test 1**	**%**	**P**	**Test 1**	**Test 2**	**Test 2-Test 1**	**%**	**P**	**CA-NH (95% CI)**	**%**	**P**
Adduction (Nm/kg)	*3.25 (0.62)*	*3.51 (0.63)*	*0.26 (0.33)*	*8.0%*	*<0.001*	*3.24 (0.50)*	*3.22 (0.46)*	-0.02 (0.35)	-0.7%	0.69	*0.29 (0.09,0.49)*	*8.9%*	*0.01*
Non-dominant	*3.22 (0.68)*	*3.49 (0.69)*	*0.28 (0.26)*	*8.5%*	*<0.001*	*3.19 (0.46)*	*3.13 (0.45)*	-0.06 (0.36)	-1.8%	0.52	*0.34 (0.12,0.55)*	*10.6%*	*<0.001*
Dominant	*3.29 (0.57)*	*3.53 (0.58)*	*0.24 (0.40)*	*7.4%*	*0.02*	3.29 (0.54)	3.30 (0.46)	0.00 (0.34)	0.0%	0.91	0.23 (-0.01,0.48)	7.0%	0.06
Hamstrings (N/kg)	4.97 (0.75)	5.12 (0.72)	0.15 (0.45)	3.0%	0.07	*5.07 (0.70)*	*5.46 (0.73)*	*0.39 (0.55)*	*7.7%*	*<0.001*	-0.27 (-0,59,0.06)	-5.4%	0.11
Non-dominant	4.84 (0.75)	4.99 (0.54)	0.14 (0.42)	2.9%	0.18	*4.93 (0.52)*	*5.32 (0.61)*	*0.39 (0.48)*	*7.9%*	*0.01*	-0.28 (-0.57,0.01)	-5.7%	0.06
Dominant	5.11 (0.75)	5.26 (0.86)	0.15 (0.49)	3.0%	0.22	5.22 (0.84)	5.61 (0.83)	*0.39 (0.63)*	*7.5%*	*0.03*	-0.26 (-0.67,0.16)	-5.0%	0.22
Sprint (s)*													
0-5 m	0.82 (0.03)	0.82 (0.03)	0.00 (0.02)	-0.4%	0.60	0.82 (0.05)	0.83 (0.02)	0.00 (0.04)	0.2%	0.26	-0.02 (-0.03,0.00)	-1.9%	0.06
0-10 m	1.53 (0.05)	1.55 (0.04)	0.00 (0.03)	-0.1%	0.88	1.56 (0.06)	1.57 (0.04)	0.01 (0.04)	0.5%	0.47	-0.01 (-0.03,0.01)	-0.6%	0.34
0-15 m	2.21 (0.06)	2.21 (0.06)	0.00 (0.04)	-0.1%	0.81	2.21 (0.07)	2.22 (0.05)	0.01 (0.04)	0.4%	0.48	-0.01 (-0.04,0.02)	-0.5%	0.43
0-20 m	2.83 (0.08)	2.83 (0.08)	0.00 (0.05)	-0.2%	0.71	2.83 (0.09)	2.83 (0.08)	0.00 (0.04)	0.2%	0.68	-0.01 (-0.04,0.02)	-0.3%	0.58

*n=14 in NH group and n=16 in CA group

Secondary outcomes: eccentric knee flexor strength and running speed

While within-group analyses showed that there was an increase in eccentric knee flexion strength in the NH group, we did not detect any significant between-group difference (table 3). We did not observe any within- or between-group differences in running speed (table 3).

Delayed-onset muscle soreness

DOMS was reported throughout the intervention period, for both muscle groups, with a median of zero. The individual range in DOMS for the hip adductors was 0 to 8 in the CA group and 0 to 6 in the NH group. The highest DOMS of 8 was reported by two players in the CA group at week 1. The range in DOMS for the hamstring muscle group was 0 to 9 in the CA group and 0 to 7 in the NH group. The highest DOMS of 9 was reported by one player in the CA group in week 5. We had no reports of any adverse effects related to performing the study interventions.

DISCUSSION

This is the first study investigating the eccentric hip adduction strength effect of the FIFA 11+ warm-up program. Our main finding was that replacing the NH exercise with the CA exercise in the FIFA 11+ warm-up program increases eccentric hip adduction strength in U19 elite male soccer players, while the standard FIFA 11+ program had no effect on eccentric hip adduction strength. The standard FIFA 11+ increases eccentric knee flexion strength in the NH group; however, we found no between-group differences.

We found an 8.9% increase in eccentric hip adduction strength effect in favor of the players performing the CA exercise. The strength increase in the present study is considerably lower compared to a recent Danish study that showed a 35.7% increase in eccentric hip adduction strength using the same exercise and testing procedure.[16] However, one crucial factor may explain the discrepancy. In the present study, we prescribed three weekly training sessions consisting of one set

on each side and a variation from 3-5 to 12-15 repetitions, resulting in a total of 72 (level 1) to 360 (level 3) repetitions on each side during the 8-weeks. The protocol used by Ishøi et al.[16] consisted of two weekly training sessions, with two or three sets on each side and a progression from 6 to 15 repetitions, resulting in a total of maximum 480 repetitions on each side. This suggests that there could be a dose-response relationship between training load and outcome, explaining the substantially greater strength effect in the Danish study.[16]

Secondary outcomes

Players performing the standard FIFA 11+ program, including the NH exercise, showed a 7.7% within-group increase in eccentric knee flexor strength, while we did not detect a significant increase in the CA group or between groups. Previous studies examining the eccentric knee flexor strength effect of the FIFA 11+ have shown conflicting results, ranging from -10.1% to 12.7% within-group change after 8-12 weeks using the FIFA 11+ during warm-up.[8,15,25] The conflicting results may reflect differences in playing levels, intervention period and compliance of the program. Also, the NordBord used to measure eccentric knee flexor strength in the present study differ from the isokinetic dynamometer used in other studies.[8,15,25] Testing using the NordBord may overestimate the measurement compared to isokinetic strength testing due to specificity, as the test set-up using a NordBord replicates the execution of the NH exercise.

The same dose-response relationship as for hip adduction strength seems to exist for eccentric knee flexor strength, as well. The 7.7% strength increase in the NH group is somewhat less than what has been previously reported when the full NH protocol is performed (11%).[18] This protocol has been demonstrated to substantially decrease the risk of hamstring injuries and re-injuries in soccer.[1,24,31] Although the strength increase from performing the FIFA 11+ is somewhat lower compared to the full Nordic Hamstring protocol, it has also been shown to be sufficient to prevent hamstring injuries.[28]

We found no within- or between-group effect on sprint speed when using FIFA 11+ warm-up program, with or without the CA exercise. This indicates that the program lacks appropriate load to increase sprint performance in elite U19 players performing it for 8 weeks. The results are in accordance with data on Italian amateur players.[15] In contrast, Reis et al.[25] showed a significant improvement in 5 m and 30 m sprint (8.9% and 3.3%, respectively) after a 12-week period using the FIFA 11+ among adolescent male futsal players. The increased sprint performance among the Portuguese futsal players might be explained by the duration of the intervention period (4 additional weeks) or the lower competitive level and baseline strength compared to the elite players in the present study.

The median of DOMS was the same for both intervention groups and it seems that only a few players report higher DOMS associated with the respective exercise. Therefore, highest values of DOMS reported were associated to football training. For implementation of the exercise as an in-season exercise, it is important to minimize DOMS. The low dose of the CA exercise in the present study seems to increase hip adductor strength without causing DOMS.

Methodological considerations

Players were not blinded to intervention type; however, we are confident that contamination between groups has been reduced to a minimum. The physiotherapist supervising every training session recorded if a player performed any other hamstring or hip adductor strength exercises during their individual training sessions. The two players that performed extensive hip adductor due to rehabilitation of groin injury suffered during the intervention period were not included in the per-protocol analyses.

Although knee flexor strength testing using the NordBord has become increasingly popular recent years, there is limited documentation on the reliability and validity of the measurements. While the test-retest reliability is reported to be good, [21] there is no data on the inter- or intra-tester reliability and an increase in 15% to 20% must be achieved to reflect a true change in strength at an individual level. Similar challenges in detecting change has been reported for hip adduction strength testing as well. Using a similar test set-up as in the present study the MDC ranged from 14.5% to 26.0%,[23] indicating that a large individual change is needed to be detected. However, in the present study the comparison is on the group level, and the MDC at group level is lower, and relates to the N.

Clinical implications and future directions

As shown in the present study, the FIFA 11+ program does not include exercises targeting eccentric hip adduction strength. There was no change in the group using the standard FIFA 11+ program for 8 weeks. The increase in eccentric hip adduction strength for players performing the CA exercise reported in the present study is slightly lower than the reported increase in hamstring strength when performing the NH protocol described by Mjølsnes et al.[18] This protocol has been demonstrated to substantially decrease the risk of hamstring injuries and re-injuries in soccer.[1,24,31] Thus, we believe that the hip adduction strength increase in the present study is clinically meaningful and the preventive effect on groin injuries by adding the CA exercise to the FIFA 11+ should be investigated.

Silvers-Granelli et al. have shown that the FIFA 11+ warm-up program reduced the risk for groin injuries in soccer players.[28] Although this results questions the need for an update of the FIFA 11+, it seems reasonable to include an exercise specifically targeting hip adduction strength. As shown in hamstring injury research, the NH exercise is performed eccentrically to match the deceleration phase of the leg during sprinting, in the position where hamstring injuries occur.[5,6] In a similar way the strength increase induced by the CA exercise might match the groin injury mechanism. A recent study examining acute groin injuries in sports showed that kicking and change of direction was the

most frequent injury mechanism for soccer players[27] and it may be hypothesized that the adductor longus is at greatest risk of injury when muscle activity and rate of stretching are maximal in the swing phase of the kick.[3] We also know that adductor-related groin pain is most frequent groin injury in soccer.[9,11,14,27] Optimizing the length-tension relationship using an exercise that includes heavy eccentric training therefore seems relevant to prevent adductor injuries.

CONCLUSION

Including the CA exercise in the FIFA 11+ program increased eccentric hip adduction strength, while the standard FIFA 11+ program did not. Since decreased hip adduction strength is a risk factor for developing groin injuries, the CA exercise could be included in the 11+ to potentially increasing the preventive effect on groin injuries.

COMPETING INTERESTS

We declare that we have no conflicts of interest in the authorship or publication of this contribution.

REFERENCES

1. Arnason A, Andersen TE, Holme I, Engebretsen L, Bahr R. Prevention of hamstring strains in elite soccer: an intervention study. *Scandinavian journal of medicine & science in sports.* 2008;18(1):40-48.
2. Bizzini M, Junge A, Dvorak J. Implementation of the FIFA 11+ football warm up program: how to approach and convince the Football associations to invest in prevention. *British journal of sports medicine.* 2013;47(12):803-806.
3. Charnock BL, Lewis CL, Garrett WE, Jr., Queen RM. Adductor longus mechanics during the maximal effort soccer kick. *Sports biomechanics.* 2009;8(3):223-234.
4. Chrisman SP, O'Kane JW, Polissar NL, et al. Strength and jump biomechanics of elite and recreational female youth soccer players. *Journal of athletic training.* 2012;47(6):609-615.
5. Chumanov ES, Heiderscheit BC, Thelen DG. The effect of speed and influence of individual muscles on hamstring mechanics during the swing phase of sprinting. *Journal of biomechanics.* 2007;40(16):3555-3562.
6. Chumanov ES, Heiderscheit BC, Thelen DG. Hamstring musculotendon dynamics during stance and swing phases of high-speed running. *Medicine and science in sports and exercise.* 2011;43(3):525-532.
7. Cohen J. A power primer. *Psychological bulletin.* 1992;112(1):155-159.
8. Daneshjoo A, Mokhtar A, Rahnama N, Yusof A. The effects of injury prevention warm-up programmes on knee strength in male soccer players. *Biology of sport.* 2013;30(4):281-288.
9. Ekstrand J, Hagglund M, Walden M. Epidemiology of muscle injuries in professional football (soccer). *The American journal of sports medicine.* 2011;39(6):1226-1232.
10. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. Intrinsic risk factors for groin injuries among male soccer players: a prospective cohort study. *The American journal of sports medicine.* 2010;38(10):2051-2057.

11. Hagglund M, Walden M, Ekstrand J. Risk factors for lower extremity muscle injury in professional soccer: the UEFA Injury Study. *The American journal of sports medicine.* 2013;41(2):327-335.

12. Hawker GA, Mian S, Kendzerska T, French M. Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP). *Arthritis care & research.* 2011;63 Suppl 11:S240-252.

13. Hollis S, Campbell F. What is meant by intention to treat analysis? Survey of published randomised controlled trials. *Bmj.* 1999;319(7211):670-674.

14. Hölmich P, Thorborg K, Dehlendorff C, Krogsgaard K, Gluud C. Incidence and clinical presentation of groin injuries in sub-elite male soccer. *British journal of sports medicine.* 2014;48(16):1245-1250.

15. Impellizzeri FM, Bizzini M, Dvorak J, Pellegrini B, Schena F, Junge A. Physiological and performance responses to the FIFA 11+ (part 2): a randomised controlled trial on the training effects. *Journal of sports sciences.* 2013;31(13):1491-1502.

16. Ishøi L, Sorensen CN, Kaae NM, Jorgensen LB, Holmich P, Serner A. Large eccentric strength increase using the Copenhagen Adduction exercise in football: A randomized controlled trial. *Scandinavian journal of medicine & science in sports.* 2015.

17. Jensen J, Holmich P, Bandholm T, Zebis MK, Andersen LL, Thorborg K. Eccentric strengthening effect of hip-adductor training with elastic bands in soccer players: a randomised controlled trial. *British journal of sports medicine.* 2014;48(4):332-338.

18. Mjølsnes R, Arnason A, Osthagen T, Raastad T, Bahr R. A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. *Scandinavian journal of medicine & science in sports.* 2004;14(5):311-317.

19. Moher D, Hopewell S, Schulz KF, et al. CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. *Bmj.* 2010;340:c869.
20. Mosler AB, Crossley KM, Thorborg K, et al. Hip strength and range of motion: Normal values from a professional football league. *Journal of Science and Medicine in Sport.* 2016.
21. Opar DA, Piatkowski T, Williams MD, Shield AJ. A novel device using the Nordic hamstring exercise to assess eccentric knee flexor strength: a reliability and retrospective injury study. *The Journal of orthopaedic and sports physical therapy.* 2013;43(9):636-640.
22. Owoeye OB, Akinbo SR, Tella BA, Olawale OA. Efficacy of the FIFA 11+ Warm-Up Programme in Male Youth Football: A Cluster Randomised Controlled Trial. *Journal of sports science & medicine.* 2014;13(2):321-328.
23. Paul DJ, Nassis GP, Whiteley R, Marques JB, Kenneally D, Chalabi H. Acute responses of soccer match play on hip strength and flexibility measures: potential measure of injury risk. *Journal of sports sciences.* 2014;32(13):1318-1323.
24. Petersen J, Thorborg K, Nielsen MB, Budtz-Jorgensen E, Holmich P. Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial. *The American journal of sports medicine.* 2011;39(11):2296-2303.
25. Reis I, Rebelo A, Krustrup P, Brito J. Performance enhancement effects of Federation Internationale de Football Association's "The 11+" injury prevention training program in youth futsal players. *Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine.* 2013;23(4):318-320.
26. Serner A, Jakobsen MD, Andersen LL, Holmich P, Sundstrup E, Thorborg K. EMG evaluation of hip adduction exercises for soccer players: implications for exercise selection in prevention and treatment of groin injuries. *British journal of sports medicine.* 2014;48(14):1108-1114.
27. Serner A, Tol JL, Jomaah N, et al. Diagnosis of Acute Groin Injuries: A Prospective Study of 110 Athletes. *The American journal of sports medicine.* 2015;43(8):1857-1864.

28. Silvers-Granelli H, Mandelbaum B, Adeniji O, et al. Efficacy of the FIFA 11+ Injury Prevention Program in the Collegiate Male Soccer Player. *The American journal of sports medicine.* 2015.
29. Soligard T, Myklebust G, Steffen K, et al. Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. *Bmj.* 2008;337:a2469.
30. Thorborg K, Couppe C, Petersen J, Magnusson SP, Hölmich P. Eccentric hip adduction and abduction strength in elite soccer players and matched controls: a cross-sectional study. *British journal of sports medicine.* 2011;45(1):10-13.
31. van der Horst N, Smits DW, Petersen J, Goedhart EA, Backx FJ. The preventive effect of the nordic hamstring exercise on hamstring injuries in amateur soccer players: a randomized controlled trial. *The American journal of sports medicine.* 2015;43(6):1316-1323.
32. Vickers AJ, Altman DG. Statistics notes: Analysing controlled trials with baseline and follow up measurements. *Bmj.* 2001;323(7321):1123-1124.