วารสารวิทยาศาสตร์และเทคโนโลยีการกีฬา ปีที่ 18 ฉบับที่ 2, ธันวาคม 2561
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CHRONIC EFFECT OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION STRETCHING ON FLEXIBILITY AND STRENGTH

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ABSTRACT

Stretching is usually included in the regular training program or part of warm-up activity before exercises. However, it is not that popular during the in-season training as it could compromise the muscle strength. Contract-relax proprioceptive neuromuscular facilitation (CR-PNF) stretching is generally known as an effective method to increase the joint range of motion, implying flexibility, but the chronic effect on muscle strength was not much studied. The aim of this study was to investigate the chronic effects of 4-week CR-PNF stretching on muscle strength, i.e. the knee flexor (hamstrings) and knee extensor (quadriceps) during the in-season training of professional soccer players. Thirty-one male professional soccer players received the CR-PNF stretching of hamstring and quadriceps muscles for 4 weeks during the in-season training. Hip and knee range of motion and hamstring flexibility (sit-and-reach test) were measured before, at the end of each week and two weeks after the stretching session in order to see if the range of motion was maintained. Knee flexion and extension isokinetic strengths were tested before and two weeks after the stretching session. Isokinetic Hamstring/Quadriceps (H/Q) ratios were also assessed. The range of motion was progressively increased from the baseline measurement as can be observed since week 2 for hamstring (hip and knee extension) and week 3 for quadriceps (hip and knee flexion), similarly for both dominant and non-dominant legs. At two weeks after the intervention, the range of motion was not significantly different from week 4 ($p>0.05$) but significantly improved as compared to the baseline ($p<0.05$). Isokinetic knee flexion strength was significantly improved ($p<0.05$) but not the case for extension strength ($p>0.05$). H/Q ratios were significantly improved after the intervention ($p<0.05$). It was concluded that during the in-season training, CR-PNF stretching was effectively able to increase the flexibility without the detrimental chronic effect on muscle strength. Improved muscle balance (H/Q ratio) consequently from the increased isokinetic flexion strength also suggested the positive effect on injury prevention.

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Keywords: Contract-relax PNF stretching / Agonist/antagonist stretching / In-season training; Range of motion / Hamstring/Quadriceps ratio

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ผลของการยืดแบบรับรู้ของระบบประสาทกล้ามเนื้อเป็นเวลาสี่สัปดาห์ ในการเพิ่มความยืดหยุ่นและความแข็งแรง

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บทคัดย่อ

การยืดเหยียดกล้ามเนื้อปกติจะใช้ในช่วงของโปรแกรมการฝึกซ้อมหรือช่วงของการอบอุ่นร่างกายก่อนที่จะมีการออกกำลังกาย อย่างไรก็ตามในการฝึกการยืดเหยียดกล้ามเนื้อไม่เป็นที่นิยมในฤดูกาลแข่งขันเนื่องจากการยืดเหยียดกล้ามเนื้ออาจส่งผลทำให้ความแข็งแรงของกล้ามเนื้อลดลง วิธีการยืดเหยียดกล้ามเนื้อแบบรับรู้ของระบบประสาทและกล้ามเนื้อเป็นวิธีที่ส่งผลที่ดีในการเพิ่มช่วงของข้อต่อและกล้ามเนื้อซึ่งส่งผลให้ความยืดหยุ่นของกล้ามเนื้อดีขึ้น แต่ผลกระทบต่อความแข็งแรงในระยะยาวยังมีการศึกษาไม่มาก วัตถุประสงค์ ของการศึกษาครั้งนี้เพื่อศึกษาผลระยะยาวของการยืดแบบรับรู้ความรู้ของระบบประสาท 4 สัปดาห์ของกล้ามเนื้อที่ส่งผลต่อความแข็งแรงของกล้ามเนื้อ knee flexor (Hamstrings) และ knee extension (Quadriceps) ระหว่างการฝึกซ้อมในฤดูกาลแข่งขัน ของนักกีฬาฟุตบอลอาชีพ การศึกษานี้ทดสอบนักกีฬาฟุตบอลอาชีพ 31 คน ทำการยืดเหยียดกล้ามเนื้อแบบรับรู้ระบบประสาทและกล้ามเนื้อของกล้ามเนื้อ Hamstrings และ Quadriceps ในฤดูกาลแข่งขันเป็นเวลา 4 สัปดาห์ การทดสอบช่วงของการเคลื่อนไหวข้อสะโพกและข้อเข่ารวมถึงความยืดหยุ่นของ กล้ามเนื้อ Hamstrings (sit and reach) จะทดสอบก่อนฝึกโปรแกรมยืดเหยียดและทุกๆสัปดาห์หลังจากสิ้นสุดโปรแกรมการยืดเหยียดรวมถึงสองสัปดาห์หลังสิ้นสุดโปรแกรมการยืดเหยียดเพื่อดูว่ายังคงรักษาสภาพความยืดหยุ่นอยู่หรือไม่ ความแข็งแรงของข้อเข่า knee flexion, knee extension ทดสอบก่อนการฝึกโปรแกรมการยืดเหยียดกล้ามเนื้อและสองสัปดาห์หลังสิ้นสุดโปรแกรมการยืดเหยียดกล้ามเนื้อ เพื่อมีการประเมินกล้ามเนื้อ Hamstrings/Quadriceps H/Q ratios ผลจากการวิเคราะห์ข้อมูลบ่งชี้ว่าช่วงของการเคลื่อนไหวเพิ่มขึ้นตั้งแต่สัปดาห์ที่ 2 ของกล้ามเนื้อ(Hamstrings)hip and knee extension และตั้งแต่สัปดาห์ที่ 3 ของกล้ามเนื้อ (quadriceps) hip and knee flexion เหมือนกันทั้งขาที่ถนัดและไม่ถนัด ในช่วงสองสัปดาห์หลังจากสิ้นสุดโปรแกรมการยืดเหยียดช่วงของความเคลื่อนไหวไม่มีความแตกต่างจากสัปดาห์ที่ 4 (p>0.05) แต่มีช่วงของความเคลื่อนไหวที่ดีอย่างมีนัยสำคัญเมื่อเทียบกับค่าพื้นฐาน (p>0.05) ความแข็งแรงของข้อเข่า Knee flexion strength ดีขึ้นอย่างมีนัยสำคัญทางสถิติ (p<0.05) แต่ไม่พิ่มความแข็งแรงของ Knee extension strength (p> 0.05) ค่าของอัตตรา (H/Q ratio) ดีขึ้นอย่างมีนัยสำคัญหลังจากโปรแกรมการยืดเหยียดกล้ามเนื้อ (p<0.05) สรุปฤดูกาลแข่งขันการยืดเหยียดกล้ามเนื้อแบบรับรู้ของระบบประสาทและกล้ามเนื้อเพิ่มประสิทธิภาพของความยืดหยุ่นโดยไม่ส่งผลเรื้อรังต่อความแข็งแรงของกล้ามเนื้อ เพิ่มความสมดุลของกล้ามเนื้อ (H / Q ratio) ที่เพิ่มขึ้นจากการเพิ่มความแข็งแรง isokinetic flexion strength ทำให้มีผลดีต่อการป้องกันการบาดเจ็บ

(วารสารวิทยาศาสตร์และเทคโนโลยีการกีฬา 2561 ; 18(2): 9-20)

คำสำคัญ: การยืดเหยียดแบบรับรู้ของระบบประสาทและกล้ามเนื้อ/การยืดเหยียดกล้ามเนื้อทำการและกล้ามเนื้อต้าน /การฝึกในฤดูการแข่งขัน / พิสัยการเคลื่อนไหวของข้อ / อัตราส่วนความแข็งแรงระหว่างกล้ามเนื้อ Hamstring ต่อ Quadriceps

INTRODUCTION

Soccer performance primarily depends on different factors including muscle flexibility. Flexibility is generally referred to the ability to move joints effectively, usually quantified in terms of the range of motion (ROM). Higher ROM benefits the soccer players in different ways. Improved hip flexion ROM, through either static or proprioceptive neuromuscular facilitation (PNF) stretching sessions, can also improve the running mechanics[1] which is a demanding factor during a soccer game. Increased hip and knee ROMs also improve the kicking speed due to both the quadriceps and hamstrings involve in the leg acceleration during a kick[2]. For injury prevention, soccer players with lower pre-season range of motion (ROM) have found to be more likely to have muscle strain injury[3].Additional examples of PNF stretching and flexibility have been stated elsewhere[4]. It is therefore necessary to improve ROM of both hip and knee joints, i.e. to target the flexibility of hamstrings and quadriceps.

However, the detrimental effects of muscle strength following stretching have also been reported particularly the acute effect. The acute effect of PNF stretching of quadriceps, while increasing ROM, can cause the peak torque, the mean power and also the EMG amplitudes (vastas lateralis and rectus femoris) to decrease[5]. The maximal voluntary contractions of biceps femoris and vastas lateralis have also been observed to decrease just after the PNF stretching[6]. PNF stretching is generally not recommended immediately before the game[7]. Therefore, in order to effectively increase the ROM by adding a PNF stretching session in-season is questionable as it could compromise the muscle strength and thereby affecting performance in the matches.

To our knowledge, no detrimental effect has been reported in the chronic effects on strength after PNF stretching. After a 4-week session of PNF stretching, no change in the peak isokinetic torque has been observed with the increased knee ROM[8]. An 8-week contract-relax PNF (CR-PNF) stretching program of quadriceps and hamstring has caused both significant gain of knee ROM and the increases in maximum knee flexion and extension isokinetic torque[9]. In summary, the chronic effect of PNF stretching is likely to improve the dynamic muscle performance[10]. So, to improve the ROM during the season, it might be able to do so by including a PNF stretching session during the in-season training that allow some time to rest before the match.

To gain better result during the in-season training, it might be worth adding a PNF session in the scheduled training program in order to improve flexibility as it may enhance the training effect as well as the training might enhance the effect of PNF stretching and finally the performance of the game. The aim of this study was therefore to examine the effect of CR-PNF stretching of 3 cycles performed 3 times a week for 4 weeks on knee and hip range of motion (ROM), flexibility and strength during the in-season training. We characterized the effect of CR-PNF stretching on the hip and knee ROMs at the baseline, the end of each week up to two weeks after the stretching sessions in order to see the flexibility profile (ROMs and sit-and-reach test) during the stretching session (Week 1 – Week 4) and how the increased ROMs maintained (Week 5 and Week 6). Then we examined if the isokinetic strength

of hamstrings and quadriceps had changed. It was hypothesized that hip and knee ROMs might improve following the CR-PNF stretching session with no detrimental effect on the isokinetic strength. Details on isokinetic strength testing can be found elsewhere[11].

METHODS

Subjects

Thirty-one male professional soccer players (20.81 ± 1.6 years; 1.72±6.92 m height; 65.10±8.20 kg weight) from a team in division 2 of Thailand football league participated in this study. The participants were on their regular in-season trainings two to three days a week for 2 hours a day, Mondays-Wednesdays. The matches were on Saturdays. The in-season training schedule is shown in Table 1. Participants had no musculoskeletal injury that limited ROM of the lower extremities. They were all naïve to the PNF stretching. Prior to the study, all participants gave the informed consent according to the protocol approved by the Human Research Ethics Committee of Mahidol University.

Table 1 The regular in-season training program schedule during the CR-PNF stretching session (Week1-Week4) and after the completion of stretching session (Week5-Week6).

Week	Day						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0	Aerobic training 1	Weight training(Gym) 1	-	-	-	Match	-
1	Leg Strength training	Aerobic training 2	Speed and agility 1	-	-	Match	-
2	Aerobic training 3	Weight training(Gym) 2	-	-	-	Match	-
3	Weight training 2	Circuit training 1	Speed and agility 2	-	-	Match	-
4	Interval training	Circuits training 2	-	-	-	Match	-
5	Aerobic training 4	Weight training(Gym) 3	-	-	-	Match	-
6	Friendly Game	Endurance with ball Group passing 20 min	Friendly Game	-	-	Match	-

Note : Details of training as follow. Ten-minute warm-up (5-minute static stretching and 5-minute dynamic stretching) and 5-minute cool-down activities were done at each training activity. Please note that the intensity specified in % is sport training which depends on each individual.

Leg strength : Squat jump 20 repetitions ×4 set, Lunge 20 repetitions×4 set, Side lunge 20 repetitions ×4 set, Burpee jump 20 repetition ×4 set

วารสารวิทยาศาสตร์และเทคโนโลยีการกีฬา ปีที่ 18 ฉบับที่ 2, ธันวาคม 2561
Journal of Sports Science and Technology Volume 18, No. 2, December 2018

Aerobic training 1 : Running 70% maximum speed 30 min

Aerobic training 2 : Running 70% maximum speed 40 min

Aerobic training 3 : Running 80% maximum speed 80 m and jogging 40 m 30 min

Aerobic training 4 : Running 80% maximum speed 80 m and jogging 40 m 40 min

Weight training(Gym) 1 : Leg extension: 12 repetitions x4 set at 70% 1 RM , Leg curl: 12 repetitions x4 set at 70% 1 RM ,Leg press: 12 repetitions x4 set at 70% 1 RM

Weight training(Gym) 2 : Push up 20 repetitions ×4 set, Sit up 30 repetitions ×4 set, Plank 1min 4set, Side plank 30s 4set left or right, Push up plank 1 min 4set

Weight training(Gym) 3 : Incline Bench Press: 12 repetitions x4 set at 70% 1 RM ,Shoulder front raises: 12 repetitions x4 set at 70% 1 RM ,Biceps curl: 12 repetitions x4 set at 70% 1 RM ,Lat pull down: 12 repetitions x4 set at 70% 1 RM

Speed and agility 1 : Sprints 5 repetitions x40 m, Sprints repetitions 5x20 m, Zigzags 10 m

Speed and agility 2 : Sprints 10 repetitions x20 m, Sprints 10 repetitions x10 m, Zigzags 10 m

Circuit training 1 : Squat jump 10 repetitions , Running 20m, Lunge 10 repetitions, Running 20m, Push up 10 repetitions, Running 20m, Sit up 10 repetitions, Running 20m ; overall 30 min

Circuit training 2 : Squat jump 10 repetitions, Running 10m, Lunge 10 repetitions, Running 10m, Push up 10 repetitions, Running 10m, Sit up 10 repetitions, Running 10m ; overall 30 min

Experimental procedure

One week before the experiment (Week 0), all the baseline measurements (sequence of measurement: height, weight, hip and knee ROMs, sit-and-reach test, and isokinetic strength) were done. The CR-PNF stretching started the week following baseline measurement (Week 1) and repeated on three consecutive days of a week (Monday-Wednesday) for 4 weeks (Week 1-Week 4). ROMs and sit-and-reach test were assessed after the stretching was complete in each week and two weeks after the intervention (week 6). Isokinetic strength was assessed again in week 6. All the measurements were done on Wednesdays.

CR-PNF stretching protocol

CR-PNF stretching was done Mondays-Wednesdays after the regular training program for 4 weeks (week1-week4). Participants completed a 5-minute warm-up (jogging, running) before receiving the CR-PNF stretching. CR-PNF stretching was done in two target muscle (TM) groups, i.e. hamstring and quadriceps (Figure 1). The stretching protocol consisted of holding the TM a passive static stretch for 10 seconds, relaxing for 1-2 seconds, then isometric contraction of TM for 6 seconds, relaxing for 1-2 seconds and finally went back into a passive static stretch for 10 seconds. Three cycles of CR-PNF stretches were repeated for each TM of each leg. After the CR-PNF stretching was complete, the cool-down consisted of 3-minute walk around the football field was performed.

วารสารวิทยาศาสตร์และเทคโนโลยีการกีฬา ปีที่ 18 ฉบับที่ 2, ธันวาคม 2561
Journal of Sports Science and Technology Volume 18, No. 2, December 2018

Figure 1 CR-PNF stretching procedure of the hamstring (top panels) and quadriceps (bottom panels), consisted of stretching (left panels) and isometric contraction (right panels).

Range of motion measurement

An elongated orthopedic goniometer (12 inches) was used to measure the ROMs. Hip flexion was measured in a supine position, starting with the knee fully flexed and hip in neutral. The center of the goniometer was positioned at the greater trochanter, and the arms of the goniometer were aligned with the lateral midline of the femur and lateral midline of the pelvis. The experimenter rested a hand on the ankle while moving the shank within a pain-free limit until resistance prevented further motion at which point the goniometer reading was taken. Hip extension was taken in the prone position, with the goniometer positioned similarly to the measurement of hip flexion, when the participants were asked to actively extend their legs as much as they can. The knee extension ROM was determined in a sitting position (90° hip joint angle), while the knee flexion ROM was determined at the standing position (0° hip joint angle). Participants either fully extend or flex their knees when the measurement was performed. The center of goniometer was aligned with the lateral femoral condyle, and the arms of the goniometer were aligned with the greater trochanter and the lateral malleolus during the knee ROM measurements. The ROM measurements were recorded in degrees, measured twice, and the best value was used.

Hamstring flexibility assessment

The sit-and-reach test was used to additionally assess the hamstring and lower-back flexibility. Participants sat on the floor with their legs extend. They were asked to keep their lower backs against the wall, with their hands resting on a measurement box while extending their arms and reaching as far as possible. The average value of the farthest reach distance from three measurements was used.

วารสารวิทยาศาสตร์และเทคโนโลยีการกีฬา ปีที่ 18 ฉบับที่ 2, ธันวาคม 2561
Journal of Sports Science and Technology Volume 18, No. 2, December 2018

Strength test

An isokinetic dynamometry (Biodex System 4; Biodex Medical Systems, Inc., Shirley, NY, USA) was used to assess the concentric strength of hamstring and quadriceps muscle of both dominant and non-dominant legs. Prior to the measurements, subjects did a warm-up consisting of 2-minute cycling. The dynamometer axis was carefully aligned with the knee joint axis. Restraining straps was wrapped around the mid-calf, thigh, waist, and chest. Subjects performed practice contractions and then maximum effort isokinetic knee extension and knee flexion contractions at velocities of 60 degree/s and 120 degree/s. Two sets of 5 contractions were performed at each velocity with a 1-minute rest period between each set. The hamstring to quadriceps peak torque ratio (H/Q ratio) was obtained from the device software.

Figure 2 Setup of the isokinetic knee flexion and knee extension test

Statistical analysis

Two-way analyses of variance (ANOVA) with repeated measures were performed to determine the effects of time (Week 0 to Week 6 for ROMs and Week 0 vs. Week 6 for isokinetic strength test) and side (dominant and non-dominant sides) in ROM measurements. For the effect of time (Week0 to Week 6) in the sit-and-reach test, one-way ANOVA was performed. Tukey post-hoc test with Bonferroni correction was done as necessary to determine the significant different pairs of the weeks. The level of significance for all statistical tests was set at $p \leq 0.05$.

RESULTS

Range of motion

The range of motion had been increased after 4 weeks of PNF stretching as shown in Figure 2, including knee flexion ($F_{5,150}$=72.045, p<0.01) and hip flexion ($F_{5,150}$=37.588 p<0.01) similarly for dominant and non-dominant sides. Despite the different pattern of change between dominant and non-dominant sides (significant interaction of time*side in knee extension; and hip extension), knee extension and hip extension were significantly increased in

both dominant (knee extension: $F_{5,150}$=20.35, p<0.01 and hip extension: $F_{5,150}$=29.52, p<0.01) and non-dominant (knee extension: $F_{5,150}$=23.618, p<0.01 and hip extension: $F_{5,150}$=36.05, p<0.01) sides. The knee flexions were significantly increased from the baseline at week 3 (t=-5.707, p<0.01) with the mean difference of 2.9 degrees, which continued to increase after week 4 (t=-12.359, p<0.01) and maintained after week 6 (t=-9.774, p<0.01) with the overall increase of 5.0 degrees at week 6. The knee extension were significantly increased from the baseline at week 1 for dominant side (t=4.951, p<0.01) and week 2 for non-dominant side, which continued to increase after week 4 (dominant: t=8.649, p<0.01 and non-dominant: t= 6.607, p<0.01) and maintained after week 6 (dominant: t=7.795, p<0.01 and non-dominant: t= 5.911, p<0.01) with the overall increase of 2.3 (dominant) and 1.6 (non-dominant) degrees. The hip flexions were significantly increased from the baseline at week 3 (t=-4.702, p<0.01) with the mean difference 5.7 degrees, which continued to increase at week 4 (t=-4.860, p<0.01) and maintained at week 6 (t=-5.913 p<0.01) with the overall increase of 7.2 degrees. The Hip extensions were significantly increased from the baseline at week 1 for dominant side and week 2 for non-dominant side (t=-5.214, p<0.01), which continued to increase after week 4 (dominant: t=-10.415, p<0.01 and non-dominant: t= -11.470, p<0.01) and maintained after week 6 (dominant: t=-6.459, p<0.01 and non-dominant: t= -9.186, p<0.01) with the overall increase of 5.4 (dominant) and 5.9 (non-dominant) degrees.

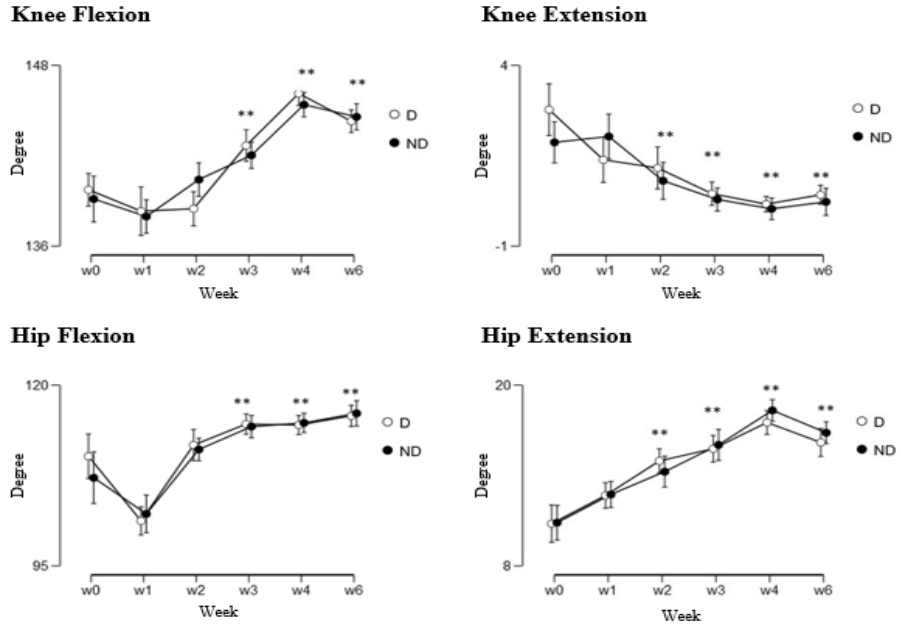
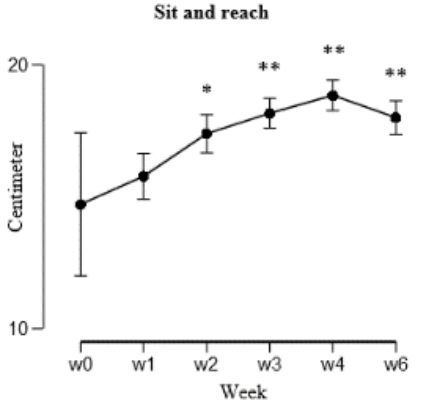


Figure 3 ROMs measured from the baseline (Week 0; w0), during the PNF stretching session (Week 1; w1 to Week 4; w4) and after completion of the CR-PNF stretching session (Week5; w5 and Week 6; w6). for dominant (D) and non-dominant (ND) sides.

Sit and reach test

The overall flexibility as observed from the sit-and-reach test (Figure 3) had significantly increased from baseline ($F_{5,150}$=6.463, p<0.05), started from week 2, continued at week 4 (t=-4.694, p<0.01) and remained to week 6.



(*)Statistically Significant difference from the baseline $p < 0.05$. (**)Statistically Significant difference form the baseline $p < 0.01$.

Figure 4 Sit-and-reach test measured from the baseline (Week 0; w0) towards Week 6 (w6).

Isokinetic strength and H/Q ratio

The isokinetic peak flexion torques were significantly increased at both 60 deg/s ($F_{1,30}$=16.841 p<0.01) and 120 deg/s ($F_{1,30}$=25.238 p<0.01), similarly for both dominant and non-dominant sides (Table 2). No significant change in the peak isokinetic extension torque was observed at 60 deg/s. Significant interaction of time and side was observed in the 120 deg/s peak extension torque and no significantly changed in both dominant and non-dominant (120 extension) sides was found. The H/Q ratios were significantly increased in both 60 deg/s (F=16.308, p<0.01) and 120 deg/s (F=21.908 , p<0.01), similarly for both dominant and non-dominant sides. (Table 2)

Table 2 The results of Isokinetic peak torques between the baseline (Week0) and two weeks after completion of the CR-PNF stretching session on (Week6)

	Flexion (N-m)		Extension (N-m)		H/Q ratio (%)	
	Week 0	Week6	Week 0	Week 6	Week0	Week 6
60 deg/s (D)	71.50±32	86.63±20 **	194.18±28	199.00±21	36.60±15	43.43±9 **
60 deg/s(ND)	64.63±39	83.57±20 **	186.27±45	199.12±28	32.92±17	44.14±9 **
120 deg/s (D)	51.07±27	69.38±19 **	146.37±27	159.19±19	34.56±14	43.28±10 **
120 deg/s (ND)	50.03±30	69.93±28 **	147.51±29	150.89±29	33.58±16	46.25±15 **

**Significant difference between week0 and week6 at p < 0.01. for dominant (D) and non-dominant (ND) sides.

DISCUSSION

PNF stretching involves the voluntary muscle contractions and stretches, with either the inhibition of stretch reflex activity[12,13] or alteration of the stretch perception[14] may decrease the muscular resistance and eventually increase the ROM. Including the PNF stretching session during the in-season training is challenging as the stretched muscles can cause either positive or detrimental effects.

This study has demonstrated that adding the CR-PNF stretching session during the regular in-season training program caused no detrimental effect. Flexibility, in terms of hip and knee flexion/extension and sit-and-reach test, were improved after the 4-week of stretching session (Figure 2, 3) while flexion strength were also increased with no significant change in extension strength (Table 2). This is consistent with previous findings that even though following stretching, the muscle strength and performance has been observed to decrease[2,3] but not likely in the case of chronic stretching where the dynamic strength and performance has been reported to improve[6,9].

The increased ROMs of this study had maintained for at least two weeks after the completion of stretching session. Usually after the stretching, increased ROM can maintain for at least 25 minutes[15]. Either the chronic stretching that had been done three times a week on three consecutive days in this study or the effect of training program may help maintain the ROMs. However, it has been suggested to perform the intermittent stretching after the comprehensive stretching session to better maintain the increased ROMs[16].

The finding of increased flexibility and strength in this study might be from the mutual enhancing effect between the training program and the CR-PNF stretching. Adding a PNF stretching session in the scheduled training may effectively enhance the flexibility as PNF stretching done after exercise has been found to improve the hamstring flexibility[17]. Improved ROMs from the CR-PNF stretching might help improve the training performance as a study has found PNF stretching can enhance muscular strength even superior to the weight training alone[18]. Further study is needed to rule out the effect from the regular training schedule.

The improved H/Q ratios from this study may suggest the effectiveness of CR-PNF stretching on the injury prevention as the H/Q ratio typically indicates the anterior-posterior balance of muscle strength around the knee joint. The increased flexion strength in this study resulted in the significant increase in the H/Q ratio, for both speeds (60 and 120 deg/s), approximately from the baseline of 30% to 40% (Table 2). However, the ratios were still in the range of injury risk as the H/Q ratios from isokinetic testing range from 50% to 80% in healthy subjects[19]. Even though this protocol of CR-PNF stretching could be beneficial to reduce the risk of ACL injury during in-season training, additional ACL prevention training program is recommended.

CONCLUSION

The 4-week PNF-CR intervention has been done in 31 male soccer players during the in-season training program to see the improvement in flexibility and strength. Flexibility, in terms of hip and knee ROMs and sit-and-reach test were observed to be increased after 4 weeks of the intervention and continued to maintain towards week 6. Flexion strength was also improved, leading to improved H/Q ratio that was beneficial to ACL injury prevention. It is likely that the CR-PNF stretching protocol similar to this study can be implemented during the in-season training program to improve flexibility and strength. If further study can conclude that increased strength is only due to the CR-PNF stretches, not the mutual enhancing effect from the regular training program in-season, this CR-PNF stretching protocol can also apply off-season.

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