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Effect of 8-Weeks PNF Stretching on Muscle Strength and Neuromuscular Activity of the Hamstring Muscles

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Abstract

Background: Hamstring injuries are common in sports that involve rapid, forceful lengthening of the hamstring muscles, such as sprinting, jumping, and kicking. This type of injury is more likely to occur in team sports such as football and handball.
Objectives: The purpose of this study was to investigate chronic effects of proprioceptive neuromuscular facilitation (PNF) stretching on muscle strength and neuromuscular activity of the hamstring muscle.
Methods: Six male team sports players (age: 24.38 ± 1.94 years; height: 180.73 ± 6.05 cm; body-mass: 80.23 ± 10.42 kg) were recruited for this study. Participants completed a 2-month rehabilitation program that included three sessions per week of contract-relax (CR) PNF stretching. Neuromuscular activity and strength were evaluated by electromyography (EMG) and force sensor before and after 8 weeks of CR-PNF stretching.
Results: The neuromuscular activity of the medial and lateral hamstring muscles was significantly different between pre-and post-training for the apex and area of muscle ($P < 0.01$). Similarly, there was a large difference between pre- and post-training for hamstring muscle strength (medial and lateral) in the contract and relax positions ($P < 0.001$).
Conclusions: Eight weeks of contract-relax proprioceptive neuromuscular facilitation (PNF) stretching is effective in increasing neuromuscular activity and muscle strength in the hamstring muscles.

Keywords: Muscle Stretching Exercises, Muscle Strength, Hamstring Muscles, Team Sports, Psychomotor Performance

1. Background

Sports injuries can have a significant impact on athletes' progress, performance, and ability to achieve their full potential (1). They can also have a major impact on individual and team sports. Researchers and experts in the fields of health and sports science are constantly working to address and reduce the incidence of sports injuries (2, 3). Team sports players are at risk of a range of injuries, with lower extremity injuries being among the most common. (4). In individual sports, athletes often perform repetitive motions that can strain the hamstring muscles over time. While, in team sports (e.g., football, basketball, handball), hamstring muscles' injuries can result from a combination of factors, including sudden changes in direction and collisions with other players, overstretching while kicking or reaching for the ball, and fatigue due to extended play time (4). The hamstring is one of the most commonly injured muscle sites in soccer (5) and various other sports (e.g., American football (6) and track and field (7)). A soccer player suffers, on average, from 0.6 muscle injuries per season, and 92% of the injuries are located in the lower limbs. Specifically, 37% of the injuries affect the hamstring muscles. The average time a player is absent due to a muscle injury is 14.3 days, but the actual absence can vary between 0.4 days and 29.2 days (14.3 - 14.9 to 14.3 + 14.9) (5). Moreover, soccer players are more likely to experience hamstring injuries compared to quadriceps injuries, and the risk of hamstring injuries is 2.5 times higher (8). The average rate of hamstring strain injuries per season for a professional soccer team is 10 injuries per season (9). A player's injury results in approximately 90 days of time loss. Additionally, each club typically misses around 15 to 21 matches per season due to injuries (10, 11).

The biarticular nature of the hamstring muscles has been proposed as a potential contributing factor to the predisposition for muscle strain injuries, particularly in sports and physical activities (12). This refers to muscles that span and cross two joints. The hamstring muscles, which consist of the biceps femoris, semitendinosus, and semimembranosus, are an example of biarticular muscles because they cross both the hip and the knee joints. These muscles play a crucial role in various activities, including running, jumping, and kicking (12). Indeed, the causes of injury to the lower extremities, including the hamstring muscles, are numerous and can be attributed to various factors. Some of the key causes includes muscle fatigue, lack of good warm-up and poor flexibility (13).

Proprioceptive neuromuscular facilitation (PNF) is a stretching technique commonly used in physical therapy and rehabilitation settings. It is designed to enhance muscle elasticity and improve both active and passive range of motion (14, 15). Proprioceptive neuromuscular facilitation is a specialized approach to therapeutic exercise and rehabilitation that aims to stimulate proprioceptors and promote responses in neuromuscular mechanisms (16). These techniques emphasize multi-planar movements, which means they involve movement patterns that occur in different directions and planes of motion. The primary goal of PNF techniques is to facilitate or strengthen certain muscle groups while inhibiting or relaxing others (16). Moreover, PNF produces greater increases in range of motion than passive static stretching. In practice, static stretching involves a slow, controlled lengthening of a relaxed muscle until the individual feels a stretch in the muscle (17). Proprioceptive neuromuscular facilitation involve combinations of alternating contractions and stretching of muscle using techniques such as the hold-relax (HR), contract-relax (CR), and slow reversal-hold-relax (SRHR) (17).

2. Objectives

The current study investigated the effectiveness of CR-PNF exercises in improving the strength and neuromuscular activity of injured hamstring muscles in team sports players after a rehabilitation period.

3. Methods

3.1. Participants

Six male team sports players (age: 24.38 ± 1.94 years; height: 180.73 ± 6.05 cm; body mass: 80.23 ± 10.42 kg) with a history of hamstring injuries participated in this study. All participants involved in team sports (i.e., football, handball and basketball) and they had completed a 2-month rehabilitation period. They were thoroughly examined by a board-qualified sports and exercise medicine physician and healthy and competitive players were excluded. The study was conducted in accordance with the Declaration of Helsinki and all participants signed an approved informed consent form.

3.2. Experimental Protocol

The training program was conducted for two months during the competitive season, with three sessions per week. It was the main part of each player's training and complementary to their individual training programs. For example, if a player had a training session at 3pm, they would train at 9am instead. The strength training component of their club's training was reduced to avoid muscle fatigue. This was done in consultation with all of the players' coaches. the exercises used in this study were high-intensity and repetitive interval exercises. The contraction-relaxation method was used for the 5-minute PNF stretching. The researcher, with the help of an assistant, would fix the limb involved in the player's performance at its maximum range of motion. When the player felt that they could achieve a new range of motion, the researcher or assistant would move the limb further. This was repeated until the 5-minute period was over. The player would then rest for an appropriate amount of time before repeating the exercise. Before and after the CR-PNF protocol, neuromuscular activity and strength of the hamstring muscles were evaluated.

3.3. Measurements

Electromyography: While performing neuromuscular activity of posterior thigh muscle, portable electromyography (EMG) device (MyoTrace 400, Noraxon, U.S.A. Inc.) was applied. This device is capable of operating in two different modes: Stand-alone mode with two channels and PC-mode with four channels. For EMG it has 20 - 500 Hz bandwidth, sampling in real time is at 1000 sample/sec/channel (myotrace 400). The skin was shaved, slightly abraded with sandpaper and cleaned with alcohol and Ag/AgCl bipolar electrodes (Blue Sensor N-00-S, Ambu Medicotest A/S, Ølstykke, Denmark) were placed according to the SENIAM guidelines (18) at an interelectrode distance of 20 mm.

Force sensor: Hamstring muscles strength was measured using a force sensor (EK3-200, U.S.A). The test was represented by performing two phases: The first is the relaxation phase and the second is the contraction phase. The player performed two repetitions and the highest value was recorded for analysis.

3.4. Statistical Analysis

To compare the effects of 8 weeks of CR-PNF stretching on neuromuscular activity and muscle strength, a paired Student *t*-test was used to verify the normality of the distribution. Values are presented as mean ± SD in the table and figures. All statistical analyses were performed using the software package STATISTICA (StatSoft®, Maisons-Alfort, France) with significance set at $P < 0.05$. Delta-change (Δ) was calculated as post-test - pre-test values.

4. Results

4.1. Strength

The pre- and post-test values of the strength of the hamstring muscles are presented in Figures 1 and 2.

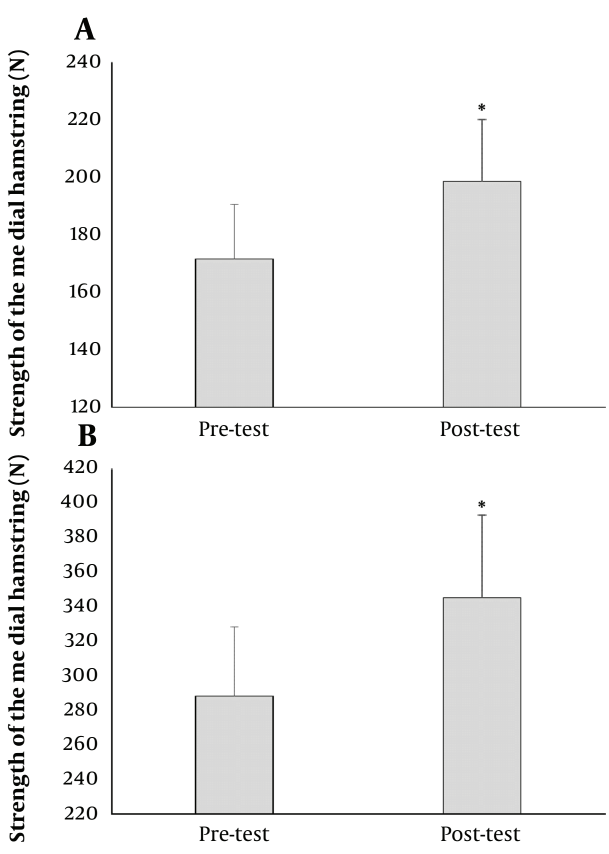

Figure 1. Strength of the medial hamstring muscle (relax (A); and contract (B)) recorded at pre- and post-test. *: Significant difference compared to pre-test.

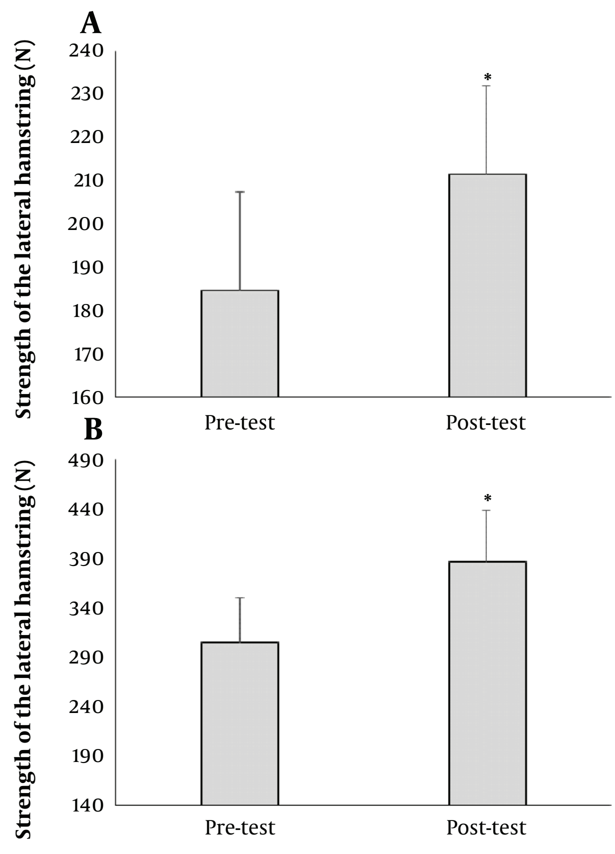

Figure 2. Strength of the lateral hamstring muscle (relax (A); and contract (B)) recorded at pre- and post-test. *: Significant difference compared to pre-test.

The results showed that the strength of the medial hamstring was significantly greater at post-test than at pre-test in both the relax (t = 4.038, $P < 0.01$, mean difference = 27.0 N) and contract (t = 6.487, $P < 0.001$, mean difference = 57.0 N) positions (Figure 1). Similarly, the strength of the lateral hamstring was significantly greater at post-test than at pre-test in both the relax (t = 5.736, $P < 0.001$, mean difference = 27.1 N) and contract (t = 6.004, $P < 0.001$, mean difference = 81.8 N) positions (Figure 2).

4.2. Neuromuscular Activity

Results of the neuromuscular activity of the hamstring muscles (medial and lateral) are presented in Table 1. The statistical analysis reported that the neuromuscular activity of the medial hamstring muscle was better at post-test compared to pre-test for the apex (t = 4.442, $P < 0.05$, Δ = 48.4 μV/s) and the area (t = 5.124, $P < 0.01$, Δ = 37.9 μV/s). Likewise, the neuromuscular activity of the lateral hamstring muscle increased from pre-test to post-test for the apex (t = 5.597, $P < 0.01$, Δ = 73.7 μV/s) and the area (t = 6.957, $P < 0.001$, Δ = 32.9 μV/s).

5. Discussion

Given the high incidence of hamstring muscle strain injuries in team sports, the purpose of this study was to investigate the potential of PNF stretching to improve muscle strength and neuromuscular activity of the hamstring muscles in these athletes. The results of this study demonstrated the efficacy of performing a CR-PNF stretching on the injured hamstring muscles in team sports players. It was found that there are significant differences between the pre and post measurements in the neuromuscular activity and strength of the hamstring muscles.

Stretching after exercise is one of the recommendations of the American College of Sports Medicine (ACSM) (19). In contrast to our results, the study of Ferber et al. (20) indicates that the ACR-PNF stretch technique demonstrated significantly higher muscle EMG activity (92 - 115% greater) in the knee flexor muscles (hamstring and gastrocnemius) compared to the CR stretch. Moreover, Marek et al. (21) have concluded that both static and PNF stretching caused similar deficits in strength, power output, and muscle activation. However, these two studies have focused on an acute effect of PNF (compared to 8 weeks in the present study). Also, the participants in the study of Ferber et al. (20) were older adults and in the study of Marek et al. (21) were healthy and recreationally active male and female volunteers. In the present study, only male players involved in team sports were included.

Results of this investigation are consistent with several studies (14, 22-25) and a review of the literature (26), indicating that PNF produces increases in strength and neuromuscular activity. Similar to our results, in the context of team sports players recovering from the hamstring muscles injuries, it has been reported that PNF exercises can be effective in improving strength and neuromuscular activity (14). Proprioceptive neuromuscular facilitation exercises can help to retrain the neuromuscular system to activate and coordinate the appropriate muscle fibers during movement, which can lead to improved strength (14). Similarly, Nelson et al. (24) showed improvements in muscular strength and athletic performance after 8 weeks of PNF training. Furthermore, Caplan et al. (22) investigated the effects of a five-week PNF stretching protocol on stride rate and stride length and they reported an increase in both parameters. Additionally, Nelson et al. (25) found that PNF is more effective than traditional strength in terms of strength gains and athletic performance over a short period of 8 weeks. Recently, Zaidi et al. (23) have demonstrated a significant effect of CR-PNF stretch techniques on increased EMG activity during maximal voluntary isometric contraction after four-weeks of intervention in adult men. In a systematic review study, Hindle et al. (26) found that PNF exercises were more effective than other types of exercise or no intervention in improving hamstring strength in individuals with hamstring strains. Also, Miyahara et al. (27) found that PNF exercises led to significant improvements in hamstring muscle activation and strength in young male university students. Moreover, in a systematic review, Borges et al. (28) concluded that PNF stretching can be effective in improving the hamstring strength and activation in athletes. Thus, these studies suggest that PNF exercises can be an effective way to improve muscle strength, function and neuromuscular activity in injured team sports players.

The limitations of this study include the small sample size, which could qualify it as a pilot study and limit the generalizability of the findings. Additionally, the study was conducted on team sports players only, so the results may not apply to other populations. Finally, range of motion (ROM) was not measured in this study, which is a limitation that should be addressed in future research.

The main strength of this study is its investigation of the long-term (8 weeks) effects of a CR-PNF rehabilitation program on hamstring muscle strength and neuromuscular activity in team sports players. Most previous studies on PNF stretching have only examined its short-term (acute) effects, and the populations studied have typically been students, women, and/or elderly individuals.

In the future, longer-term studies with longer follow-up periods are recommended to better understand the long-term effects of CR-PNF stretching on hamstring muscle strength and neuromuscular activity in team sports players. Additionally, it is important to note that CR-PNF stretching should be performed under the guidance of a qualified healthcare or rehabilitation professional, especially for individuals with hamstring injuries. Proper technique and progression are essential to avoid further injury or harm.

5.1. Conclusions

An 8-week CR-PNF rehabilitation program is effective in increasing hamstring muscle strength and neuromuscular activity in team sports players. These findings may have practical implications for the frequency of PNF stretching needed to increase strength gains in team sports players.

Table 1. The Neuromuscular Activity of the Medial and Lateral Hamstring Muscles Recorded at Pre- and Post-test

Variables	Pre-test	Post-test
Neuromuscular activity of medial hamstring muscles (μV/s) [a]		
Apex	293.28 ± 89.28	341.68 ± 98.19
Area	274.23 ± 94.26	312.22 ± 100.18
Neuromuscular activity of lateral hamstring muscles (μV/s) [a]		
Apex	327.29 ± 99.28	401.01 ± 96.29
Area	311.39 ± 92.49	344.34 ± 104.48

[a] μV/s: Microvolt/second.

Footnotes

Authors' Contribution: B. K. A. L. and J. H.: Data collection and analysis; B. K. A. L. and J. H.: Writing the first version of the manuscript; B. K. A. L., M. M. S. K. and H. C.: Drafting and revising the manuscript. All authors have participated in preparation of the final version of the manuscript, whose contents they approve.

Conflict of Interests: No conflict of interest exists.

Data Reproducibility: The data presented in this study are openly available in one of the repositories or will be available on request from the corresponding author by this journal representative at any time during submission or after publication. Otherwise, all consequences of possible withdrawal or future retraction will be with the corresponding author.

Ethical Approval: The study was carried out in accordance with the guidelines contained in the declaration of Helsinki.

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Informed Consent: The organization and each player gave their written informed consent to participate in the research.

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