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Comparison of effects of two different rehabilitation protocols for acute hamstring strain management in highly-trained athletes

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Abstract

Introduction. **Hamstring strain injuries (HSIs) are prevalent among athletes and are detrimental to sports performance.** Aim of Study. **This study aims to compare two different rehabilitation protocols for managing pain, functional abilities, and muscular strength after HSIs.** Material and Methods. **Forty-five participants with acute hamstring strain were randomly allocated to three rehabilitation protocols. The first group performed baseline treatment (BT), consisting of 30 minutes of interferential therapy and manual therapy (i.e., an ice pack, myofascial release, and hamstring isometric exercises), and was considered a control group. The second group performed BT and a progressive agility and trunk stabilization (PATS) protocol. The third group performed BT and Russian current stimulation and a criteria-based rehabilitation program (CBRP). All participants were treated five consecutive days a week for three weeks. Pre- and post-treatment data was collected for pain (Numerical Pain Rating Scale [NPRS]), functional assessment (Functional Assessment Scale for Acute Hamstring Injuries [FASH]), and maximal isometric strength of hamstring muscles.** Results. **All three groups showed significant within-group improvements in all dependent variables (all $p \leq 0.001$). When the three groups were compared, a significant difference was observed, favoring superior improvements in both experimental groups compared to the control group. In addition, when the experimental groups were compared, a significantly greater improvement in all dependent variables was observed in the CBRP compared to PATS.** Conclusions. **In conclusion, the findings of the study suggest that there is a significant difference between the rehabilitation protocols in managing hamstring injuries, with a greater improvement observed after the criteria-based rehabilitation program.**

KEYWORDS: soft tissue injuries, leg injuries, athletic injuries, hamstring muscles, analogue pain scales, plyometric exercise.

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Introduction

The hamstring muscle group in the lower extremity is located within the fascial compartment of the posterior segment of the thigh and comprises three muscles (i.e., biceps femoris, semimembranosus, and semitendinosus) [19, 26]. These muscles originate from the pelvis and extend along the length of the femur, crossing both the femoroacetabular and the tibiofemoral joints [19, 26]. The hamstring muscles are involved in a variety of actions, from standing to jumping and sprinting, among other explosive movements [1, 19]. The hamstring group's muscles are innervated by the sciatic nerve (L3-S4) that splits into the tibial nerve and the common peroneal nerve at the knee. The tibial nerve innervates the semimembranosus muscle, the semitendinosus muscle, and the long head of the biceps femoris, whereas the short head of the biceps femoris is innervated by the common peroneal branch of the sciatic nerve [1]. The biceps femoris, the largest hamstring muscle, is particularly prone to injury due to the distinct neurological innervation of its short head [1]. The hamstring muscles are characterized by long tendons with prominent musculotendinous junctions, which enhance athletic performance by providing a "spring"-like effect. These actions complement the anterior cruciate ligament (ACL) by resisting anterior tibial translation [1, 19].

The structural and functional properties of the hamstring muscles make them susceptible to strain injuries under various athletic conditions. Two primary mechanisms have been identified for hamstring strain injuries (HSIs) based on the type of contraction involved [15]. The first mechanism involved quick eccentric contraction, typically occurring during high-speed activities, such as sprinting [15]. The second mechanism, associated with slower, forceful stretching movements like dancing or wrestling, often results in injuries to semimembranosus muscle attachments and requires longer recovery periods [15]. Hamstring tissues are predominately composed of type II fibers, which may contribute to increased incidence of HSIs [6]. Garrett et al. [6] demonstrated that while the hamstring muscles are extensively utilized in high-performance sports, they are more vulnerable to strain injuries compared to other muscle groups such as the vastus lateralis that also has a high proportion of type II fibers but is less frequently injured. Anatomical differences within the biceps femoris may also predispose it to injury. Specifically, the long head has shorter fascicle length and a greater physiological cross-sectional area compared to the short head that has longer fascicles. This architectural distinction is likely to increase the susceptibility of the long head to strain injuries [25].

The reoccurrence of HSIs presents a significant clinical concern, as they often require longer healing time compared to first-time HSIs. Recurrence rates for HSIs range from 12–33% of athletes annually, with over 50% of these occurring within the first month after returning to sports (RTS). For the hamstring muscles, 34% of these recurrences are attributed to inadequate or inappropriate implementation of rehabilitation protocols [25]. Since the 1980s, the prevalence of lower limb injuries in soccer has shifted from ankle sprains to HSIs, a pattern persisting over the past three decades. In the past 10 years, HSIs (n = 85) among National Football League teams were the second most common injury, following knee sprains (n = 120) [20]. The average recovery duration of HSIs ranges from 8 to 25 days, depending on severity and location, as well as other factors [11]. A study on 858 Australian soccer players found the highest injury recurrence in the first two weeks post-RTS, with rates of 12.6% and 8.1%, respectively. Similarly, it was found that for sprinters, a reinjury risk during a 22-week season was 30.6%, with 15 out of 30 HSIs linked to previous injuries [21].

The neuromuscular regulation of the lumbopelvic region, including anterior and posterior pelvic tilt, has optimized hamstring performance in sprinting and high-speed skillful movements. Variations in pelvic positioning can affect the hamstring's length-tension or force-velocity relationships. This has prompted some therapists to incorporate trunk stabilization and progressive agility exercises in hamstring rehabilitation protocols. Exercises like trunk stabilization and neuromuscular control have been proven to be beneficial in encouraging sports participation in athletes with chronic hip adductor pain [21]. Progressive rehabilitation activities improve neural alterations, resulting in enhanced muscular activation and coordination. This leads to an increase in maximal isometric strength over time [23]. A progressive criteria-based rehabilitation program (CBRP) consists of valid and reliable evaluation metrics for managing athletes with acute HSIs. This approach aids clinical decision-making during the RTS phase. The choice to return to sports is arguably the most challenging stage as it affects the athletes' risk of reinjury, although limited evidence supports specific RTS timelines [24].

The management of HSIs involves routine therapies such as ultrasound, electrical stimulation, thermotherapy, and cryotherapy [1, 16]. In the acute phase of injury, the RICE protocol (rest, ice, compression, and elevation) remains the standard course of action for reducing pain and swelling [3]. Subsequently, low-intensity, pain-free movements are performed for the lower extremity and core region to prevent muscle atrophy, maintain neuromuscular control, and reduce muscle inhibition [1]. A gentle soft tissue massage is used to decrease muscle spasms and maintain appropriate hamstring length [25]. Eccentric training is used to increase tensile strength [1, 3]. Resistance exercises and range of motion exercises are also included in rehabilitation protocols such as a stretching and strengthening (STST) protocol, progressive agility and trunk stabilization protocol (PATS), and CBRP [21, 24]. Some professionals may prefer to use emerging alternative modalities in addition to traditional physical therapy methods, such as instrument-assisted soft tissue mobilization and dry needling [1], medical treatment for HSIs including corticosteroid injections and platelet-rich plasma [3]; a surgical intervention is usually considered a last resort for tendon avulsion injuries.

After reviewing several research studies [21, 24], it was found that CBRP and PATS are beneficial to the treatment of HSIs. The PATS protocol is a dynamic rehabilitation approach aimed at restoring function in athletes with HSIs. It comprises progressive agility exercises, trunk stabilization, and recovery management techniques (icing) with the aim of core strengthening and overall stability improvement in a sequential order [21]. Russian current stimulation (RCS), also known as neuromuscular stimulation, is a type of electrotherapy that is used in rehabilitation. It applies medium-frequency electrical currents to stimulate motor nerves, boost muscle activation, and increase neuromuscular reeducation [27]. CBRP is a systematic rehabilitation process with ordered steps (criteria phases) that aid in clinical decision-making for a successful RTS and reducing recurrence rates. Both PATS and CRBP are widely used, improving recovery time and reducing recurrence rates; however, the present study was conducted to identify the most effective protocol. According to the study, RTS decisions are complex, and in professional sports it may be preferable for a player with hamstring strain to return to sports in 3 weeks [24]. It was hypothesized that CBRP will be a more effective protocol compared to PATS.

Aim of Study

This study aims to compare the effectiveness of the PATS protocol versus RCS combined with CBRP on pain, functional performance, and maximal isometric strength of hamstring muscles after HSIs.

Materials and Methods

Subjects

Forty-five national-level male and female athletes (age range: 16–30 years; mean ± standard deviation: 22.6 ± 4.1 years) from different sports (e.g., athletics, soccer, cricket, kabaddi, handball) were recruited for the study (Table 1). The subjects were highly-trained athletes with a minimum training age of 6 years, accustomed to high levels of exertion (minimum 20 hours/week). The inclusion criteria for the participants were: (I) localized pain on palpation of hamstring muscle; (II) reduced flexibility; (III) reports of pain on strength tests and history of acute discomfort in a hamstring muscle while training. Athletes with recent or previous extrinsic trauma to the hamstring group of muscles, whether sharp or blunt, radicular pain in a hamstring muscle, continuing or chronic lower-back issues, or radiological ultrasonographic evidence of deep vein thrombosis, Type I diabetes, or neoplasm were excluded from the study [21, 24]. The participants were randomly allocated to the experimental and control groups. The sample group was identified and obtained from an outpatient department and other affiliated sports complexes in Jalandhar, Punjab, India. The study was explained to the subjects, who were then asked to sign voluntary informed consent forms before participation. The research study was approved by the Institutional Ethics Committee of the Sports Physiotherapy Department, DAV Institute of Physiotherapy and Rehabilitation, Jalandhar.

Table 1. Distribution based on sports and gender of the total sample

Sports	Group A	Group B	Group C
Athletics	1 (M)	1 (M)	2 (M)
Soccer	11 (M)	12 (M)	10 (M)
Cricket	2 (M)	2 (M)	2 (M)
Kabaddi	1 (F)	0	0
Handball	0	0	1 (F)

Note: M – male, F – female, Group A – control group (interferential therapy, manual therapy); Group B – experimental group I (interferential therapy + manual therapy + progressive agility and trunk stabilization); Group C – experimental group II (interferential therapy + manual therapy + Russian current stimulation + criteria-based rehabilitation protocol)

Study design

The study employed a true experimental pre-post control group design. Three groups of 15 subjects were randomly assigned to the control group (Group A), experimental group I (Group B), and experimental group II (Group C).

Outcome measures

Data on pain, functional assessment, and isometric hamstring strength was collected at baseline and post-intervention after three weeks of using the Numerical Pain Rating Scale (NPRS), Functional Assessment Scale for Acute Hamstring Injuries (FASH), and strain gauge, respectively. The NPRS tool is an effective way to document pain severity. A subject or patient has to indicate pain they experience from 0 (no pain) to 10 (most severe pain). The FASH tool is a validated 10-item questionnaire assessing functional limitations associated with HSIs, with a lower total indicating greater disability [13]. A portable strain gauge (Model no. WH-A08) was used to measure isometric hamstring strength. The participants were instructed to lie in a prone position on an elevated treatment couch. The measurement process involved the use of two straps. One strap was attached to the ground, while the other was tied to a lower limb (near an ankle). The strain gauge was placed between the two straps. The participants were then instructed to perform knees flection.

Procedure
The intervention treatment lasted for three weeks [24], with the protocol being conducted five consecutive days per week, with sessions lasting 30 to 70 minutes depending on the group and phase of the intervention. For example, the intervention for the control group lasted approximately 30 minutes, whereas the intervention for the experimental group lasted longer. A baseline assessment was conducted before the implementation of the protocol, with a follow-up assessment after the completion of the three-week intervention. Figure 1 represents the flow diagram of the study.

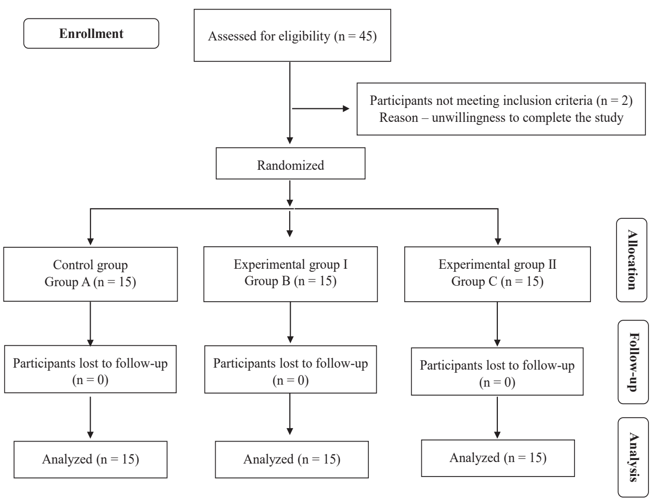

Figure 1. Schematic representation of the study timelines

Treatment protocol
Interferential therapy and manual intervention
The interferential therapy and manual intervention were administered to the participants across all three groups as mandatory baseline treatment (BT) and served as the control and common intervention. The protocol was administered for 10 minutes at a frequency range of 90–130 Hz in vector mode with four channels to prepare a body for activity and relieve discomfort. Following this, a 20-minute session was conducted including myofascial release (MFR), isometric exercises, and the application of cold packs to the hamstring muscles [1, 3, 16].

Progressive agility and trunk stabilization
The experimental group I was administered PATS in addition to BT. The detailed intervention followed during the study is available in the appendix [21].

Russian current stimulation and criteria-based rehabilitation program
The experimental group II was administered RCS and CBRP in addition to BT. During this protocol, the participants were instructed to remain in a prone lying position, and then RCS was applied to the posterior part of affected leg for 10 minutes (10/50/10 regimen: 10 seconds "on", after that 50 seconds "off", and then another 10 seconds "on") [16].
After that CBRP for HSIs was administered as per the details mentioned in the study by Tol et al. [24].

Statistical analyses
The data is presented as mean and standard deviation. The normality of the data was assessed using the Shapiro–Wilk test. For the non-normally distributed data, non-parametric tests were conducted. Inferential statistics, analysis of covariance (ANCOVA), and Quade ANCOVA tests were used for the analysis. The Bonferroni correction and Tukey's method were employed for pairwise comparisons to find the mean difference among the groups in case of a significant main effect result. Effects sizes (ES) were calculated for pre- to post-intervention, using a customized Excel sheet, and interpreted as trivial (< 0.2), small (0.2–0.6), moderate (> 0.6–1.2), large (> 1.2–2.0), very large (> 2.0–4.0), or extremely large (> 4.0) [12]. In addition, ES for ANCOVA were calculated using partial eta squared (η_p^2) and were interpreted as small (< 0.06), moderate (≥ 0.06–0.13), and large (≥ 0.14). The statistical significance was set at a p-value of 0.05. All statistical analyses were conducted using the SPSS software (Version 26).

Results
No negative situations were developed during the study. All of the participants followed a regular schedule. They attended all sessions. The study's adherence rate was approximately 90%. All three groups showed a significant improvement in pain, FASH, and hamstring

Table 2. Statistical outcomes

Variables	Experimental group I (n = 15)			Experimental group II (n = 15)			Control group (n = 15)			ANCOVA p-value (η_p^2)
	Pre	Post	ES	Pre	Post	ES	Pre	Post	ES	
Pain	5.9 ± 0.8	2.9 ± 0.7*	3.90	6.1 ± 1.5	1.3 ± 1.1*#	3.59	5.6 ± 1.0	3.5 ± 1.0	2.11	<0.001 (0.79)
FASH	54.1 ± 10.1	77.1 ± 7.9*	2.46	51.7 ± 10.4	87.7 ± 4.1*#	4.42	56.4 ± 11.2	70.26 ± 8.9	1.34	<0.001 (0.70)
Hamstring strength	12.3 ± 1.2	17.6 ± 1.3*	4.17	13.5 ± 2.3	23.05 ± 3.0*#	3.53	13.8 ± 1.6	16.2 ± 1.3	1.58	<0.001 (0.73)

Note: ES – effect size, FASH – Functional Assessment Scale for Acute Hamstring Injuries
* significant difference compared with the control group; # significant difference compared with the experimental group I
All groups showed significant differences (improvement) from pre- to post-intervention assessments in all outcome variables.

strength from pre- to post-intervention assessments (all $p \leq 0.001$). However, the magnitude of improvement was very large to extremely large for the experimental groups and large to very large for the control group. Furthermore, when the three groups were compared, a significant difference was reported for all dependent variables. The post hoc analyses showed a significant difference between the experimental and control groups, favoring a superior improvement in both experimental groups compared to the control group. In addition, when the experimental groups were compared, a significantly greater improvement in all dependent variables was observed in the experimental group II compared to the experimental group I. The detailed statistical outcomes are presented in Table 2.

Discussion

The study aimed to compare the efficacy of two different rehabilitation protocols on acute HSIs among athletes against the standardized rehabilitation protocol used as the control condition. The results showed that all three groups (i.e., both the experimental groups and the control group) significantly improved in all selected dependent variables. However, the experimental groups demonstrated greater improvements compared to the control group. When both experimental groups were compared, experimental group II (i.e., RCS and CBRP) showed significantly greater improvement than experimental group I (i.e., PATS) in all dependent variables.

The significant improvements in the control group across all dependent variables are likely attributable to the standardized protocol. One of the reasons may be the application of the interferential therapy (IFT) protocol, which stimulates deep body tissues, providing physiological benefits like muscle stimulation, blood flow enhancement, and bone healing [8]. Previous studies have reported that IFT protocols minimize pain, making it a valuable addition to sports medicine care [8]. Furthermore, MFR have considerable clinical and biological impacts on human fibroblasts. Traumatized fascia disrupts the biomechanics of the body, causing myofascial pain and a decreased range of motion. Modeled repetitive motion strain and MFR exhibit morphological alterations and increased cellular apoptosis [29]. This may have resulted in the improvement in the control group. Moreover, the standardized protocols used by the participants of the control group are well-researched [5, 7].

Furthermore, a significantly greater improvement was observed in both experimental groups compared to the control group. The additional improvement in both experimental groups may be due to the inclusion of resistance training exercises. Studies have shown that resistance training improves myokines, which positively impact metabolic, cardiovascular, mental, and immune functions [30]. Both PATS and CBRP involve systematic and progressive loading based on clinical judgment. The PATS protocol has two phases of rehabilitation before RTS, whereas CBRP includes six phases. By the end of the three-week study, all subjects in the experimental group I had progressed to phase 2 of the PATS protocol, whereas the subjects in the experimental group II had completed phases 4, 5, and 6 of CBRP.

This study found that the PATS protocol and manual intervention therapy groups significantly decreased hamstring strain, a sports injury-related variable, compared to the control group. Another study reflects a modified PATS rehabilitation program and a progressive running and eccentric strengthening program successfully restored muscle function after HSIs; however, athletes remained magnetic resonance imaging-positive despite clinical clearance [22].

The PATS protocol significantly reduced pain and improved functional performance due to its emphasis on neuromuscular regulation and controlled loading of the hamstring muscle end-range tension [21]. This protocol restricts end-range tension and prioritizes controlled movement in less stressful planes of motion, allowing for early and safe tissue loading during rehabilitation [21]. Similarly, a significantly greater improvement was observed after CBRP compared to the control group. This may be due to the protocol's focus on functional and skill-specific lower limb training, which may have facilitated better neuromuscular integration and enhanced coordination in the healing tissue. This protocol may also have promoted faster neuromuscular integration and coordination within the healing tissue. All of these factors may contribute to greater pain relief, improved FASH scores, and increased muscle strength.

The experimental group I performed the PATS protocol that required the subjects to perform lower-limb activities at a moderately lower intensity than CBRP, which is a combination of agility, plyometric, and resistance training, all of which are seemingly more intense and complex. It is well-known that high-intensity exercises generate higher levels of endorphins [4, 9, 10, 14, 17]. Therefore, CBRP might have elevated circulating endorphin levels more than in the other groups, perhaps leading to greater pain relief. Another factor that may be linked to this impact is workout duration (i.e., longer workout duration involved in CBRP compared to PATS). Goldfarb et al. [9] have reported that increasing the length of a graded workout over a critical intensity elevated circulating endorphin levels. The inclusion of plyometric exercises in CBRP involving the stretch-shortening cycle muscle action of the lower extremity may also be responsible for the aforementioned findings. Plyometric exercises have been shown to improve the reactive strength of the lower limbs and other physical fitness abilities [2, 18]. In addition, the experimental group II was also subjected to RCS. Aside from the therapeutic benefit of pain relief, it also promotes muscle build-up. These multifactorial reasons may be responsible for significantly greater pain relief, improved muscle strength, and improved functional scores in the subjects from the experimental group II compared to the group I [16, 28].

The study has several limitations. Firstly, the sample included only two female participants, limiting the generalizability of the findings to female athletes. Due to the biological differences, future research should be conducted exclusively on female participants. Secondly, radiological assessments were not performed after acute hamstring strain to quantify the extent of injury, as the inclusion was based solely on clinical history and physical examination. Radiological assessments would provide more precise injury categorization and allow for a detailed evaluation of recovery with each protocol. Lastly, the study did not include fitness testing prior to RTS or long-term follow-up to assess reinjury incidences with both protocols. Incorporating these elements in future research could enhance the understanding of protocols' efficacy and long-term outcomes.

Conclusions

In conclusion, all three groups (i.e., two experimental groups and one control group) showed significant improvements in pain reduction, improved FASH scores, and hamstring muscle strength after three weeks of the intervention. However, PATS (i.e., experimental group I) and CBRP (i.e., experimental group II) protocols showed significantly greater improvement in all outcome variables compared to the standardized protocol (i.e., control group). However, CBRP yields the most favorable results. These findings highlight the potential of advanced, phase-based rehabilitation approaches in optimizing recovery from acute HSIs in athletes.

Conflict of Interest

The authors declare no conflict of interest.

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