Lasers Med Sci (2016) 31:1133–1141
DOI 10.1007/s10103-016-1963-2

ORIGINAL ARTICLE

Short-term effects of high-intensity laser therapy, manual therapy, and Kinesio taping in patients with subacromial impingement syndrome

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Received: 1 March 2016 / Accepted: 13 May 2016 / Published online: 25 May 2016

Abstract Subacromial impingement syndrome (SAIS) is a major contributing factor of shoulder pain; and treatment approaches (Kinesio® taping [KT], Exercise [EX], manual therapy [MT], and high-intensity laser therapy [HILT]) have been developed to treat the pain. The key objective of this study was to compare the effects of KT, MT, and HILT on the pain, the range of motion (ROM), and the functioning in patients with SAIS. Seventy patients with SAIS were randomly divided into four groups based on the treatment(s) each group received [EX ($n=15$), KT + EX ($n=20$), MT + KT + EX ($n=16$), and MT + KT + HILT + EX ($n=19$)]. All the patients were assessed before and at the end of the treatment (15th day). The main outcome assessments included the evaluation of severity of pain by visual analogue scale (VAS) and shoulder flexion, abduction, and external rotation ROM measurements by a universal goniometry. Shoulder pain and disability index (SPADI) was used to measure pain and disability associated with shoulder pathology. Statistically significant differences were found in the treatment results of all parameters in MT + KT + EX and HILT + MT + KT + EX groups ($p<0.05$). When the means of ROM and SPADI results of three groups were compared, statistically significant differences were found between all the groups ($p<0.05$). These differences were significant especially between the groups MT + KT + EX and KT + EX ($p<0.05$) and HILT + MT + KT + EX and KT + EX ($p<0.05$). HILT and MT were found to be more effective in minimizing pain and disability and increasing ROM in patients with SAIS. Further studies with follow-up periods are required to determine the advantages of these treatments conclusively.

Keywords Manual therapy · Taping · Laser · Shoulder

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Introduction

One of the most common causes of shoulder pain is the occurrence of tendinopathy resulting from the impingement of rotator cuff tendons under the coracoacromial arch [1]. Several factors contribute to subacromial impingement syndrome (SAIS), including rotator cuff weakness, capsular tightness, poor scapulohumeral rhythm, and muscle imbalance of the scapular upward rotation force couple [2]. The treatments of SAIS include numerous interventions, depending on pain severity, therapy involving analgesic and nonsteroidal anti-inflammatory drugs [3], steroid injections [4], and physiotherapy [5] (ultrasound [US] therapy [6], laser therapy [7], manual therapy [MT] [8], and extracorporeal shock wave therapy [9]). Also, rehabilitative exercise approaches are necessary for the treatment of SAIS, including active and passive range of motion (ROM) exercises, muscular and capsular stretching exercises, and strengthening exercises [5, 10]. However, a limited number of studies suggest that exercise, manual therapy, and laser therapy are effective in decreasing pain and improving function in patients with SAIS [10, 11].

High-intensity laser therapy (HILT) is a treatment method that is gaining popularity in the recent years. HILT employs a neodymium-yttrium aluminum garnet laser. The treatment consisted of a high peak power (1–3 kW), a wavelength of 1064 nm, a maximum energy for a single impulse of 150 mJ at a frequency of 20–25 Hz, an average power of 6 W, a fluency

of 760 mJ/cm^2, and a duration for the single impulse of less than 150 ms. These ultra short impulses effect a deep action in the biological tissue (3–4 cm), with a homogeneous distribution of the light source in the irradiated soft tissue, but without excessive thermal enhancements. It reduces pain and edema with photomechanic effects in deep tissues. HILT also improves the microcirculation and tissue regeneration with these effects. Biostimulation, anti-inflammatory, and analgesic properties contribute to an effective improvement in painful bone-muscle-joint pathologies, including shoulder problems. The relief from pain and the increase in the range of motion enable the early initiation of rehabilitation programs. HILT has been recommended to be performed in eight to ten sessions each lasting for 10–15 min depending on the underlying problem. HILT application is a painless and safe form of the treatment that prevents heat accumulation [12]. Karaca treated 42 SAIS patients with HILT for 3 weeks (3 days per week) and stated that HILT was found to be effective in the short term in the treatment of pain and disability in patients with SAIS [13]. Also, Kim et al. determined that in management of frozen shoulder, HILT provided significant pain relief at 3 and 8 weeks and they stated that HILT is a noninvasive adjuvant treatment that can reduce pain in frozen shoulders [14].

As a major component of SAIS treatment program, studies, and systematic reviews clearly support the use of exercise to treat pain and disability in patients with SAIS resulting in improvements in either function [8, 15], pain [8, 15, 16], or range of motion [8] when thrust and nonthrust manipulation and manual stretching were appended to an exercise-based program. Senbursa et al. stated that SAIS patients treated with MT combined with supervised exercise showed improvement of symptoms including increasing strength, decreasing pain, and improving function earlier than observed for exercise-alone programs [8]. Tate et al. found that a treatment program aimed at strengthening rotator cuff and scapular muscles with stretching and manual therapy aimed at thoracic spine and the posterior and inferior soft-tissue structures of the glenohumeral joint appeared to be effective in the majority of patients with SAIS [17].

Lately, treatments with Kinesio® taping (KT) applications were also widely used for the treatment of SAIS. KT applications could reduce pain, normalize the effected muscle function, and cause repositioning of the scapula and glenohumeral joint during movement [18, 19]. KT method was originally generated by a Japanese chiropractor, Kenzo Kase, in the year 1980 [20]. Although KT has been widely used in rehabilitation protocols and prevention of sports injuries, scientific studies supporting the efficacy of KT are limited. Several researchers have reported that KT might be effective in decreasing pain [21, 22], increasing range of motion [21, 23], decreasing disability [22], and improving arm and hand functional skills [24]. Consequently, further research needs to be conducted to study the effects of KT on different physiological systems. KT is believed to lift the skin from the fascia and increase blood flow [20] so that it provides better distribution of oxygen in the muscles and decreased inflammation [25].

As the reduction in pain remains one of the major objectives of SAIS treatment, it is important to determine which technique offers the most effective treatment. As there is a dearth of literature comparing the short-term effects of KT, MT, and HILT on the physiotherapeutic interventions of SAIS, this study aims to compare the effects of KT, MT, and HILT on pain, ROM, and function in patients with SAIS.

Materials and methods

Research design

The study protocol was approved by the University Ethics Committee, and a written consent was obtained from all the participants of the study. Seventy patients with SAIS were randomly divided into four groups based on the treatment(s) they received [exercise (EX) ($n=15$), KT + EX ($n=20$), MT + KT + EX ($n=16$), and MT + KT + HILT + EX ($n=19$)]. KT application including supraspinatus and deltoid muscle inhibition technique and glenohumeral mechanical correction technique were applied to the second group. For the third group, KT was combined with MT treatment. For the forth group, HILT was performed in addition to KT + MT. HILT, MT, and KT treatments were given three times a week. All the patients were also subjected to a home exercise program (EX) during 15 sessions of treatment. All patients were assessed by an experienced physiotherapist, and the treatments were performed by another experienced physiotherapist in order to provide a single blind structure of the study. The patients were randomly assigned to one of the four groups using an online random allocation software program (GraphPad Software QuickCalcs, GraphPad Software Inc., La Jolla, CA, USA).

Participants

Seventy-five patients who had been admitted to the hospital with the complaints of shoulder pain (5/10 points from visual analogue scale) and subsequently diagnosed with SAIS were recruited in the study. SAIS patients were diagnosed by a physical medicine and rehabilitation doctor and exhibited symptoms for at least 3 months prior to admission. The exclusion criteria included those (a) with soft tissue or bone problems affecting the shoulder, (b) who had acute inflammation affecting the shoulder region, (c) had any neurologic problems, (d) had scoliosis, (e) had any systematic rheumatic problems, (f) who had undergone orthopedic problems or surgery affecting neck, and (g) who were obese (BMI > 30 kg/m^2). A total of 70 patients were randomised according to the

exclusion criteria. The details of inclusions and exclusions of the subjects through final data analysis are presented in Fig. 1.

Assessments

Pain All of the patients were assessed before and at the end of the treatment (15th day). The assessments included the evaluation of severity of pain by VAS. VAS is a 10-cm line with no marks along it, anchored with the words "no pain" on one hand, and "the most severe pain" on the other. The subjects were simply instructed to place a mark along the line at a level representing the intensity of their pain during activity [26].

Range of motion Shoulder flexion, abduction, and external rotation ROM measurements were obtained with a universal goniometer, and the active movements were recorded. The goniometer was pivoted at the acromion for abduction, greater tubercle for flexion, and olecranon for external rotation at 90° shoulder and elbow flexion [27].

Function The shoulder pain and disability index (SPADI) was used to measure pain and disability associated with shoulder pathology. This index is validated for subjects with shoulder dysfunctions undergoing physical therapy or general medical treatment with diagnoses of impingement syndrome, degenerative joint disease, nonspecific shoulder pain, osteoarthritis, total shoulder arthroplasty, rotator cuff surgery, glenohumeral instability/dislocation, rotator cuff syndrome, adhesive capsulitis, status post-fracture, and shoulder weakness. The scoring range is 0–50 SPADI points for pain and 0–50 SPADI points for function/disability with a total score of 0–100 (worse pain and function/disability). Higher scores reflect greater pain and disability [28, 29].

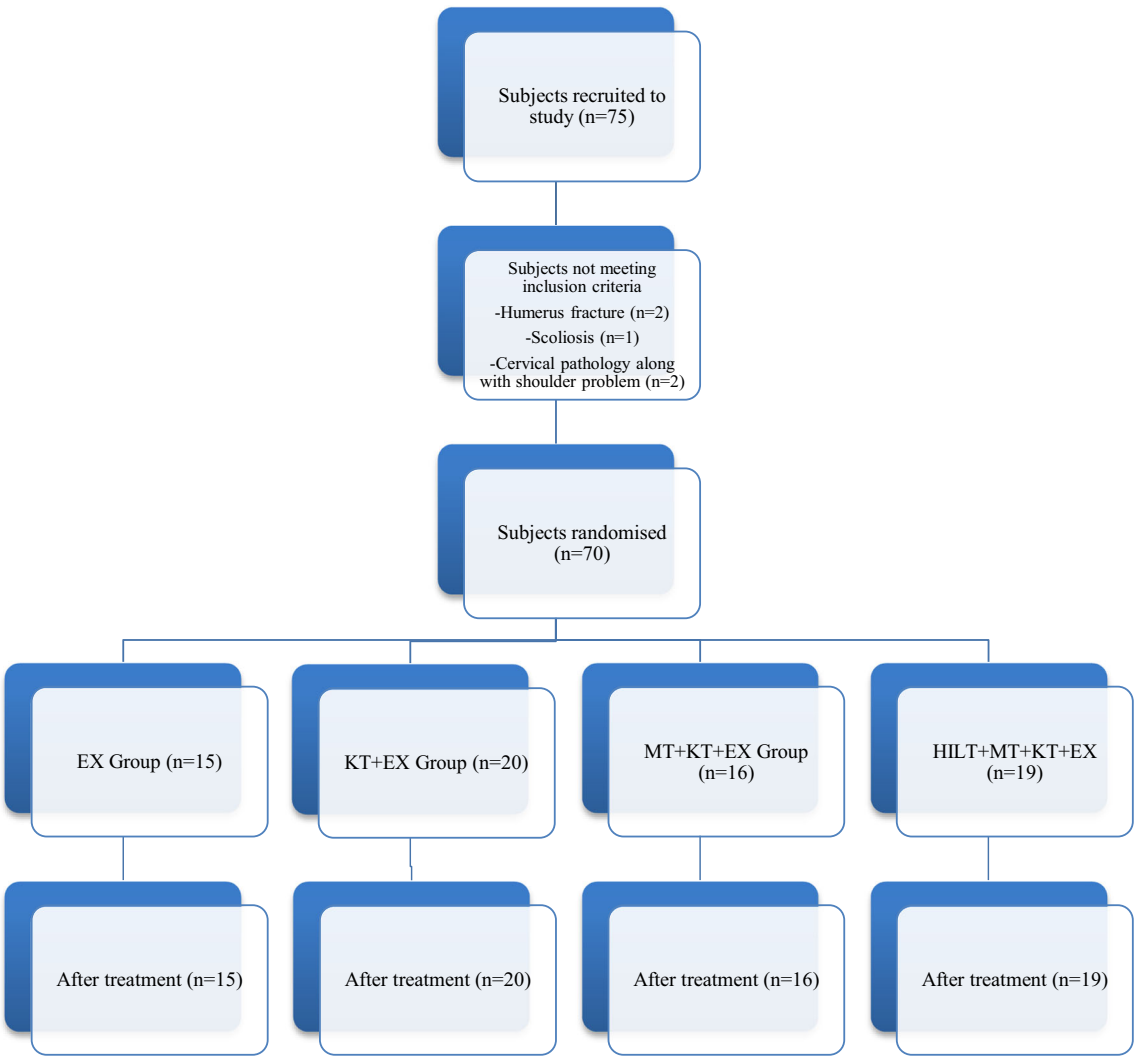

Fig. 1 Flowchart of the study

Treatments

Treatment interventions were given during the 15 days of treatment period. The first group only received home exercise program as the treatment. The second group received KT application 3 days per week for a total of 15 days of the treatment. The third group also received KT application similar to the first group in addition to MT treatment for 3 days per week. The fourth group received KT and MT treatments in addition to HILT for 3 days a week. All patients also underwent a home exercise program during the 15 sessions of the treatment. The flowchart of the study is shown in Fig. 1.

KT application included the supraspinatus and deltoid muscle inhibition techniques and the glenohumeral mechanical correction technique. KT muscle inhibition techniques were applied with 10–15 % tension from insertion to origin for related muscles. Glenohumeral mechanical correction was applied from anterior part of the glenohumeral joint to the posterior part with 50–75 % tension of the tape to mechanically correct the joint (Fig. 2). The subjects were instructed to take the tape off before the subsequent application [20]. Manual treatment consisted of deep friction massage on the supraspinatus muscle, radial nerve stretching, scapular mobilization (Fig. 3a), glenohumeral joint mobilization (Fig. 3b), and proprioceptive neuromuscular facilitation techniques.

HILT group received HILT with a neodymium-yttrium aluminum garnet laser having a pulsating waveform produced by an HIRO® 3.0 device reaching very high power peaks (3 kW) with an Nd:YAG pulsed source (wavelength 1064 nm) (Arcugnano, Via Volta, 9 Vicenza, Italy) (Fig. 4). A standard handpiece endowed with fixed spacers was used to ensure the same distance from the skin and the verticality of 90° to the zone to be treated with a bright spot diameter of 5 mm. Three phases of treatment including starting, trigger, and closing were performed for each session. An initial phase involved fast manual scanning (100 cm^2/30 s) of the zones of muscular contracture, particularly for the upper trapezius, supraspinatus, and deltoid muscles and anteriorly for the pectoralis minor muscle during abduction of shoulder position. Scanning was performed in both transverse and longitudinal directions with the arm positioned in internal rotation and extension to expose the rotator cuff. In this phase, a total energy dose of 1000 J/cm^2 was administered. An intermediate phase involved applying the handpiece with fixed spacers vertically to 90° on the

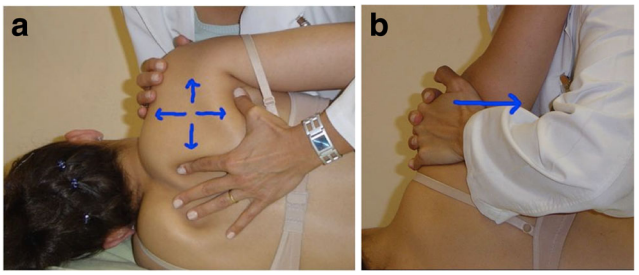

Fig. 3 **a** Scapular mobilization technique. **b** Glenohumeral joint mobilization technique

Fig. 2 KT application including supraspinatus and deltoid muscle inhibition techniques and glenohumeral mechanical correction technique

Fig. 4 High-intensity laser therapy (HILT) application

trigger points including four phases for each point until a pain reduction of 70 to 80 % was achieved in 6 s. In this phase, the mean energy dose was 50 J. A final phase involved slow manual scanning (100 cm^2/60 s) of the same areas treated in the initial phase until a total energy dose of 1000 J was achieved. Three steps were predicted in the starting/initial and final phases of the treatment; the fluencies used were 510, 610, and 710 mJ/cm^2, respectively. Therefore, the total dose of energy administered was approximately 2050 J. The total time taken to apply all the three stages of HILT was approximately 30 min [7, 12, 30].

All the patients were instructed to perform the active ROM, stretching, and strengthening exercise program including rotator cuff muscles, rhomboids, levator scapulae, and serratus anterior with a Thera-Band at home at least seven times a week for 10–15 min. The exercises were taught by a physiotherapist, and all the patients did the exercises everyday during the 3 weeks without fail. An instruction of the exercise program was provided as a shoulder exercise brochure [31]. For self-training at home, a Thera-Band was used because this seemed more appropriate than the dumbbells. The main advantage of the Thera-Band was the availability of different levels of resistance, so that it could be adjusted individually to the patient's level of strength [32, 33].

Statistical analysis

The power analysis indicated that 15 participants for each group were needed with 80 % power and a 5 % type 1 error. The power analysis of our study showed a power of 80 % with pain intensity as the primary outcome. The data were analyzed using statistical software (SPSS version 18, Inc., Chicago, IL, USA). All the statistical analyses were set a priori at an alpha level of $p<0.05$. The tests for homogeneity (Levene's test) and normality (Shapiro-Wilk) were used to determine the appropriate statistical methods to apply for comparison between the groups. According to the test results, the nonparametric Wilcoxon test was used to compare between baseline and post-treatment within a group, while the Kruskal-Wallis test was used for comparisons between the groups. Mann-Whitney's *U* test was used for possible differences which may occur between groups in order to identify the group that provided the difference. Parametric test assumptions were not possible due to small sample size and inhomogeneous parameters.

Results

No statistically significant differences were observed between the groups at baseline in terms of age, shoulder flexion, and abduction ROM ($p>0.05$). Seventy subjects with the mean age of 47.1 ± 13.8 years participated in this study (EX group, X ± SD = 40.6 ± 11.7; KT + EX group, X ± SD = 49.4 ± 12.6; MT + KT + EX group, X ± SD = 45.4 ± 15.5; HILT + MT + KT + EX group, X ± SD = 51.1 ± 14.3). Statistically significant differences were found between the results obtained before and after the treatment of all parameters in the groups, MT + KT + EX and HILT + MT + KT + EX ($p<0.05$). In the KT + EX group, SPADI total ($p<0.01$) and SPADI pain ($p=0.02$) results were found significantly different, but all other parameters were not found to be significantly different in comparison with assessments before and after treatment ($p>0.05$) (Table 1). The percentages of increase and decrease of assessment parameters are presented in Table 1.

When comparing HILT + MT + KT, MT + KT, and KT applications with exercise, statistically significant difference was found at ROM parameters and SPADI total results ($p<0.05$ for all cases) for HILT and MT applications. For KT application, SPADI pain and SPADI disability parameters were significantly different than EX ($p<0.05$ for all cases) (Table 2).

When comparing three groups in means of ROM and SPADI results, statistically significant differences were found between all groups ($p<0.05$). These differences were significant between the groups, MT + KT + EX and KT + EX ($p<0.05$ for all cases) and HILT + MT + KT + EX and KT + EX ($p<0.05$ for all cases). When comparing groups HILT + MT + KT + EX and MT + KT + EX, significant difference was only found in shoulder abduction ROM results after treatment ($p=0.031$) (Table 3).

Discussion

In this study, the effects of HILT, MT, and KT in patients with subacromial impingement syndrome was investigated, and it was found that MT and HILT possess great benefits in terms of treatment against KT with regard to pain, disability, and shoulder ROM results. When the HILT and MT treatment approaches were compared, HILT is found to be more effective on shoulder abduction ROM against MT.

It is believed that HILT quickly reduces inflammation and painful symptoms [34]. The reduction of pain has a great effect on increasing ROM, and hence, the quality of life of the patients. It utilizes a particular waveform with regular peaks of elevated values of amplitude and distances (in time) between them to decrease thermal accumulation phenomena, and it is capable of rapidly inducing in the deep tissue photochemical and photothermic effects that increase blood flow, vascular permeability, and cell metabolism [35]. Santamato et al. studied the short-term effects of HILT against ultrasound therapy (US) in the treatment of people with SAIS and found that at the end of the 2-week intervention, participants in the HILT group showed a significantly greater decrease in pain than those in the US therapy group. The participants diagnosed with SAIS showed greater reduction in pain and

Table 1 Comparison between before and after treatment results of assessment parameters

	EX group				KT + EX group				MT + KT + EX group				HILT + MT + KT + EX group			
	BT X ± SD	AT X ± SD	p	%	BT X ± SD	AT X ± SD	p	%	BT X ± SD	AT X ± SD	p	%	BT X ± SD	AT X ± SD	p	%
Shoulder external rotation ROM	86.00 ± 15.49	90.00 ± 0.00	0.317	+4.65	82.75 ± 20.48	87.00 ± 13.41	0.102	+5.13	42.50 ± 21.90	71.28 ± 12.89	0.001*	+67.71	49.73 ± 22.51	78.57 ± 11.78	0.000*	+57.99
Shoulder abduction ROM	175.33 ± 18.07	180.00 ± 0.00	0.317	+2.66	175.00 ± 22.36	180.00 ± 0.00	0.317	+2.85	121.42 ± 43.34	161.21 ± 8.21	0.007*	+32.77	130.26 ± 31.11	167.78 ± 9.19	0.000*	+28.80
Shoulder flexion ROM	176.66 ± 12.90	180.00 ± 0.00	0.317	+1.89	175.75 ± 13.10	180.00 ± 0.00	0.180	+2.41	130.35 ± 44.43	169.64 ± 8.19	0.001*	+30.14	140.00 ± 29.39	172.73 ± 7.42	0.000*	+23.37
SPADI total score	44.73 ± 17.17	38.72 ± 18.63	0.020*	−13.43	72.65 ± 30.13	39.95 ± 28.26	0.000*	−45.02	111.00 ± 16.92	14.57 ± 12.55	0.001*	−86,88	114.89 ± 11.94	13.16 ± 9.45	0.000*	−88.55
SPADI pain score	67.20 ± 11.48	4.00 ± 4.70	0.001*	−94.04	55.80 ± 21.16	30.20 ± 27.16	0.002*	−45.88	74.43 ± 5.25	5.00 ± 7.59	0.001*	−93.29	76.42 ± 4.88	4.21 ± 5.07	0.000*	−94.50
SPADI disability score	53.80 ± 23.14	10.60 ± 6.71	0.001*	−80.29	39.60 ± 26.27	23.30 ± 21.79	0.064	−41.17	77.14 ± 16.52	9.79 ± 8.50	0.001*	−87.31	80.16 ± 13.07	7.37 ± 4.52	0.000*	−90.81

*$p < 0.05$

BT before treatment, *AT* after treatment, *KT* Kinesio taping, *MT* manual therapy, *HILT* high-intensity laser therapy, *ROM* range of motion, *SPADI* shoulder pain and disability index, *%* percentage of improvement, + increase, − decrease

Table 2 Differences from EX group for after treatment results of all parameters

	KT + EX and EX p^a	MT + KT + EX and EX p^a	HILT + MT + KT + EX and EX p^a
Shoulder external rotation ROM	0.805	0.000*	0.000*
Shoulder abduction ROM	1.00	0.000*	0.000*
Shoulder flexion ROM	1.00	0.000*	0.000*
SPADI total score	0.633	0.000*	0.000*
SPADI pain score	0.005*	1.00	0.973
SPADI disability score	0.046*	0.477	0.537

*$p < 0.05$

EX exercise, *KT* Kinesio taping, *MT* manual therapy, *HILT* high-intensity laser therapy, *ROM* range of motion, *SPADI* shoulder pain and disability index

[a] Comparison of two groups

improvement in articular movement, functionality, and muscle strength of the affected shoulder after ten treatment sessions of HILT than did participants receiving US therapy over a period of two consecutive weeks [7]. Karaca also stated that HILT was found to be effective in the short term in the treatment of pain and disability in patients with SAIS [13]. Alayat et al. investigated the effect of HILT in treatment of patients with chronic neck pain on cervical ROM, pain, and functional activity and stated that the combination of HILT + EX effectively increased cervical ROM, functional activity, and reduced pain after 6 weeks of treatment [36]. Also considering lateral epicondilitis patients, Akkurt et al. stated that HILT is a reliable, safe, and effective treatment option in lateral epicondilitis patients in the short and long term considering pain, functional status, and quality of life [37].

In the present study, the results obtained during abduction position of shoulder after six treatment sessions with the experimental protocol suggested greater effectiveness of HILT than of KT and MT in the treatment of SAIS. The participants treated with HILT showed a greater reduction in pain and more improvement in articular movement and functionality of the affected shoulder than the other therapies. The percentages of improvement in assessed parameters are significantly higher after HILT and MT treatment approaches.

Senbursa et al. stated that SAIS patients treated with manual therapy combined with supervised exercise showed improvement of symptoms including increasing strength, decreasing pain, and improving function earlier than exercise-only program [8]. Martı´nez-Segura et al. suggested that a single cervical manipulation is more effective in reducing neck pain at rest and in increasing the active cervical range of motion than a control mobilization procedure in subjects suffering from mechanical neck pain [38]. Heredia-Rizo et al.

Table 3 Differences between groups for after treatment results of all parameters

	MT + KT + EX and KT + EX p^a	HILT + MT + KT + EX and KT + EX p^a	HILT + MT + KT + EX and MT + KT + EX p^a	p^b
Shoulder external rotation ROM	0.000*	0.000*	0.073	0.000*
Shoulder abduction ROM	0.000*	0.000*	0.031*	0.000*
Shoulder flexion ROM	0.000*	0.000*	0.265	0.000*
SPADI total score	0.001*	0.000*	0.655	0.000*
SPADI pain score	0.005*	0.002*	0.967	0.002*
SPADI disability score	0.017*	0.005*	0.906	0.017*

*$p < 0.05$

EX exercise, *KT* Kinesio taping, *MT* manual therapy, *HILT* high-intensity laser therapy, *ROM* range of motion, *SPADI* shoulder pain and disability index

[a] Comparison of two groups

[b] Comparison of all groups

stated that combined treatment using analgesic electrotherapy, postural advice, and MT improves active and passive ROM of the shoulder, as well as the functionality of the upper limb in subjects with SAIS, regardless of the MT protocol [39]. Braun et al. stated that MT and exercise seem to be effective for shoulder impingement [40]. According to a review, few evidences point to the fact that MT might decrease pain in patients with RC tendinopathy [41].

In addition, KT application is a newly used component of rehabilitation in subjects with SAIS and rotator cuff tendinitis. A reduction in edema and pain remains the major aims of the treatment. Many authors reported that pain reduction and increase in range of motion is possible with KT in subjects at the early phase of SAIS [18–20]. Also, Merino-Marban et al. studied the efficacy of KT application on calf pain and ankle range of motion in athletes and observed that applying KT on the calf seems to immediately increase ankle dorsiflexion range of motion [42]. Contrary to these, Alam et al. reported that KT did not cause significant difference in shoulder external rotation peak torque and shoulder internal and external range of motion in healthy individuals [43]. The results of this present study show that KT exerts positive effects on pain reduction, but this does not provide a significant increase in ROM. KT might prove to be less effective on tissue mobilization compared to HILT and MT treatment approaches. This might be the reason for the absence of any significant increase on the range of motion enabled by KT. Although KT group experienced lesser SPADI pain results at baseline, KT has still made significant difference on pain after treatment.

The key objective of this study was to determine the effects of HILT, MT, and KT, all of which affect the skin, fascia, and connective tissue underneath in terms of pain reduction. Pain reduction and mobilization of pathologic tissue fibers would affect an increase in ROM and decrease the disability. According to the results of this study, HILT and MT are more effective in decreasing pain and disability and increasing the ROM.

Study limitations

One of the major limitations of this study was the lack of follow-up period (the period without treatment) to determine the long-term effects of HILT, MT, and KT treatment approaches. Further studies taking into account the follow-up periods are needed for the precise determination of the advantages of these treatments that could offer vital information for rehabilitation programs of patients with SAIS. No studies have yet been conducted to compare the effectiveness of these different physical therapy approaches, and we believe that the results of this study will offer valuable information to design effective rehabilitation programs for patients with SAIS.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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