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Abstract

Subacromial pain syndrome (SAPS) defined as pain of non-traumatic origin localized around the acromion, is a debilitating, common and often chronic condition. Among many proposed underlying causes of SAPS, hypoperfusion and hypoxic conditions in and around the tendons may be an intrinsic cause of SAPS. **PURPOSE:** To determine if adding high intensity aerobic interval training (HIIT) of the rotator cuff to usual care was feasible in SAPS, and improved shoulder endurance more than usual care alone. Additionally, to examine the influence on shoulder pain and disability and the response of tendinous microcirculation following HIIT. **METHODS:** 21 subjects with chronic SAPS were randomized to two groups: Experimental group (EG,n=13) receiving HIIT in addition to treatment as usual, and control group (CG,n=8) receiving treatment as usual. Before and after 8 weeks of exercise therapy, endurance performance was assessed by an incremental abduction exercise of the arm to exhaustion (TTE). Pain and disability was assessed by the shoulder pain and disability index (SPADI). Contrast enhanced ultrasound (CEUS) of the m.supraspinatus and tendon was utilized to indicate tendon blood flow. **RESULTS:** Endurance in the TTE-test improved by an estimated 233 seconds more on average in EG than in CG (p=0.001, 95%CI:102to363) (p<0.001). The SPADI score was reduced 22 points more on average in EG (p=0.017, 95%CI:-40to-5). The change from pre to post-test was significant in EG for both TTE-test and SPADI improvement (p<0.001). EG also experienced less pain during exercise after the intervention compared to CG (p<0.001). CEUS indicated an increase in tendinous blood flow in EG (p=0.019). **CONCLUSION:** HIIT rotator cuff exercise appear to be a feasible intervention in SAPS, increasing endurance performance more than usual care alone. **Key words:** SAPS, Blood flow, Ultrasound, Contrast enhanced, Vascularization

Introduction

Chronic shoulder pain (duration > 3 months) is a common musculoskeletal disorder, second only to lower back pain (1). The prevalence is especially high among manual labor workers requiring prolonged overhead arm positions, or repetitive overhead sports such as swimming or volleyball (2). Limitations in daily life are common in the patient group, as well as sick leave due to the shoulder pain (1). Shoulder pain patients are characterized by reduced range of motion (ROM), as well as impaired muscle strength and endurance of the shoulder (3-5). Ultimately, shoulder pain may lead to disability pension at a relatively young age (6).

Attempting to define the aetiology of chronic shoulder pain, Neer (7) developed the term "shoulder impingement syndrome". Indicating mechanical stress to the tendinous portion of the rotator cuff, exhibited by the acromion during lifting of the arm, as a mechanism responsible for shoulder pain development. However, the role of mechanical impingement as a cause of chronic shoulder pain is debated (8).

Mechanisms intrinsic to the tendon itself offer alternate explanations for the development of chronic shoulder pain (9). Although no one clear pathology has been found, degeneration of the tendons appear to be linked to changes occurring in response to a deficient healing response (10). Possibly induced by hypoperfusion (11) and subsequent hypoxic triggering of cell apoptosis, inflammation and a shift in the tendon collagen matrix towards the structurally weaker type III collagen (12). Attempting to incorporate the wide aetiology of chronic shoulder pain in a term that incorporates these intrinsic factors Diercks et al. (13) named the condition subacromial pain

syndrome (SAPS). SAPS encompass all non-traumatic shoulder problems around the acromion causing pain.

SAPS should preferably be treated conservatively (13), as studies have found equivalent effects of physical exercise programs and surgical treatment (14). Current guidelines for treatment of SAPS advocate exercise therapies specifically focused on the rotator cuff and scapular stabilizing muscles performed at low intensity and high frequency, within the pain threshold, and with a focus on eccentric loading (13). However, the heterogeneity in exercise therapies previously studied make it difficult to draw clear conclusions as to what protocols may be favorable for best outcomes. Thus, the current guidelines seem, rightly, predominantly influenced by the fundamental ethical concept *primum non nocere* (first, do no harm). Additionally, several studies focus on symptom relief rather than normalization of physiological underlying adaptations in SAPS.

Considering that hypoperfusion and hypoxia may be intrinsic causes of SAPS , designing exercise therapy to selectively target local circulation and oxygen delivery may be favorable. Studies indicate that high levels of metabolic demand, blood vessel wall tension, and shear rate seem to be a requisite to stimulate capillary growth (15). In muscle tissue high intensity aerobic training appear to be superior to lower intensity training in increasing capillarization (16). Moreover, arranging the high intensity aerobic training in intervals (HIIT) allows for a potent training stimulus without termination of exercise due to high levels of lactate and muscle fatigue (17). Such training has been found to be well tolerated and effective in several patient groups (18, 19). Recently, our group demonstrated that when working with a small muscle mass in the

upper extremity oxygen consumption and shear rate was not different between 100% and 80% of the maximal work rate (WRmax), however lactate buildup and task termination occurred faster during 100% WRmax (20). Moreover, at 80% WRmax ~1.5 minutes was required to reach 85% of peak shear rate, and ~2minutes to reach 85% of peak oxygen consumption ($\dot{V}O_{2peak}$), which may be regarded as high aerobic training stimulus. Thus, four-minute intervals as previously described by Helgerud et al. (17) appear to be a relevant approach to induce stimuli capable of improving oxygen delivery in isolated muscle exercises (20).

As blood vessels generally emanate from the musculo-tendineous junction into tendons , blood flow in peritendinous regions increase in parallel with muscle blood flow (21), and intratendinous blood flow, visualized by contrast enhanced ultrasound (CEUS), increase following exercise (22, 23). Capillary growth and tendon perfusion may be proportional to training adaptations in muscle tissue. Thus, the aim of this study was to investigate 1) if HIIT in addition to usual care would be feasible in SAPS patients, and improve rotator cuff endurance more than treatment as usual, and 2) if the HIIT-group would reduce pain and disability, as well as increase microcirculation in the supraspinatus tendon, more than the group receiving treatment as usual.

Methods

Study design and timeline

This study was designed as a randomized controlled trial, where subjects with SAPS who met the inclusion criteria were allocated to either the experimental group (EG) conducting HIIT in addition to treatment as usual, or the control group (CG) receiving treatment as usual. Treatment

as usual consisted of home exercises with follow-ups from a physiotherapist, on average every other week. Home exercises were individually customized scapular stabilizing, rotator cuff and pain-free ROM exercises. Inclusion criteria were: Pain >3 months, normal passive ROM, age 18-70 yr., minimum two of four positive tests (Painful arc, Hawkins impingement test, Neers sign, Yokum test). Exclusion criteria were: glenohumeral instability, full rotator cuff tear, previous or scheduled surgery of affected shoulder, rheumatoid arthritis or osteoarthritis, other musculoskeletal problem that could explain the problem, unstable heart disease, serious somatic or mental disease, corticosteroid injection within the last month, pregnancy, allergies related to contrast fluid, inability to provide informed consent or lack of ability to complete the intervention. Subjects were recruited from both primary and secondary care.

The study was approved by the Norwegian Regional Committee for Medical and Health Research Ethics (REK: 2015/1200), and registered in clinical trials (NCT02701465). Subjects gave their written informed consent before participating in the study. All parts of the study were performed according to the Declaration of Helsinki. Once included and after the pre-test, subjects were randomized 1:1 by a third party service at our university. During a transition of work tasks in the project, nine subjects were randomized by computer program by the last author. Before and after 8 weeks of HIIT or treatment as usual, subjects presented to the laboratory for two days of testing separated by 1-2 days rest.

Subject descriptives

Descriptive data on participants were collected at day one. Height and weight were measured using a manual height scale (SECA 220, Seca GmbH & co. KG, Hamburg, Germany) and a

digital weight scale (SECA 877, Seca GmbH & co. KG, Hamburg, Germany). Age, sex and symptom duration were recorded.

Endurance capacity

On test day one, to assess the endurance capacity during shoulder abduction-adduction subjects performed a time to exhaustion (TTE) test with increasing workload. During the TTE-test, subjects were standing abducting and adducting the arm form 0 ° to 90 ° back to 0 °**,** approximately 30 ° anterior in the frontal plane (scapular plane), with the thumb pointing upwards. One repetition was conducted every 2 seconds, guided by a metronome configured to 0.5 Hz. The weight was increased from unloaded movement by 250 g each minute until the subject failed to maintain the rhythm or movement despite vocal encouragement, were able to complete 10 min of work, or pain increased beyond 5 on a 0-10 visual analog scale (VAS). The cause of exercise termination was noted and the highest work rate reached was recorded as WRmax.

Contrast enhanced ultrasound determination of tendon blood flow

Following the TTE-test a rest period of 10 min were given before subjects were seated on a chair without armrests with the affected arm placed behind the back such that the thumb was pointing upwards and touching the spine approximately at L5. Using a 9L probe with a Vivid E9 ultrasound machine (GE Healthcare, Little Chalfont, UK) the m. supraspinatus and muscle tendon transition was visualized to confirm an intact tendon. Next, a marking pen was used to index the best probe position for visualization of the supraspinatus tendon. An ultrasound image of this positioning was also recorded and printed such that the greater tuberosity and humeral

head could be used as landmarks to ensure similar probe positioning in all subsequent scans both before and after the 8-week intervention period.

A 20-18G intravenous catheter (BD Veneflon Pro Safety, Becton, Dickinson and Company, Franklin Lakes, New Jersey) was placed by a medical professional in an antecubital vein on the contralateral arm. A 1.5 ml bolus of ultrasound contrast fluid (Optison, GE Healthcare, Chicago, Illinois, USA) was injected followed by a 10 ml saline flush, both at a rate of 1 $ml \cdot s^{-1}$. No subjects experienced adverse effects following the injections.

Immediately after the injection, the subjects performed 3 minutes of exercise in the same movement as for the TTE-test with a workload corresponding to 80% of their respective pre-test WRmax. The exercise procedure was used to increase the signal from capillaries and improve the visualization of tendon microcirculation.

Following the exercise subjects reassumed the seated position with the arm behind their back and guided by markings on the skin and the printed ultrasound image the m. supraspinatus and tendon was visualized using the contrast harmonic mode of the ultrasound machine, with a mechanical index of 0.07. All ultrasound recordings were taken over 15.7 s using the cine loop mode, and within 4 min of Optison injection.

Ultrasound imaging quantification and analysis was performed on a PC using EchoPac software (GE Healthcare, Chicago, Illinois, USA). The software allows analysis of selected regions of interest (ROI) within which a quantification of mean signal intensity over the 15.7 cine loop can

be made ($dB \cdot mm^{-2}$). A higher signal intensity signify a higher contrast detection, and therefore is an indication of vascularity. The ROI was placed in the area of greatest signal enhancement (**Figure 1**), the width, length, and tilt of the ROI was noted, additionally anatomical landmarks such as the greater tuberosity and humeral head guided placement, such that an identical ROI and placement was used within each subject at pre- and post-test. A test-retest pilot on seven healthy shoulders revealed a coefficient of variance of 4.6 % for the CEUS method in our laboratory.

Pain and disability questionnaires

On day two, subjects submitted two self-report questionnaires designed to assess level of pain and functional impairment related to the pain. The first was the Shoulder Pain and Disability Index (SPADI), which is a two part 13 item questionnaire granting a total score between 0 and 100 where 0 is no pain/disability and 100 is worst pain/disability (24). A Norwegian translation of the SPADI, that was translated according to recommended guidelines, and showed an intraclass correlation coefficient of 0.89 (95%CI: 0.82-0.93) was employed in the current study (25). The second questionnaire was the short questionnaire for surveillance of longstanding pain, developed by the Norwegian Pain Association (NPA). Specifically, the three questions regarding level of pain were recorded from the NPA questionnaire (least-, worst- and average pain of the former week). NPA was scored on a numeric scale form 0 (no pain) to 10 (worst imaginable pain).

Training intervention

Following the two-day pre-test, all subjects performed 8 weeks of training in their respective group EG or CG. Both groups received standardized usual care consisting of home exercises

with regular follow ups with the physiotherapists every other week in average. The main goal was to re-establish normal shoulder movement patterns through awareness, which the participants could transfer to daily activities. Focus was individual customized scapular stabilizing exercises, rotator cuff exercises, and pain-free range of motion exercises, as previously described by Granviken and Vasseljen (26). The CG continued the program, and the EG additionally received 3 sessions of HIIT per week. The HIIT was performed in the same movement and frequency as the TTE-test with a workload corresponding to 80% of WRmax. Intervals lasted 4 minutes and were repeated 4 times interspaced by 3 minutes of active recovery where the subject walked leisurely on a treadmill (PPS Med, Woodway, UK). If the subject was able to continue the final interval for one additional minute, the workload was increased by 250 g in the following session. Subjects reported pain on a scale from 0 to 10 before and during the sessions. The workload was adjusted continuously to maintain pain below 5, if pain exceeded this point the session was terminated. Each completed session according to protocol was recorded.

Statistical analyses

Power calculation based on TTE data from Brox, Roe (27), power 0.8 and alpha 0.05 indicated a sample size of n=24 to detect mean group differences of minimum 30 seconds. To assess effect of the intervention analysis of covariance was applied, with outcome after treatment as dependent variable, and baseline value and treatment group as covariates (28). IBM SPSS statistical software (version 25) was used for statistical analysis, except for the dichotomous variable of pain during TTE where StataCorp STATA (version 13) was used. Within-group change from pre to post-test was assessed by Wilcoxon signed rank or McNemar's test in the

case of dichotomous variables. Differences between group anthropometrics was assessed with two sample T-test. For all analyses, the level of significance was set to $p<0.05$. Data are presented as means ± SD in text and tables, and means ± SE in figures for clarity.

Results

Subject characteristics

21 subjects completed the study (**Table 1**), two subjects dropped out of the study between pre and post-testing (one from CG, and one from EG). The dropouts were both for reasons unrelated to the testing or training. Three subjects were excluded prior to post-test due to exclusion criteria revealed post randomization. For complete study flow chart in line with the *CONSORT 2010 Statement* see **Figure 2** (29). One subject in the CG received a corticosteroid injection during follow up. Analysis with and without this subject did not yield different findings, thus the subject was included in the analysis. Subjects in the EG completed 22 ± 3 of the planed 24 training sessions over the 8-week intervention (92 ± 13% compliance).

Shoulder endurance performance

Endurance in the TTE-test improved by an estimated 233 seconds more on average in the EG than in the CG ($p= 0.001$, 95%CI: 102 to 363, **Figure 3**). The increase from pre to post-test was significant within the intervention group ($p<0.001$), no change from pre to post-test was observed for the CG. The WRmax increased by 964 g more on average in the EG than in the CG ($p=0.003$, 95%CI: 386 to 1543). Both groups exhibited a significant within group increase in WRmax from pre- to post-test, EG: 692 ± 480 g to 1846 ± 857 g ($p=0.003$) and CG: 719 ± 525 g to 906 ± 533 g ($p=0.034$).

Shoulder pain and disability

The SPADI score (**Table 2**) was reduced 22 points more on average in the EG (p=0.017, 95%CI: -40 to -5). The change from pre to post-test was also significant in the EG (p<0.001), but not in the CG. Between groups, only the intensity of the least pain experienced the last week was significantly different (p=0.045). The worst pain experienced the last week showed a trend to decrease from pre to post-test in the EG (p=0.051). There was a significant difference between groups on experience of pain during the TTE-test (p<0.001, Risk difference; 66%).

Tendon blood flow

Signal enhancement, as a measure of blood flow, in the supraspinatus tendon ROI measured by CEUS did not exhibit any group effect (pre: -30.5 ± 5.4 $dB \cdot mm^{-2}$ and -33.4 ± 2.8 $dB \cdot mm^{-2}$ to post: -28.3 ± 5.9 and -31.3 ± 5.1, for EG and CG respectively). The EG showed an increase in signal intensity from pre to post-test (p=0.019), there was no significant change in the CG.

Discussion

The main finding of this study was that 8 weeks of HIIT appear to be a feasible intervention in SAPS patients and superior with regard to increases in shoulder endurance capacity in the abduction exercise (TTE). Secondly, the participants in the HIIT group reported a larger reduction in pain and disability. There were no significant improvement in CEUS following HIIT in the EG compared to CG concerning increased tendon microcirculation. However, these findings add to the understanding of pathology and clinical treatment in SAPS, indicating HIIT could be a relevant supplement to exercise therapy of SAPS. However, larger studies are needed to confirm the effects and mechanisms targeting hypoxia related intrinsic causes.

Shoulder endurance capacity

Following 8 weeks of HIIT abduction exercise of the arm, targeting the affected m. supraspinatus and tendon, TTE increased 136% in the EG. This is higher than what has previously been reported for a similar HIIT protocol of plantar flexion, where an increase in TTE of 42% was reported (18). Although at a fixed workload, O'Leary et al. (30) found TTE following 18 sessions of cycling HIIT to be increased by 148%. Moreover, in that study HIIT was found to increase ischemic pain tolerance, whereas continuous training at moderate intensity did not improve pain tolerance. In the current study, 9 out of 13 subjects, in the HIIT group, terminated the TTE-test during pre-test due to pain sensation exceeding 5 on the VAS, whereas only one subject terminated due to pain at post-test (**Table 2**). This significant reduction may be related to increased ischemic pain tolerance following HIIT, in addition to delayed anaerobic conditions due to improved aerobic capacity in the trained muscles. Indeed, Beach et al. (3) demonstrated a negative correlation between both arm external rotation and abduction endurance to shoulder pain in competitive swimmers.

In line with the increase in TTE, WRmax also increased more in the EG compared to the CG. However, both groups exhibited an increase in WRmax of 167% and 26% for the EG and CG respectively. This increase in the EG is higher than previous publications employing similar HIIT protocols to that of the current study in single limb exercises, who report an increases of 37% and 43.9% (18, 19). Additionally, at post-test 7 subjects in the EG reached the cut-off at 10 min during the incremental test, no subjects in any group reached this ceiling at pre-test. Thus if the test had allowed for further increase in workload the increase and group difference may have been further amplified. This may also add to the explanation of why termination due to pain was

reduced in the EG at post-test. As aerobic capacity is improved following single limb HIIT (18), the 10 minute cut-off may occur prior to, or at least shift, the occurrence of the pain threshold as well as accumulation of lactic acid due to anaerobic metabolism (31). Furthermore, the HIIT may also augment compensatory musculature, and thus ameliorate shoulder endurance capacity.

Shoulder pain and disability

In the current study, HIIT reduced self-reported pain and disability in the EG on average 22 points more compared to the CG. The within group change in the EG was 28 ± 24 points. A clinically significant reduction in SPADI score has been described to lie in the range of 8 to 13 points (32). However, up to a 20 point reduction has been estimated for clinical significance (33). Thus, the reduction in the EG following 8 weeks of HIIT lie above this most stringent criteria for clinical significance. Inherent to self-reported outcomes is influence of social and personal events on the reported value. The SD in SPADI change was similar between EG and CG, and comparable to previous reports from larger validation studies, that have found SPADI to be a relevant instrument to discriminate between groups and detect change over time in clinical studies (34). Although, not statistically significant the CG reduced their SPADI score by 10 ± 22 points, which may indicate a minimally clinical significant improvement according to Roy et al. (32). A previous study of the intervention received by the CG reported a 17 point reduction in SPADI score at 6 week follow up (26). Another 6 week home based exercise program consisting of resistance training showed a difference of 5.5 points after exercise, and following a control period after completion the exercise program, a significant reduction of 16.92 points (35). Thus, our results on SPADI seem to be in the low end of the effects that have previously been reported from home exercise programs in shoulder pain patients. Moreover, supervised exercise in

patients with high baseline SPADI score could be related to larger improvements than in subjects with similarly high baseline score in home exercise (26). Similar to our results in the EG reductions in SPADI score of ~20, 27 and 31 points have been reported following supervised exercise for 5, 6 and 12 weeks respectively (36, 37). However, although the supervision may be one cause of the group differences, Granviken and Vasseljen (26) reported no difference in SPADI following supervised or home exercise, indicating that the added HIIT could be the cause of the group differences. Indeed, Osteras et al. (38) demonstrated that high dose exercise in SAPS patients was more effective in reducing pain and activity limitations compared to a lower dose program during a 12 week intervention. Moreover, at both 6 and 12 month follow up there was still a significant difference between the groups. High intensity exercise has also been found to produce larger exercise-induced hypoalgesic effects compared to lower intensities (39). Additionally, aerobic endurance training enhance ischemic pain tolerance (40). However, exercise to exhaustion is found to decrease pain threshold (41), indicating that to high intensity, and duration, may not be favorable. This adds to the rationale of using HIIT as the interspacing of intervals with active rest (3 minutes) promotes lactate removal and the relatively short duration of intervals (4 minutes) inhibit termination due to exhaustion. Exercise training also mitigates pain catastrophizing, and may reduce fear avoidance, thus enhancing coping with pain and reducing perceived disability (42).

Tendon blood flow in response to training

To the authors knowledge this is the first study to assess CEUS as an indication of tendon microvascularization in response to a training intervention. Previous investigations have used CEUS of the supraspinatus tendon and muscle to address regional differences of signal

enhancement within the tendon, in response to acute exercise, and following surgical treatment (22, 23, 43). Such use of CEUS has been found to be an effective tool for assessment of tendinous blood supply (23). In the current study no difference from pre to post test was found between groups, however there was a within group increase from pre- to post-test in the EG. Thus, it cannot be concluded from the current study that HIIT improves the capacity for tendon blood flow more than the conventional treatment in the CG. Interestingly, a previous study utilizing CEUS in Achilles tendons found no correlation between severity of pain and disability to neovascularization (44). However, this neovascularization was related to the failed healing response in tendinopathy, whereas increased blood flow following exercise may be linked to normalization of tendon blood supply (45). Although the link between tendon vascularity and pain and disability seem equivocal, the significant increase from pre- to post-test in the EG, together with the superior effects on pain and disability may indicate a link between SAPS severity and tendinous blood flow. Support to this notion may be gleaned from other studies demonstrating reduced post exercise signal enhancement in the supraspinatus with age above 40 years (23), and that age above 50 years is associated with increased risk of rotator cuff tendinopathy (46). However, the development of chronic SAPS appear to be complex with regard to underlying pathology, as even shoulders that exhibit abnormalities linked to pain and tendinopathy remain asymptomatic (47). Thus, it appears that SAPS consists of an interplay of unfavorable factors, of which impaired blood flow and hypoxic conditions may be one. Moreover, HIIT emerges as a relevant approach for targeting hypoxia related pain in SAPS through augmenting tendon microcirculation.

Feasibility of high intensity interval shoulder exercise in SAPS patients

Compliance with the protocol was high at 92 ± 13%. This is in line with Granviken and Vasseljen (26) who reported a compliance of 80% to supervised training in a group of SAPS patient. Nikander, Malkia (48) reported that 97% of subjects were able to complete an endurance-training program to treat neck pain in female office workers. Compliance up to 100% have been reported in other patient groups when applying HIIT to isolated muscle groups (18, 19). The compliance in these and our study may be enhanced due to social support offered to the subjects by researchers and therapists. However, supervised training did not result in higher compliance compared to unsupervised training when offered to office workers within working hours (49). Similarly, the home exercise group in the study by Granviken and Vasseljen (26) had a compliance of 88% vs. 80% in the supervised group. The high compliance in the current study is a good indication that the subjects tolerated the intervention. The continuous supervision of pain by the therapist, and adjustment of workload if indicated, was likely of importance to the compliance and tolerance of the intervention. Thus, supervision by a therapist may be critical to achieve the effect of HIIT on SAPS observed in the current study. It is possible that similar effects can be obtained incorporating HIIT in a home based program. However, the patient should be well acquainted with the pain-workload adjustments necessary to avoid worsening symptoms. During 12 weeks of conventional physiotherapy in SAPS patients, a mean of 2.5 sessions/ week has been described (50). Although slightly higher, the three sessions per week in the current study should be considered feasible in a limited timeframe (8 weeks) and clinical setting. The protocol is not time or resource demanding (average session lasting ~30min), and may be performed outside the clinic if required.

Study limitations

The EG and CG ended up in a slightly skewed distribution after inclusion of subjects. This was due to the two randomization software's that were used during the period of the study. Thus, while randomization is a strength it also caused a difference in group size. This was further augmented by those subjects dropping out of the study (**Figure 1**). Additionally, the relatively modest sample size in this experiment may cause a single subjects impact on the outcome to increase. The random allocation also resulted in unbalanced sex distribution between groups, which probably explains the higher BMI in the EG. Notably, there was no significant difference in shoulder endurance between EG and CG at pre-test, indicating that the group distributions did not influence the baseline for our primary outcome variable. However, sex distribution may have influenced the response to training. Thus, while controlling for selection bias, random group differences that may influence outcome can arise. To mitigate this impact, weighing sex in the group distribution during randomization may be considered.

Of notice, corticosteroid injection within one month prior to pre-test was an exclusion criterion in the current investigation. Such treatment is common in treatment of SAPS. However, the immediate effects on symptoms appear to weather over time (51), thus the rationale for exclusion was the possibility of positive influence on the pre-test and consequently confounding of the effect following the exercise interventions at post-test.

Notably the home based exercise was not systematically recorded for volume comparison in the current study. Thus, we cannot exclude that some subjects exercised more/ less than others did, and importantly if there were group differences in adherence to the recommendations. Given full

compliance, the volume in the EG would be higher due to the added HIIT. However, anecdotal comments from some subjects in the HIIT group indicated that they felt the sessions were exercise enough. Also, physiotherapists reported that subjects in both groups frequently complained of not adhering to the home exercise due to pain. Importantly the home based exercise model does not record volume as a key part of the therapy, therefore the current study represents a true comparison of treatment as usual and HIIT in addition to treatment as usual.

Conclusion

Adding HIIT abduction exercise to usual care in treatment of SAPS appear to be a feasible intervention, that enhance shoulder endurance capacity more than home based exercises with bi-weekly physiotherapist follow up alone. Additionally, adding HIIT to the treatment of SAPS-patients resulted in greater reductions in pain and disability. Tendon vascularity assessed by CEUS revealed an increased signal intensity from pre- to post-test following HIIT, indicating increased tendon microcirculation and oxygen availability as a possible mechanism for the functional improvements, and reduction in pain. Thus, HIIT could be considered a feasible and potent approach to reduce pain and improve function in conservative treatment of SAPS.

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Conflict of interest

The authors declare no conflict of interest financial or otherwise. Results are presented clearly, honestly, without inappropriate manipulation of data, falsification or fabrication. The Results of this study does not constitute endorsement from the ACSM

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Figure 1. Elliptical region of interest (ROI) on supraspinatus tendon in a 15.7-second cine loop contrast enhanced ultrasound recording.

Figure 2. Flow chart of enrollment, inclusion, allocation, follow-up and analysis of study participants. EG = experimental group receiving high intensity interval training in addition to usual care, CG = control group receiving usual care.

Figure 3. Time to exhaustion during shoulder abduction exercise with incremental resistance, increased by 250 g /minute, starting as unloaded movement. Before (PRE) and after (POST) 8 weeks of shoulder pain rehabilitation as usual (CG) and added high intensity interval training of the rotator cuff (EG). Values are means ± SE; EG n = 13, CG n = 8, † Significant between group effect ($p<0.05$), * Significant change within group from pre to post-test ($p<0.05$)

Figure 1

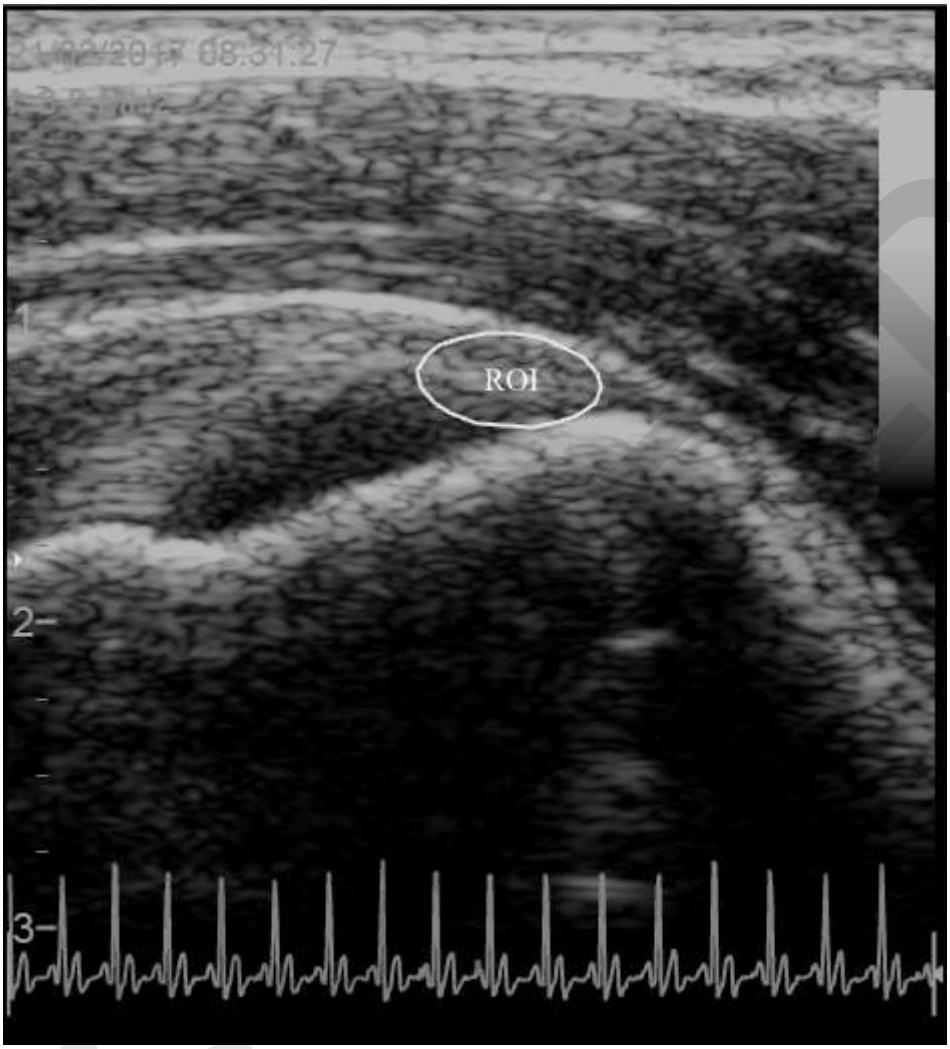

Figure 2

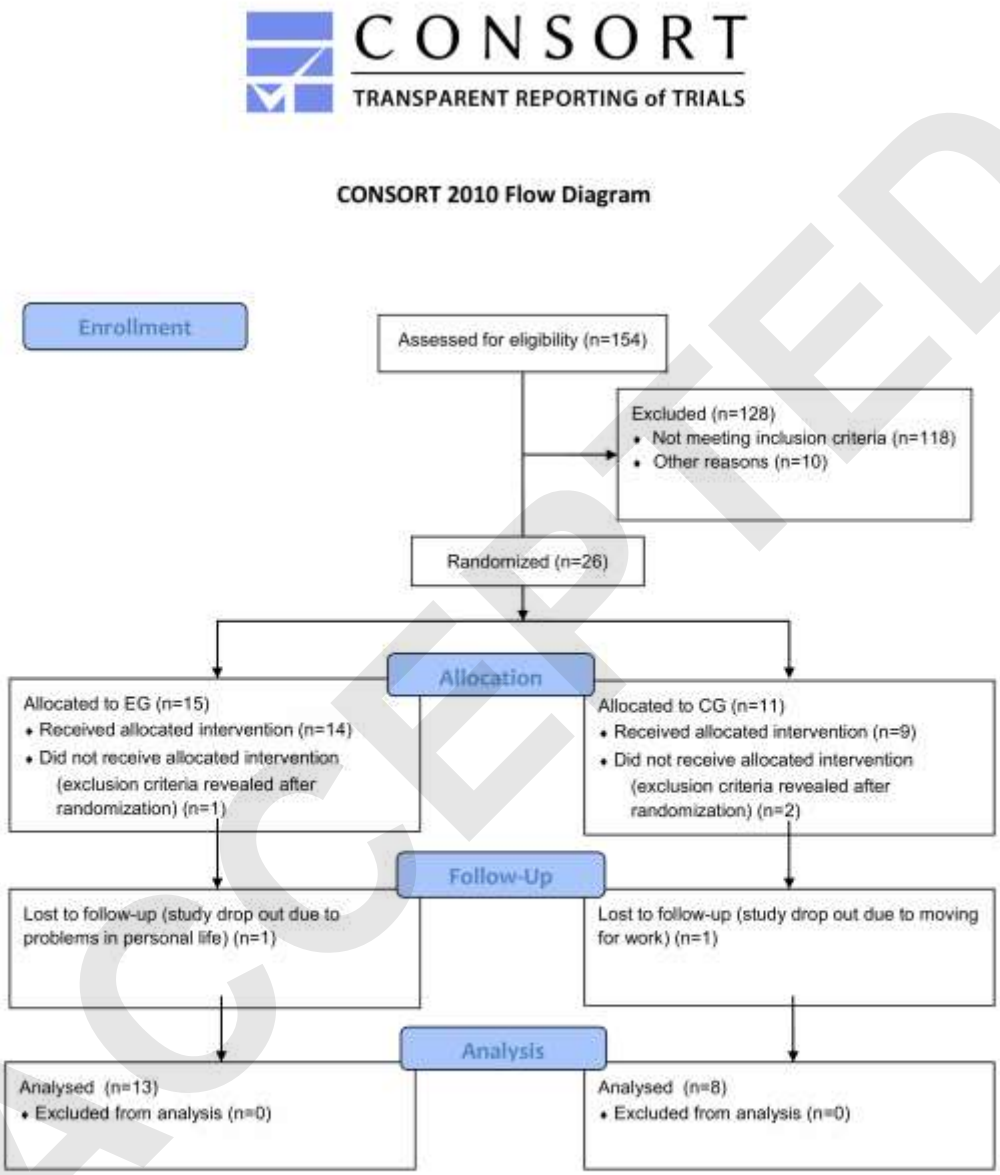

Figure 3

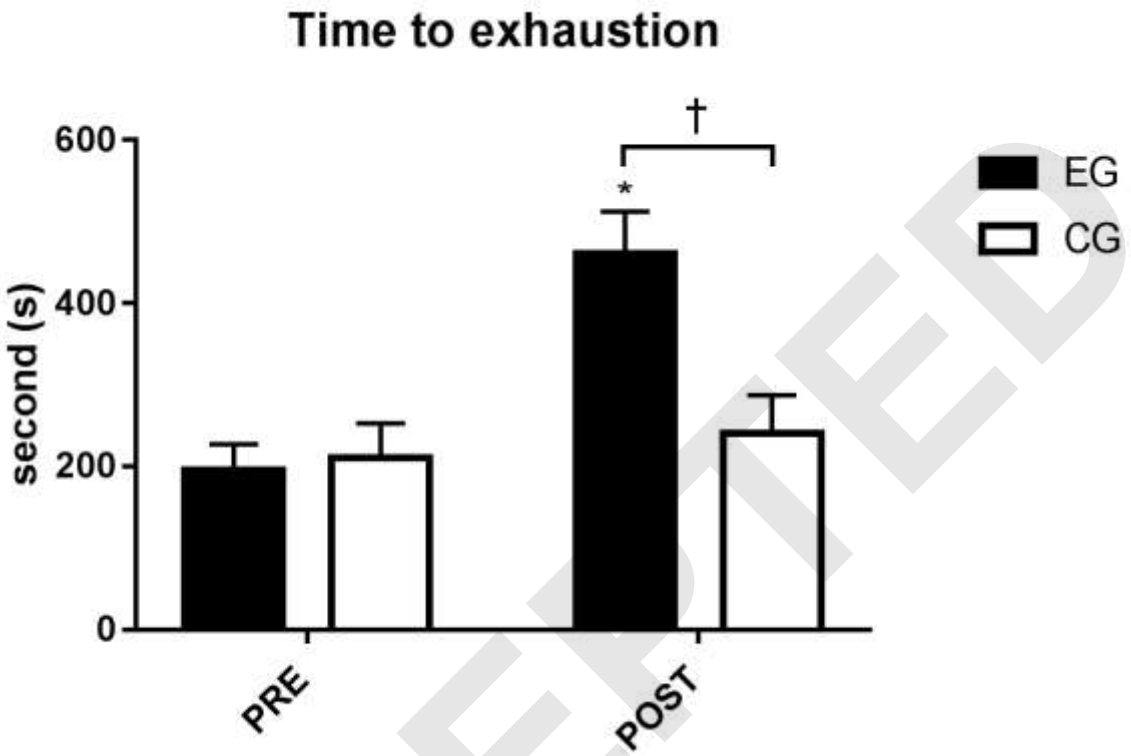

Table 1. Subject anthropometrics.

	EG (n=13)	**CG (n=8)**	
Age, yr.	47 ± 12	50 ± 14	
Sex, male/female	9/4	2/6	
BMI, kg/m^2	29 ± 5	24 ± 2	†
Symptom duration, months	38 ± 62	48 ± 53	

Data are mean ± SD. †$p<0.05$ between group difference.

Table 2. Pain and function scores.

	EG (n=13)		CG (n=8)		
	PRE	**POST**	**PRE**	**POST**	
SPADI, (0-100)	45 ± 24	17 ± 16*	51 ± 16.5	41 ± 23	†
NPA, (0-10)					
average	4 ± 2	3 ± 2	5 ± 2	4 ± 2	
worst	6 ± 2	4 ± 3	7 ± 2	6 ± 3	
least	2 ± 3	1 ± 2	2 ± 1	3 ± 2	†
Pain during TTE-test, (Yes/No)	9/4	1/12*	7/1	6/2	†

Data are means ± SD. SPADI; Shoulder pain and disability index, NPA; Norwegian pain association questionnaire, TTE; time to exhaustion. † Significant between group effect ($p<0.05$), * Significant change within group from pre to post-test ($p<0.05$).