Acute effects of contract-relax PNF and static stretching on flexibility, jump performance and EMG activities: A case study

D.O.I: http: doi.org/10.4127/jbe.2016.0099

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ABSTRACT

The purpose of this case study was to describe the acute effects of contract-relax proprioceptive neuromuscular facilitation (CRPNF) and static stretching (SS) on hamstring flexibility, vertical jump performance and electromyography (EMG) of *vastus lateralis* (VL), *vastus medialis* (VM) and *gastrocnemius* (GAS) in two sedantary males. Each participant completed 8 activities: warm-up, pre-stretching range of motion (ROM) of hip, pre-stretching countermovement jump (CMJ), pre-stretching EMG recording, CRPNF or SS procedure, post-stretching ROM of hip, post-stretching CMJ and post-stretching EMG recording. The results of this study revealed that there were no significant increases in ROM of hip (25,34% and 24,19%) and no significant decreases in CMJ (-8,67% and -8,17%), EMG activities of VL (-12,52% and -29,34%), VM (-13,02% and -32,80%) and GAS (-20,63% and -24,81%) following CRPNF and SS. There were no significant differences were found between both experimental groups for all variables ($p > 0,05$). It was concluded that CRPNF ans SS resulted in similar changes of ROM of the hip joint, CMJ and EMG activities of VL, VM and GAS muscles in sedantary males.

Key Words: *Hip flexion, Range of motion, Countermovement jump, Root mean square, Knee extensor muscles, Gastrocnemius.*

INTRODUCTION

Most medical professionals, coaches and athletes consider aerobic conditioning, strength training, and flexibility exercises integral components of conditioning programs. (33). Flexibility has been defined as the ability of a muscle to lengthen and allow one joint (or more than one joint in a series) to move through a range of motion (52). Gender, age, excessive adipose tissue, skin, stiff muscle ligaments, and tendons are factors that impact on muscle flexibility and joint range of motion (15).

Three types of stretching have been traditionally defined in the literature that may increase flexibility: ballistic stretching, static stretching, and proprioceptive neuromuscular facilitation (52, 10). Ballistic stretching is a technique involving a rhythmic, bouncing motion. The bouncing uses the momentum of the extremity to lengthen the muscle (13). However, because of the rapid and forceful nature of ballistic stretching and the potential to exceed the extensibility limits of a muscle, this method of increasing ROM has not been widely supported in the literature (37). The static technique incorporates a slow stretch of a particular muscle or muscle group, held at the point of discomfort for a period of time ranging from 6 to 60 seconds (10). The static stretch takes advantage of the inverse myotatic reflex, which promotes muscle relaxation and hence further stretch and ROM. The slow, controlled movement allows the stretch to be performed safely, with reduced risk of injury as compared to the other forms of stretching (13, 52). Proprioceptive neuromuscular facilitation (PNF) is a popular method of stretching that utilizes inhibition techniques (10, 20): contract-relax (CR), hold-relax (HR) and contract-relax antagonist-contract (CRAC) appear to be most commonly used. PNF stretching is usually performed with a 100% maximal voluntary isometric contraction (MVIC), which can possibly lead to of a contraction induced injury and muscle soreness (20). Hindle et al., (20) revealed that this contraction has been proven when held a total of 3–10 seconds but Feland and Marin (13) preferred 3-6 seconds to produce better effects. Studies suggest that autogenic and reciprocal inhibition mechanisms occur during PNF. An isometric contraction of a stretched muscle during applied PNF triggers the autogenic inhibition mechanism (51) and creates a subsequent reduction in muscle tension through stimulation of Golgi tendon organs. This mechanism lowers the resistance to stretch and is important to improve ROM. In addition, tension during the maximum isometric contraction of the stretched muscle results in less resistance to length changes in that muscle. Alternatively, concentric contraction of an antagonist muscle causes reciprocal inhibition. Because of this reciprocal inhibition, an active reduction in resistance takes place in the target muscle. A reduced excitability of motor neurons connected with the stretched muscle will cause reciprocal inhibition and provides muscle compliance by allowing muscle lengthening (51).

The literature reports many benefits from stretching, including improved flexibility (33, 52), reduce the risk of injury (10), enhance athletic performance (13, 15, 29), enhance running economy (13) and possibly decreased symptoms of delayed onset muscle soreness (10). Athletic trainers and rehabilitation professionals may recommend that their athletes or patients stretch before performing strengthening exercises or strength assessment tests. However, authors of systematic reviews (46, 42) and many original studies have suggested that pre-exercise stretching may temporarily compromise a muscle's ability to produce force (29, 40). Numerous studies have demonstrated that traditional static stretching actually decreases performance in activities that require strength, speed, and power (1, 14, 24, 32, 34, 42, 50). Depth-jump performance, a good indicator of power output, has been shown to be significantly reduced after static stretching (9, 24) as has vertical-jump height (50). Studies of strength and power have demonstrated performance decreases of as much as 30% (14, 24). Cornwell et al. (9) recommend that stretching should be avoided before an explosive exercise (e.g. sprint, jumps) since it would exert negative effects on the muscular performance. Other studies have shown that an acute passive stretching exercise does not impair the maximal force and speed of muscle contraction (47, 17).

Therefore, the purpose of the present study was to investigate the acute effects of contract-relax PNF and passive static stretching exercises on hamstring flexibility, vertical jump performance and EMG activities of vastus lateralis, vastus medialis and gastrocnemius muscles.

MATERIAL AND METHODS

The stretching protocols included passive static stretching and contract–relax PNF (CRPNF) on both hamstrings, quadriceps and triceps surae muscles and lower back muscles. Participants were randomly assigned to each protocol. On the first occasion, participants A and B performed passive static stretching and CRPNF, respectively, with reversed order on the second occasion. The time between the two occasions was on average 24 hours.

Both participants were familiarized with the stretching protocoles and test exercises at least one week before the beginning of the experiment. During the familiarization session, each participant completed 8 activities: (1) warm-up, (2) prestretching ROM of hip, (3) prestretching CMJ, (4) prestretching EMG recording, (5) passive static or CRPNF stretching, (6) poststretching ROM of hip, (7) poststretching CMJ and (8) poststretching EMG recording. Pre- and post-test were performed under the same environmental conditions and time (between 9 am and 11 am) as participants' respective familirization sessions. Measurements were performed before and immediately after each stretching protocol. Participants were encouraged to give their best effort.

Participants

Two sedantary males volunteered in this study. Descriptive characteristics of the participants are tabulated in Table 1. Both participants were recreationally active but not involved in any structured physical training regime. Participants were instructed not to perform excessive physical activity before the testing sessions but to continue with their normal routines. Both participants were informed of the purpose of the study, completed a medical history form and signed an informed consent form approved by the Ethical Review Committee of the University of Chichester (UK).

Table 1.
Participants' descriptive characteristics

Participants	Age (year)	Weight (Kg)	Height (cm)
A	32	78,30	181
B	30	76,50	168

Stretching Protocol

Each stretch was performed on lower back muscles, hamstrings, quadriceps and triceps surae muscle groups. The passive static and CRPNF were performed 30 seconds to a point of discomfort but not pain, as acknowledged by the participant (29). All stretches were performed 4 times for each muscle (29). Between repetitions, the leg was returned to a neutral position for a 30-second rest period (16). When participants were in a resting period, the same prodecure was performed with the opposite lower extremity. The order of stretching was the following; hamstring stretch, triceps surae stretch, quadriceps stretch and lower back stretch.

Stretching Exercises

Two experimental groups performed the same stretching exercise and passive static stretching group maintained to hold the ROM to target joints for 30 seconds. The CRPNF procedure consisted of 3 stages. In the first stage, the participant was flexed to their target joint as far as possible for 10 seconds. In the second stage, the participant performed a voluntary contraction with the stretched muscle against a force executed submaximally by the researcher for 5 seconds. Following the 5 s voluntary contraction, each participant relaxed for 5 seconds and then in the third stage, the researcher applied to the target muscle stretching force at the newly found end range for 15 seconds (51). Table 2 contains the protocols for both stretching procedures.

Table 2.
Instructions to participants for the 2 stretching protocols.

	First Stretch Time	Contraction Time	Second Stretch Time	Repetition Number	Resting Time	Total Stretch Time (both legs)	Total Protocol Time (with rest)
CRPNF PROTOCOL							
Hamstring and Triceps surae muscle	10 s	5 s	15 s	4	30	30 s x 4 x 2= 240 s	700 s
Quadriceps	10 s	5 s	15 s	4	30	30 s x 4 x 2= 240 s	
Lower back muscle	10 s	5 s	15s	4	30	30 s x 4 x 1= 120 s	
PASSIVE STATIC STRETCHING PROTOCOL							
Hamstring and Triceps surae muscle	30 s	–	–	4	30	30 s x 4 x 2= 240 s	600 s
Quadriceps	30 s	–	–	4	30	30 s x 4 x 2= 240 s	
Lower back muscle	30 s	–	–	4	30	30 s x 4 x 1= 120 s	

Hamstring and triceps surae stretches were performed with the participant lying supine on a floor mat and dominant leg's knee joint was extended while the hip was held at 90˚of flexion while simultaneously flexing the ankle joint to 90˚ (neutral ankle position) and then the ankle joint flexing dorsally (Figure 1). The opposite lower extremity remained flat on floor mat (10). Quadriceps stretch was performed with the participant lying prone on a floor mat and the leg fully extended, dominant leg was flexed at the knee joint and slowly pressed down so the participant's heel approached the buttocks (Figure 2). If the heel was able to contact the buttocks, the knee was gently lifted off the supporting surface, causing a slight hyperextension at the hip joint to complete the stretch (29). The lower back stretch was performed with the participant sitting on the floor mat with both legs straight out in front of participant. The participant bent forward and reached out to touch the toes and stretched as far as possible while keeping the knees straight and researcher helped them from their back to keep their position (Figure 3).

Figure 1. *Hamstring and triceps surae muscles stretch.*

Figure 2. *Quadriceps muscle stretch.*

Figure 3. *Lower back stretch.*

Assessment of Passive Flexion at the Hip

The straight leg raised protocol was used to determine flexibility of hamstring of dominant leg. The participant lay supine on the floor mat. The lateral epicondyle of the dominant leg's femur was palpated and the hip joint measurements were performed using a standard handheld goniometer (51). The other leg was held straight on the floor mat (44), while the researcher moved the dominant leg throught the maximum range. The participant indicated that he had reached maximum ROM by saying "stop;" this was defined as participant's end point. Generellly Two different ways were used for determination of the end point; Ayala et al., (2) reported that the endpoint for straight-leg raising was determined by 1 or both of 2 criteria: a) the examiner's perception of firm resistance, and b) palpable onset of pelvic rotation.

However, Several researchers (6, 7, 13, 30, 31) used participants' complaint of discomfort when they measured hip flexion. Lumber spine and pelvic of participants were not rotated during measurements, Therefore participant complaint was preferred to use in this study. The ROM was defined as the angular displacement from the supine position (0) to the participant's end point. The mean score of the three measures was taken and recorded in degrees (38). Before measuring the dominant hip flexion range, the researcher ensured that the lumbar spine was in contact with the floor mat by checking that a towel placed under the participant's lumbar spine could not be removed.

Countermovement Jump (CMJ) Measurements

Prior to the countermovement jump (CMJ) testing sessions, the participants performed a warm-up of five minutes jogging on treadmill at a self-selected pace. Following the warm-up, participants performed three practice trials. After the placement of the EMG electrodes, each participant performed three jumping trials. During all jump assessments participants were instructed to keep their hands placed on their hips. Flying times were determined by jump mat (designed by University of Chichester) and jumping heights were calculated by following formula: h= g x t2/8, where h is the reached height, g is the gravity acceleration (9,81 m/s2) and t is the flight time of jump (39).

Electromyography

EMG of three muscles of the dominant leg was recorded during the eccentric phase of CMJ performance. The selected muscles were vastus lateralis (VL), vastus medialis (VM) and gastrocnemius medialis (GAS). Thorough skin preparation for all recording electrodes included removal of body hair and dead epithelial cells with a razor, slight abrading with sandpaper and cleansing of the designated areas with an isopropyl alcohol (34). Bipolar surface electrodes (blue sensor electrodes) were placed along the longitudinal axes and muscle belly of the selected muscle (34) at an interelectrode distance of 20 mm for VL (3, 12), VM (12, 45) and GAS (9, 12). Hermens et al., (19) reported that researchers were used between 10-50 mm for electrode distance in order to measure different types of muscles but largely preferred distance was 20 mm for bipolar electrode configurations by Many Researchers.

Therefore, 20 mm was preferred in this study. The reference electrode was placed over the patella of the dominant leg (36). The wires connecting the electrodes were well secured with tape to avoid artefacts from lower limb movements.

Signal Processing

The EMG signals was sampled at a frequency of 1 KHz, stored on a computer using a 16 bit A/D converter data acquisition system (MT8 Telemetry System, MIE Medical Research Ltd, Leeds, UK) and EMG activity was quantified as the root mean square (RMS) values by software (Myodat 5.0 Software, MIE Medical Ressearch Ltd, Leeds, UK). Raw EMG data were root mean squared (RMS) with a time averaging period of 25 ms to produce linear envelope for each muscle activity pattern (12). The EMG system bandwidth was 10–500 Hz (3, 45) with an overall gain of 1000 (5). The amplitude for 1.0 s was calculated when the participant was in the eccentric phase of knee of CMJ (2). EMG was normalized to a MVIC (5).

Statistical analysis

Descriptive statistics was used to calculate means and standard deviations for all variables. The data normality was checked by using the Shapiro-Wilk analysis. Mann-Whitney U test was performed to examine the differences between pre-tests of both groups (flexibility, CMJ, RMS values of EMG activity for VL, VM and GAS). Wilcoxon Signed Ranks Test was used for the differences of pre- and post-tests between static stretching and CRPNF stretching groups. All data analysis was performed by means of the IBM-SPSS statistical software 20.0 for Windows (SPSS, Inc., Chicago, IL). The level of statistical significance was set at $p<0,05$.

RESULTS

Mann-Whitney U was used to assess any differences for the pretest scores between the two groups on ROM of hip, CMJ, RMS values of VL, VM and GAS. As can be seen from Table 3, the results indicated that no differences between two groups for ROM of hip, CMJ, RMS values of VL, VM and GAS, (Z=0,000, p>0,05), (Z= 0,000, p>0,05), (Z= -1,549, p>0,05), (Z= -1,549, p>0,05), (Z= -0,775, p>0,05), respectively.

Table 3.
Mann-Whitney U test results for two groups on pretests of ROM of Hip, CMJ, RMS values of VL, VM and GAS.

Tests	Groups	N	Mean ± SD	Mean Rank	Sum of Ranks	Z	p
Rom of Hip	CRPNF	2	62,50 ± 12,97	2,50	5,00	0,000	1,000
(Degree)	SS	2	62,67 ± 16,97	2,50	5,00		
CMJ	CRPNF	2	27,69 ± 5,61	2,50	5,00	0,000	1,000
(cm)	SS	2	27,78 ± 5,71	2,50	5,00		
VL	CRPNF	2	154,31 ± 11,63	1,50	3,00	-1,549	0,112
(%)	SS	2	170,77 ± 2,39	3,50	7,00		
VM	CRPNF	2	144,77 ± 1,15	1,50	3,00	-1,549	0,112
(%)	SS	2	197,29 ± 21,78	3,50	7,00		
GAS	CRPNF	2	136,49 ± 15,12	2,00	4,00	-0,775	0,439
(%)	SS	2	156,73 ± 35,50	3,00	6,00		

Table 4 shows the ROM of hip, CMJ, RMS values of VL, VM and GAS for pre and post-test measurements. Accordingly, there was non-significant increase in ROM of hip (25,34% and 24,19%), non-significant decrease in CMJ (-8,67% and -8,17%), in RMS values of VL (-12,52% and -29,34%), VM (-13,02% and -32,80%) and GAS (-20,63% and -24,81%) in CRPNF and static group, respectively (Figure 4).

Table 4.
Rom of hip, CMJ, root mean square values of VL, VM and GAS muscles in two experimental groups initially and immediately after the flexibility exercise sessions of two stretching protocoles.

Tests	Groups	Sections	Mean ± SD	N	Mean Rank	Sum of Ranks	Z	p
Rom of Hip (Degree)	CRPNF	Pre	62,50 ± 12,97	0[a]	0,00	0,00	-1,342	0,18
		Post	78,34 ± 10,37	2[b]	1,50	3,00		
	SS	Pre	62,67 ± 16,97	0[a]	0,00	0,00	-1,342	0,18
		Post	77,83 ± 12,02	2[b]	1,50	3,00		
CMJ (cm)	CRPNF	Pre	27,69 ± 5,61	2[a]	1,50	3,00	-1,342	0,18
		Post	25,29 ± 3,70	0[b]	0,00	0,00		
	SS	Pre	27,78 ± 5,71	2[a]	1,50	3,00	-1,342	0,18
		Post	25,51 ± 5,10	0[b]	0,00	0,00		
VL (%)	CRPNF	Pre	154,31 ± 11,63	2[a]	1,50	3,00	-1,342	0,18
		Post	134,99 ± 28,60	0[b]	0,00	0,00		
	SS	Pre	170,77 ± 2,39	2[a]	1,50	3,00	-1,342	0,18
		Post	120,67 ± 15,44	0[b]	0,00	0,00		
VM (%)	CRPNF	Pre	144,77 ± 1,15	2[a]	1,50	3,00	-1,342	0,18
		Post	125,92 ± 6,26	0[b]	0,00	0,00		
	SS	Pre	197,29 ± 21,78	2[a]	1,50	3,00	-1,342	0,18
		Post	132,58 ± 27,80	0[b]	0,00	0,00		
GAS (%)	CRPNF	Pre	136,49 ± 15,12	2[a]	1,50	3,00	-1,342	0,18
		Post	108,33 ± 3,87	0[b]	0,00	0,00		
	SS	Pre	156,73 ± 35,50	2[a]	1,50	3,00	-1,342	0,18
		Post	117,85 ± 19,62	0[b]	0,00	0,00		

a. post-test < pre-test $p < 0,05$*
b. post-test > pre-test

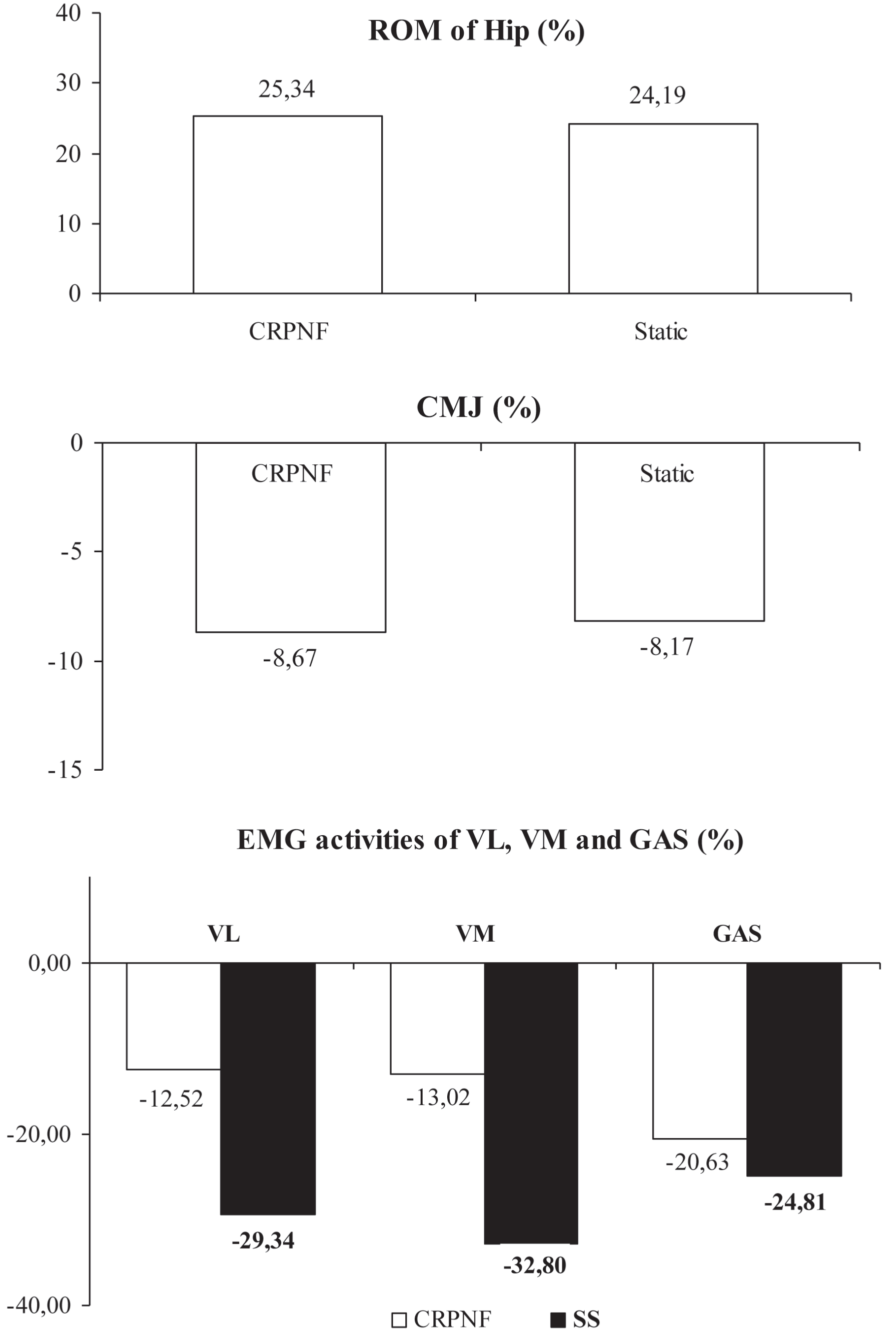

Figure 4. *The percentage difference based on pre- and post-test values of groups for each variable.*

DISCUSSION

The present study was designed to assess the acute effects of two different stretching techniques performed for 30 seconds and 4 repetitons on hamstring flexibility, vertical jump performance and EMG activities of vastus lateralis, vastus medialis and gastrocnemius muscle. The results showed that neither the CRPNF nor SS caused any change on ROM of hip joint, CMJ, RMS values of VL, VM and GAS muscles.

However, hip flexion increased by 25,34% and 24,19% after CRPNF and SS protocols, respectively, so neither technique was superior to the other. The two stretching techniques were equally effective in improving ROM of hip joint. A number of studies have demonstrated that ROM remains significantly increased after the PNF stretching protocols had been applied. Rees et al. (35) reported an increase on ankle ROM (7,8%), maximal isometric strength (26%), rate of force development (25%) and MTU stiffness (8,4%). The increased MTU stiffness after the training period was explained by adaptations to maximal isometric muscle contractions applied in PNF stretching bouts. As a stiffer MTU system is linked with an improved ability to store and release elastic energy, PNF stretching should benefit certain athletic performance due to a reduced contraction time or greater mechanical efficiency.

As in the case of PNF stretching on the positive effect on ROM, findings of the present study support previous investigations using SS protocols. Power et al. (34) examined whether a SS routine decreased isometric force, muscle activation, and jump power while improving range of motion (ROM). SS resulted in a significant increase in sit and reach ROM ($P<0,05$), and compared with the control condition, ROM increased by 10% (POST), 8% (30 min), 7% (60 min), 6% (90 min), and 6% (120 min) poststretch. In another study, Docester et al. (11) evaluated the relative effectiveness of standing and supine hamstring stretching in increasing hamstring flexibility (each leg three times for 30 s each). Their results shown that prestretching and poststretching measurements were significantly different for both the standing and supine stretch. No significant difference in change score existed between the two stretches. The gains in the ROM after stretching programme on hamstring muscle for 30-s are quite similar to gains by the SS group in the present study.

Previous studies authors have reported various PNF techniques to improve hip-flexion ROM more efficiently than SS (13, 15) whereas Gribble et al. (16) and Davis et al. (10) found SS to be more effective than PNF stretching. The results of our study are consistent with previous studies that illustrated no significant difference between PNF and SS (15, 33, 51, 43). In these studies, it was demonstrated both SS and PNF had some degree of improvement in flexibility, but there was no significant difference among the groups.

Funk et al. (15) compared 5 minutes of SS and PNF on hamstring flexibility performed with and without exercise. PNF resulted in a significant increase in flexibility after 60 minutes of exercise when compared with baseline (9,6%) and without exercise (7,8%). No differences were observed with SS across time. In addition, no order effect among conditions occurred and no differences were observed between PNF and SS. In a study by Gribble et al. (16), They found that both SS and PNF were equally effective in improving hamstring ROM (+33,08° ± 9,08° and +35,17° ± 10,39°, respectively). Feland et al. (13) reported that one repetition (32 seconds) of stretching provided an acute increase in flexibility of the hamstrings. CRPNF and SS significantly improved flexibility. However, there was a significant difference between CRPNF and SS techniques in those aged 55 to 64 years, with CRPNF stretching producing significantly greater gains in acute (short term) hamstring flexibility than the static stretch.

Jump Performance and Power Output

We determined the acute effects of CRPNF and SS on CMJ performance. The results showed that neither CRPNF stretching nor SS exercises caused any change on the CMJ performance. However, jump height was non-significant decreased by 8,67% and 8,14% in CRPNF and SS group, respectively. Only a limited number of studies reported the effects of different types of acute stretching on jump performance. Below, the results of the present study are compared with those previous relevant studies.

Contrary to the widely held belief that stretching protocols improve physical performance, numerous studies have demonstrated that CRPNF and SS actually decreases performance in activities that require strength, speed, and power. Kovacs (24) reported that depth-jump performance, a good indicator of power output, was significantly reduced after SS, as has vertical-jump height (knee flexion and extension maximal performance (1-RM) measured 10 min after SS were reduced by 7,3% and 8,1%, respectively). During counter-movement vertical jumps, Church et al. (8) reported that the CRPNF stretching technique of the lower extremities resulted in a statistically significant, yet small, decrease (mean reduction in vertical jump displacement was 1,47 cm or 3,0%); the application of a SS of the same muscles resulted in no significant differences in vertical jump height. Cornwell et al. (9) reported that following stretching of the triceps surae, a significant decrease [mean (SD) 7,4 (1,9%); P<0,05] in jump height occurred for CMJ, but for Statik Jump, no significant change in jump height was reported. Similarly, Bradley et al. (6) reported that **v**ertical jump height decreased after SS and PNF stretching (4,0% and 5,1%, P<0,05) and there was a smaller decrease after ballistic stretching (2,7%, P>0,05). Power et al. (34) reported that after SS, there were 9,5% and 5,4%

decrements in the torque or force of the quadriceps for MVC. Force remained significantly decreased for 120 min (10,4%), paralleling significant increases (6%) in sit and reach ROM (120 min). After SS, there were no significant changes in jump performance or peak force measures. In terms of dynamic movement, Nelson et al. (32) found that after acute three different stretching exercises of the quadriceps muscle, decreases in isokinetic knee extension peak torque of 7,2% and 4,5% occurred at 1,05 and 1,57 rad × s^{-1}, respectively, with no significant effects at higher velocities. Siatras et al. (42) found that gymnasts mean speed during the run of vault significantly decreased after the application of the SS protocol. They revealed the inhibitory role of an acute SS on running speed in young gymnasts.

The results of the present study refer to the lack of change of vertical jump height after acute CRPNF and SS which are in agreement with previous studies using different stretching methods. Manoel et al. (28) found that none of the there stretching protocols (statik, dynamic and PNF) caused a decrease in knee extension power. No change in vertical jump height values in present study could be associated with reduction in muscle stiffness. A stretch-induced decrease in muscle stiffness has been reported by Magnusson et al. (27). Similar results were reported by Knudson et al. (23), who showed that 20 young volunteers experienced no significant changes in the following lower extremity kinematic variables during a counter-movement jump: peak vertical takeoff velocity, duration of concentric and eccentric phases before take-off and knee angle. Stretching prior to stretch-shortening cycle activities like the vertical jump resulted in small decreases in performance in some participants, but the nonsignificant biomechanical changes suggest that neuromuscular inhibition may be the mechanism rather than changes in muscle stiffness. A possible explanation provided for these results were that the stretching bout affected the storage and return of elastic energy. Furthermore, Laur et al. (26) have not observed any significant modification in maximal velocity and power after the stretching exercise, whatever the method applied. The forces produced by the calf muscles at all velocities (20,70 cm/s) were unchanged. In another study, Hunter and Marshall (21) found that stretching appeared to have no significant effect on CMJ or DJ technique. Unick et al. (47) reported that there was no significant difference in VJ scores as a result of static or ballistic stretching, elapsed time, or initial flexibility scores. They also suggested that stretching prior to competition may not negatively affect the performance of trained women.

Electromyography

The results showed that neither CRPNF nor SS caused any change on the RMS values of VL, VM and GAS muscles. Accordingly, there was non-significant decrease in RMS values of VL (12,52%, 29,34%), VM (13,03%, 48,82%), and (20,63%, 24,81%) following CRPNF and SS, respectively.

Only a limited number of studies have been reported examining the effects of different types of acute stretching on EMG activities. These studies reported that stretching-induced decreases in muscle activation by surface EMG (14, 4, 9, 50, 34). Fowles et al. (14) reported that 60% of the stretching-induced decreases in force production of the triceps surae (up to 15 min post-stretching) were due to neural factors. Moreover, Behm et al. (4) suggested that at least part of the stretching-induced decreases in maximal force production of the leg extensors was due to decreases in muscle activation. Avela et al. (1) reported decreases in motor unit recruitment (EMG amplitude) and firing frequency (zero crossing rate) after repeated passive stretches of the plantar flexors. Nelson et al. (32) found an inhibitory effect of acute muscle stretching on voluntary knee extensor torque. Other research reported after a series of thirteen 135 s passive stretches of the plantar-flexor muscles in 12 young volunteers a significant 28% decrease in isometric voluntary torque immediately after stretching (14). It has showed the negative effect of stretching on the maximal voluntary contraction by Fowles et al. (14) and explosive performance by Laur et al. (26). Behm et al. (4), reported a 12,2% reduction in the isometric knee extension maximal voluntary contraction (MVC) 6–10 min after an acute 20 min stretching regime. Post-stretch quadriceps iEMG activity decreased 20,2% while hamstrings iEMG decreased 16,8% from pre-stretch measures. Marek et al. (29) reported that significant decreases in peak torque, mean power output and EMG signal amplitude (decreased neural activation). Power et al. (34) reported that SS resulted in significant 9,5% and 5,4% decrements in quadriceps MVC. Kay and Blazevich (22) found that electromyographic activity recorded during maximal plantarflexion did not change significantly after stretching, similar to results of the present study. Cornwell et al. (9) reported that there was no significant change in the static jump height, but there was a significant decrease in EMG during the jump after stretching. Nelson et al. (32) hypothesized that a decline in musculotendinous stiffness of the stretched muscles is the cause of the force reduction. Fowles et al. (14) observed a 25% loss in maximum voluntary force after 30 minutes of passive stretching of the plantar flexors. Power et al. (34) found after acute SS that there was a 9,5% decrement in the torque or force of the quadriceps for MVC. Kubo et al. (25) revealed that there were no significant differences in the activation levels (iEMG) of each triceps surae muscles before and after stretching training. Furthermore, Wiemann and Hahn (49) found that static and ballistic stretching and stationary cycling decreased EMG activity significantly. On the contrary, Wallmann et al. (48) investigated the effects of SS of the gastrocnemius muscle on maximal vertical jump performance using electromyographic activity (EMG) of the gastrocnemius musculature to record muscle activation during vertical jump performance. Vertical jump height was 5,6% lower when poststretch heights were compared with prestretch heights. Gastrocnemius EMG was 17,9% greater when the EMG during poststretch jumps was compared with prestretch jumps. A possible justification for the differences reported for both studies may be due to the different types of data collection procedures. The data collection in the present study performed ROM hip measurement before EMG recording.

Static and PNF stretching probably impaired performance through mechanical and neurological mechanisms such as reduced musculotendinous unit (MTU) stiffness (14, 47), altered reflex sensitivity and decreased muscle activation (4,6). Stretching-induced force deficits involve mechanical factors and neural factors. Most authors agree that both factors interact and contribute to create a muscular force deficit following stretching. The mechanical factor most responsible for decreases in force and power production is the temporary loss of muscular stiffness following stretching (41, 29). This loss increases the length of sarcomeres within individual muscle fibers and decreases the contact between actin and myosin, thereby altering the length-tension relationship and decreasing force (32). In addition, the muscle fibers must shorten over a longer distance to reach maximal contraction. This can pose a problem for explosive power performance because the muscle can't contract rapidly or generate maximal force. Neurological mechanisms that change reflex sensitivity and motor unit activation have been proposed or found to decrease after stretching (14, 9). For example, SS produces a myotatic reflex, while contract-relax PNF stretching causes autogenic and reciprocal inhibition, which in turn decreases neural activity in the stretched muscle (6).

Our results indicated non-significant decreases in muscle activation (EMG amplitude) as a result of the stretching protocols, which was inconsistent with previous studies (14, 34). The amount of stretching that must be performed to see immediate changes in muscle length as related to musculotendinous stiffness is unknown. It is possible that the duration of stretching performed in this study may have been too short for the elastic properties of the musculotendinous unit to be altered. Halbertsma et al. (18) showed that after a 10-minute bout of stretching, the range of motion (ROM) was increased but muscle stiffness was unchanged. Magnusson et al. (27) also showed that 3 sets of 45 seconds of stretching had no acute effect on the viscoelastic properties of the hamstring muscle. Therefore, the quantity of stretching used in the present study (4 sets of 30 seconds) may not have been enough to alter the viscoelastic properties of the muscles. However, we acknowlegde that the findings of this study was based on two participants.

The study indicated that neither the acute CRPNF nor SS caused any significantly change on ROM of hip joint, CMJ, RMS values of VL, VM and GAS muscles. Bradley et al. (6) reported the vertical jump performance to be diminished for 15 minutes if performed after static or PNF stretching.

Limitations and Future Research

This study was to compare the effects of acute CRPNF and static stretching protocols on ROM of hip joint, CMJ and EMG activities of VL, VM and GAS. Further studies are needed to able to compare different types of stretching techniques, such as PNF and ballistic stretching or static and ballistic stretching. Future studies should also use different durations or repetitions of stretch. Another limitation to this study was that EMG was recorded from the medial gastrocnemius and not the lateral gastrocnemius or soleus. However, Avela et al. (1) reported similar reductions in activation from the gastrocnemius and soleus following stretch, which indicates a consistent change in EMG of the plantarflexors. Thus, it could be suggested that the medial gastrocnemius was largely indicative of the whole triceps surae muscle complex. This study can not confirm a lack of change of activation in other muscles after the stretch routines. The last limitation of this study was that lack of participants, therefore we suggest that future studies are needed to conduct the same study with more participants.

CONCLUSION

Consequently, PNF or SS immediately prior to an explosive athletic movement is not recommended. However, if static or PNF stretching is necessary before an event, coaches and athletes should ensure that stretching occurs at least 15 minutes before performance. This study does recommend the static stretching technique before training or competition. This technique provides several advantages over PNF. First of all, the passive stretching technique is easier to perform and does not need any advanced skills on the side of clinicians. Furthermore, PNF requires the individual to actively participate in the exercise by applying an opposite.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. Neal Smith for constructive comments on the paper and Russell Peters for technical assistance during data collection. No sources of funding were used to assist in the preparation of this study. Equipment was provided by the Department of Sport and Exercise Sciences at the University of Chichester (UK).

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