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Prevention and Rehabilitation

Scapula motor control training with Proprioceptive Neuromuscular Facilitation in chronic subacromial impingement syndrome: A case report

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ABSTRACT

Introduction: Shoulder complaints have high re-occurrence rates and scapular control seems to be a major influencing factor in sub-acromial impingement syndromes (SIS). Scapular dyskinesia disrupts the scapulohumeral rhythm, altering biomechanical loads on the rotator cuff in shoulder movements. As a result, this disturbs the natural healing process. Proprioceptive Neuromuscular Facilitation (PNF) seems to be a promising treatment approach because it has a focus on motor learning. This case report seeks to illustrate the clinical reasoning and feasibility of applying the comprehensive nature of PNF in a patient who was not responsive to standard physiotherapy.

Case description: A 47-year-old male, a former professional handball player, was diagnosed with a SIS based upon a rotator-cuff tendinopathy, scapular dyskinesia and degeneration of supraspinatus tendon. The patient presented complaints of right sided shoulder pain in overhead activities and in reaching behind the back.

Patient management: PNF-based motor-control training was provided over a period of five weeks. This approach included specified PNF-pattern exercises with specific PNF-facilitation principles and techniques. The results were improvements beyond the minimal clinical important difference and/or minimal detectable change for physical functioning, pain, range of motion, and functional disability of the shoulder.

Discussion and conclusion: PNF provided an opportunity for motor control training, restored altered movement patterns in the patient's daily life activities. The approach addressed motor learning effects and structural impairments. PNF-patterns have been described as: "mimicking functional activities" from daily life and from sports. In cases where standard strengthening and mobilization exercises are not effective, a specified PNF-based therapy has shown to be a feasible alternative.

1. Introduction

Musculoskeletal conditions are one of the most prevalent and costly disorders globally (Murray et al., 2012), with shoulder pain being the third most common cause of musculoskeletal consultation in physiotherapy setting (Kooijman et al., 2013). The annual incidence of shoulder complaints is estimated to at 29.3 per 1000 a year and its prevalence in the general population is estimated between 41% and 48% (Greving et al., 2012). Sub-acromial Impingement Syndrome (SIS) has been identified with a prevalence of almost 40% among shoulder pathologies (Aceituno-Gómez et al., 2019). SIS has significant economic consequences owing to its treatment costs and losses incurred through workplace absenteeism (Virta et al., 2012; Hopkins et al., 2016). Shoulder complaints have an unfavourable outcome; only about 50% of all new episodes presented in the primary care setting show complete recovery within six months, and one year after the first consultation, 40–50% of patients report that their symptoms have persisted or recurred (Lewis, 2009). SIS is resulting in functional limitations which significantly interfere with the subject's quality of life (Aceituno-Gómez et al., 2019). Thus, shoulder pain induced by SIS is widespread and imposes a considerable burden on the affected person and society.

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Impingement syndrome was first defined by Charles Neer in 1972, described as the tightness of the soft tissues under the acromion that compromise its functionality (Neer, 1972). However, a direct correlation between radiograms, diagnostic ultrasound, MRI, and shoulder symptoms experienced by patients is under debate (Miniaci et al., 2002; Connor et al., 2003; Worland et al., 2003). For this reason, the term "sub-acromial impingement syndrome" is considered outdated, and the current preferred nomenclature is rotator-cuff tendinopathy (Lewis, 2009). Intrinsic and extrinsic factors such as; Inflammation in the supra humeral space, inhibition of the rotator cuff muscles, degeneration of the rotator cuff tendons, and altered kinematics may play a role, and currently SIS covers a range of pathologies from subacromial bursitis to rotator cuff tendinopathy and full-thickness rotator cuff tears (Lewis, 2009; Harrison and Flatow, 2011). Abnormal scapular position has been described as one of the major contributing factors among potential functional causes of rotator-cuff tendinopathy (Escamilla et al., 2014). Altered scapular motion that occurs during active shoulder movements is referred to as scapular-thoracic dyskinesia (Kibler et al., 2009, 2013). It presents itself by diversified scapular motion resulting in a functional instability in activities involving arm elevation (Jobe et al., 1989; Kibler et al., 2009, 2013). Dyskinesia might increase the risk of developing shoulder pain by 43% (Hickey et al., 2018), and simultaneously it appears to be a non-specific response to various shoulder dysfunctions, since no specific pattern of dyskinesia is associated with a specific diagnosis (Ginn and Cohen, 2005). In patients diagnosed with tendinopathy, intermuscular coordination between the lower trapezius and serratus anterior, as well as between the lower trapezius and upper trapezius is disrupted in arm elevation tasks, indicating two altered ratios and the importance of the muscle function (Michener et al., 2016).

Research into scapular stability exercises for the management of SIS is increasing, yet there is little evidence on their efficacy (Ginn and Cohen, 2005). Interventions focused on reducing scapular dyskinesia compared to just stretching and strengthening exercises result in significantly better shoulder disability measures (Moura et al., 2016; Struyf et al., 2013). The addition of scapular stabilization exercises to stretching and strengthening exercises can be significantly beneficial in increasing the strength, developing joint position sense and decreasing dyskinesia (Başkurt et al., 2011).

PNF is a rehabilitation concept which is widely used by physiotherapists and forms part of the physiotherapy curriculum in many countries (Westwater-Wood et al., 2010; Smedes et al., 2016). PNF has been described as a comprehensive rehabilitation concept, promoting motor learning, motor control, strength and mobility (IPNFA, 2019; Smedes et al., 2016). This comprehensive rehabilitation approach includes task-oriented training with manual facilitation aimed at motor learning and motor control (Adlers et al., 2014; Smedes et al., 2016). The activation of the nervous system seems to be more efficient using PNF-patterns compared to simple axial movements (Shimura and Kasai, 2002). It induces changes in cortical activity, which suggests possible benefits at a cortical level (Moreira et al., 2017). The activation of specific scapular muscles is significantly higher when performing PNF arm patterns compared to maximum voluntary contraction (Witt et al., 2011). Also, PNF positions improve movement efficiency of the joint by inducing changes in the muscle activation sequence (Shimura and Kasai, 2002) and it reportedly helps in the early recovery of the patients with SIS (Nakra et al., 2013).

This case report seeks to illustrate the clinical reasoning and feasibility of using the comprehensive nature of the PNF-concept, which seemed to be a suitable approach for the status of SIS in a patient who had not responded to conventional exercise therapy.

2. The case/patient characteristics

A male patient of 47 years old had complaints for five years of right sided shoulder pain in activities overhead and in reaching behind the back and was diagnosed in 2014 with a degeneration of the supraspinatus tendon (ultrasound scan). The pain was localised at the superior anterior-lateral aspect of the glenohumeral joint (around the insertion of the m. supraspinatus). The patient used to play professional handball until 15 years ago. At the time of presentation, the patient was a manager for his company in three different locations. The complaints were most often provoked in reaching overhead for office binders, in lifting overhead plates, cups and saucers into kitchen cupboards and in reaching behind the back to "tuck in his shirt". These three activities were identified by the patient within the patient specific complaints (PSC) on a visual analogue scale (VAS) with respectively a 7, a 7 and a 5 out of 10 expressing being uncomfortable with the activity (Stevens et al., 2016). The patient had no evident cervical, thoracic, or lumbar problems. There were no systemic illnesses such as diabetes or rheumatism present, nor any previous surgery in shoulder and neck area. An informed consent was provided by the patient allowing the anonymous use of his data from assessment and treatment for publication.

3. Patient management

3.1. Initial assessment and monitoring

In the last five years, the patient was treated with conventional exercise therapy (2014, 2016 and 2017), which focused on strengthening using fitness equipment. Furthermore, the patient received ultrasound (2014), shock-wave, dry needling (2017), and massage treatment modalities (2014, 2016 and 2017). These interventions resulted in varying alleviations of the complaints, but no long-lasting relief was achieved.

The patient assessment revealed a clear scapular dyskinesia (see Fig. 1a). Therefore, a motor learning strategy was defined, consisting of specific PNF pattern training based upon specified PNF facilitation principles; see Table 1 (Adlers et al., 2014; Smedes et al., 2016). The effectiveness of this approach was monitored by measuring patient's specific complaints, pain, the range of motion (ROM) of shoulder movements and physical function of the shoulder.

The PSC was monitored with a visual analogue scale (VAS) for three personal identified ADL issues (Stevens et al., 2016). The average pain intensity over the preceding 24 hours at T0, T1 and T2 was monitored with the "Numeric Pain Rating Scale" (NPRS, ranging from 0 to 100) (Williamson and Hoggart, 2005) (ICC = 0.74; 95% CI (Mintken et al., 2009). Measuring ROM with a goniometer has shown to be reliable with an intraclass correlation coefficient (ICC) of $\geq$0.94 (Kolber and Hanney, 2012). To evaluate the patient's level of physical function, the "Patient Specific Functional Scale" (PFSF) was used, its reliability has an ICC of 0.713 (Hefford et al., 2012). To assess the pain in the functional activities of the shoulder, the "Shoulder Pain and Disability Index" (SPADI) was used, which has an ICC of 0.85 (Ekeberg et al., 2008). However, some caution is advised regarding the reliability with repetitive use on the same patient (Breckenridge and McAuley, 2011). For this reason, the "American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form" (ASES) has been added (ICC = 0.84; 95% CI (Michener et al., 2002).

Monitoring took place at the start of this study (T0), after five weeks of intervention (T1) and four weeks after finishing the intervention (T2), see Table 2.

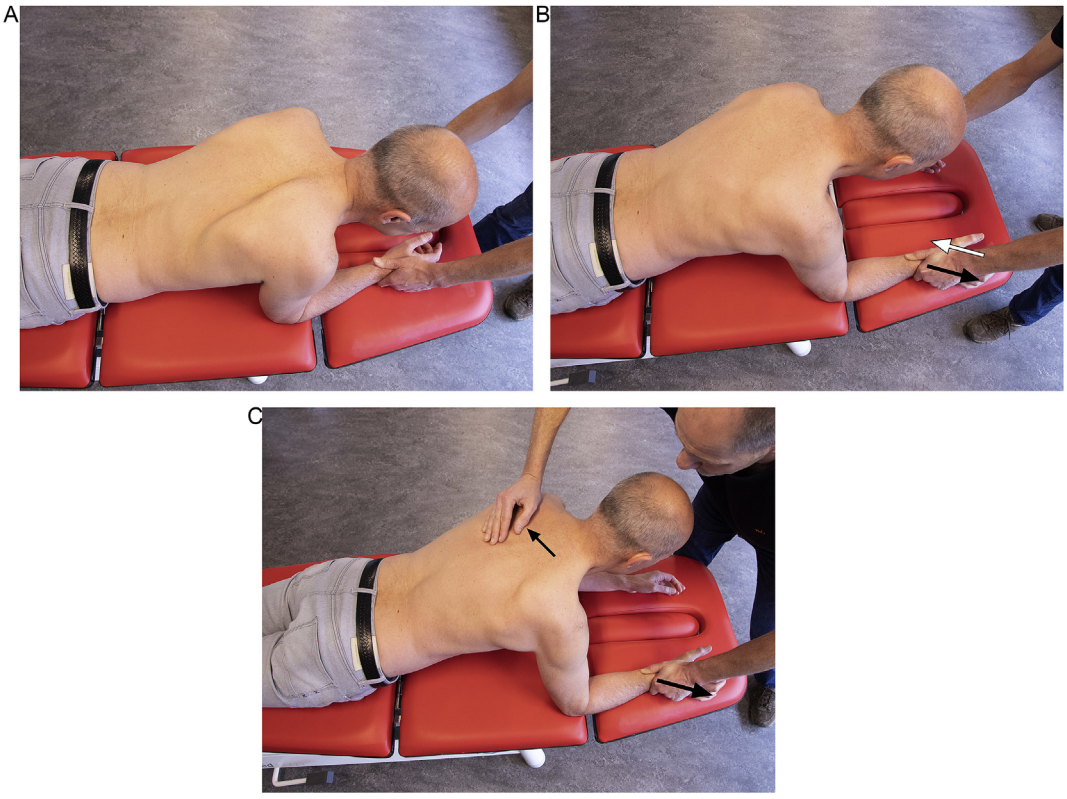

Fig. 1. a, b, c Prone on elbows, activating flexion/abduction/lateral rotation (D2).
1a: Note the "winging" position of the scapula as a sign for scapular dyskinesia and instability.
1b: Note the scapular position changing 1a to 1b.
Black arrow: patient activation into flexion/abduction/lateral rotation. White arrow: resistance from the therapist.
1c: Reinforcement and irradiation for scapular stabilizers with resistance from distal and proximal.
Black arrows: patient activation of arm direction and thorax opposite direction.

3.2. Physical treatment and intervention

To address the patient's problems the main objective was defined as a motor learning effect for motor control in reaching activities. The defined exercise regimen, consisting of PNF scapular patterns and upper extremity patterns in a functional context, was executed (Adlers et al., 2014, p 4–11). This regimen addressed several sub goals such as: increase of ROM, scapular muscles strength and dynamic scapular stabilization (scapular dyskinesia minimization). To address the scapular dyskinesia and instability through improving the intermuscular coordination of the upper trapezius, lower trapezius and serratus anterior for lateral rotation of the scapula (Kibler et al., 2013), the PNF pattern "anterior elevation" was used (Adlers et al., 2014). The basic procedures of "timing for emphasis" and "irradiation" (see Table 1) were utilized to enhance the motor learning effect on recruiting and strengthening the serratus anterior and lower trapezius (Adlers et al., 2014; Smedes et al., 2016; Johnson and Johnson, 2002). Magarey and Jones (2003) advocate scapular patterns to enhance motor control in the dynamic stabilization of the scapula in patients with shoulder dysfunction.

To functionally enhance intermuscular coordination of dynamic scapula stabilization in arm elevation such as in lifting and reaching for objects, the D1 (Flexion/Adduction/Lateral rotation) and D2 (Flexion/Abduction/Lateral rotation) arm patterns were used because they all have scapular lateral rotation as a component and they mimic functional reaching activities (Adlers et al., 2014; McMullen and Uhl, 2000; Myers and Lephart, 2000).

Witt et al. (2011) demonstrated isolated activation of the serratus anterior with minimal activation of (all parts of) the trapezius muscle during the D1 extension pattern (Extension/Abduction/Medial rotation). The D2 flexion pattern resulted in the greatest activation of the upper, middle, lower trapezius, and serratus anterior muscles. The D2 extension pattern (Extension/Adduction/Medial rotation) minimized upper trapezius activity while maximizing the activation of the lower trapezius and serratus anterior (Witt et al., 2011). It has been suggested that passive and active repositioning of the shoulder in the functional position, when repeated, stimulates the unconscious motor programming (Sørensen and Jørgensen, 2000).

For achieving the sub-goals of ROM, serratus anterior strength, and dynamic scapular stabilization (scapular dyskinesia minimization), the PNF-techniques "rhythmic initiation", "combination of isotonics" and "dynamic reversals" were used, see Table 1 (Adlers et al., 2014; Smedes et al., 2016). Rhythmic initiation was defined with a passive, assisted, resisted and active phase of agonistic muscles activity (Adlers et al., 2014, p 34–35). Different kinds of agonistic muscle contraction; concentric, static, and eccentric, which mimic activities such as lifting an object and placing it down again, were the characteristics of the technique "combinations of isotonics" (Adlers et al., 2014, p 35–37). Successive contractions of agonist and antagonist directly consecutive characterize "dynamic reversals" and imitate alternating muscle activations like in using a hand saw (Adlers et al., 2014, p 37–39). These techniques were performed in the "normal timing" of the whole pattern and all three in a "timing for emphasis", with the emphasis on scapular positioning. In this specified way, effects on body structures such as the role-glide mechanism of the glenohumeral joint, muscle force

Table 1
Terminology within the PNF-concept.

PNF Philosophy	Positive approach - assessment on abilities - start treatment with an activity the patient can do - set up a patient for success - indirect treatment - no pain/respect pain		Functional approach - use of ICF classification oriented - functionally assessment and treatment - optimize functional level of patient - Evaluation of the situation, and the treatment goal.	Mobilization of reserves - active patient participation, use of irradiation - intensive training – repetition and variations (change of positions, activities and environment) - supportive training-program	Treatment of total human being. - in assessment and treatment (direct and indirect) - environmental and personal factors (physical, intellectual and emotional)			Use of motor learning and motor control principles	
PNF basic principles & procedures for facilitation	Tactile stimulus (lumbrical grip) (exteroceptive)	Verbal stimulus (exteroceptive)	Visual stimulus (exteroceptive)	Optimal resistance (proprioceptive)	Traction (proprioceptive)	Stretch/ Elongation (proprioceptive)	Irradiation and reinforcement (proprioceptive)	Pattern (procedural)	Timing (procedural)	Body mechanics (procedural)	Summation (procedural)
PNF techniques for rehabilitation	Rhythmic Initiation (agonistic technique)	Replication (agonistic technique)	Combination of Isotonics (agonistic technique)	Stretch through range (agonistic technique)	Stretch at beginning of range (agonistic technique)	Dynamic Reversals (antagonistic technique)	Stabilizing Reversals (antagonistic technique)		Rhythmic stabilization (antagonistic technique)	Hold Relax (relax/ stretching technique)	Contract Relax (relax/ stretching technique)

of the serratus anterior and the trapezius were addressed besides the specific task of lifting and reaching overhead. The order of movements of the total pattern was defined as “normal timing”. The facilitation of one specific sequence within the whole movement pattern has been called “timing for emphasis” (Adlers et al., 2014, p 26–27; Smedes et al., 2016; Johnson and Johnson, 2002).

Furthermore, the mentioned patterns of muscle activation were administered in closed chain situations, such as: prone on elbows (Fig. 1a and b + c) and in stance while supporting the upper body on outstretched hands. The closed chain positions emphasized the stability in the scapulothoracic and glenohumeral fulcrums, where the effort was delivered by the desired muscles and the load came from the body weight (Adlers et al., 2014, p 205–207; O’Sullivan et al., 2014, p 419–420).

To enhance functional reaching the principle of motor learning of “controlled mobility” or “mobility on stability” was used (Adlers et al., 2014, p 194; O’Sullivan et al., 2014, p187-189). Facilitating the scapular stability with a focus on eccentric contraction of the lower trapezius, steady resistance to the scapula was provided while at the same time facilitation for dynamic reaching within flexion diagonal D1 was given (Fig. 2) (Adlers et al., 2014).

The intervention was provided over a period of five weeks with two therapy sessions per week of 45 minutes, resulting in 10 sessions or a total treatment time of 7.5 hours. Furthermore, practising the newly learned activities and tasks in a home exercise program was ensured. Prescribed exercises were provided in writing and with an illustration, compliance was monitored with a personal logbook.

4. Results

At T1 the direct effect from the intervention was measured and all outcomes had improved. The PSC of reaching for office binders and into kitchen cupboards improved by 5 points on the VAS (both from 7 to 2), “tuck in the shirt” improved by 4 points (from 5 to 1). The general experienced pain had disappeared at T1 (NPRS from 60 to 0). The ROM had improved by 29° for flexion (from 91 to 120), by 31° for abduction (from 90 to 123) and by 17° for lateral rotation (from 35 to 52). Physical function, monitored with the PSFS, SPADI, and ASES, also improved. The PSFS by 2.3 points (from 5.3 to 7.6), the SPADI lowered by 49 points (from 65 to 16) and the ASES rose by 31.7 points (from 41.6 to 73.3). At T2, the retention of the effects 4 weeks after finishing the intervention was measured. All but one outcome measure had improved further. The average pain experience was described as a mild soreness in general, indicated as a ten on the NPRS (0–100). At T2 the PSC of reaching for office binders improved by another point (from 2 to 1), reaching into kitchen cupboards improved by another 2 points on the VAS (from 2 to 0), “tuck in the shirt” improved also by another point (from 1 to 0). Flexion ROM had increased by another 12° (from 120 to 132), abduction by another 29° (from 123 to 152), and lateral rotation by another 5° (from 52 to 57). The PSFS had gained a further 0.4 points (from 7.6 to 8), the SPADI had lowered by a further 5 points (from 16 to 11) and the ASES had improved by another 15 points (from 73.3 to 88.3). (See Table 2).

5. Discussion

5.1. Clinical reasoning

SIS problems are often categorized into primary- and secondary impingements (Belling and Jørgensen, 2000). Secondary impingement has been stated to result from instability in the shoulder (Belling and Jørgensen, 2000). Instability has been defined as any functional deficit resulting in pathological motion (Belling and

Table 2
Outcome measurements/overview of patient monitoring.

Outcome measure	T0	T1	T1-T0 (difference)	T2	T2-T0 (difference)
PSC Office binders	7	2	5	1	6
PSC cupboard	7	2	5	0	7
PSC tuck in shirt	5	1	4	0	5
NPRS	60	0	−60	10	−50
ROM Flexion	91°	120°	29°	132°	41°
ROM Abduction	92°	123°	31°	152°	60°
ROM Lateral rotation	35°	52°	17°	57°	22°
PSFS	5.3	7.6	2.3	8	2.7
SPADI	65 (50%)	16 (12.3%)	−49	11 (8.46%)	−54
ASES	41.6	73.3	31.7	88.3	46.7

T0- Baseline assessment; **T1**- Post-intervention assessment; **T2**- Follow-up assessment; **PSC** - Patient Specific Complaints; **NPRS** – Numeric Pain Rating Scale; **ROM** - range of motion; **PSFS** – Patient Specific Functional Scale; **SPADI** – Shoulder Pain and Disability Index . **ASES** - American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form.

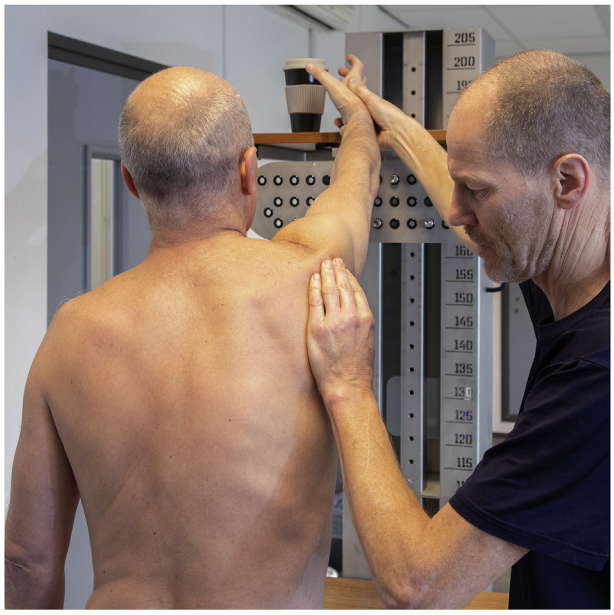

Fig. 2. Functional reaching in D1.
Note the facilitation for dynamic scapular stabilization, while active reaching (controlled mobility).

Jørgensen, 2000). Because the patient of this report demonstrated scapular dyskinesia, it was likely that a secondary impingement had been present. Furthermore, Jobe et al. (1989) suggested a "functional instability"; as an activity related issue without glenohumeral joint laxity (Jobe et al., 1989). Biomechanical imbalances of the scapula as the dynamic base for the most mobile joint in the human body (Quillen et al., 2004), might lead to an abnormal distribution of tension and result in an overload in the soft tissues of the glenohumeral joint. Scapular exercises decrease dyskinesia (Başkurt et al., 2011), which might result in a more gradual distribution of tension and load on soft tissues throughout the active movements, thus facilitating the healing process (Khan and Scott, 2009). Patient categorization in groups below 35 and above 35 years of age has been proposed (Jobe et al., 1989). In the latter group, a degenerative ageing process might result in compromising the subacromial space as described by Neer (1983). Based upon the above described components it would seem that the patient's diagnosis from this case might be more specified and detailed as an SIS within the categories of secondary impingement and functional instability with a degenerative ageing component. A simple strengthening program would, in that case, not seem sufficient.

5.2. Clinical perspective

To provide a personalized intervention, the therapy provided required addressing different components that influence the patients' activity and participation levels as defined in the international classification of functioning, disability, and health (ICF) (World Health Organisation, 2013). The comprehensive nature of the PNF-concept delivers interventions on body structure and function, such as muscle strength, coordination, and muscle flexibility, as well as functional task training (Johnson and Johnson, 2002; Adlers et al., 2014; Smedes et al., 2016). Motor learning effects have been described in using the PNF-concept in different settings such as in post stroke treatments (Smedes and Giacometti da Silva, 2019; Cayco et al., 2017) and also in musculoskeletal disorders such as "frozen shoulder" (Lee, 2015).

Several motor learning theories were utilized in the therapy; active repetitive movements resulting in a variety of practice, maximum sensory input via tactile (grasping sensory-rich objects) and proprioceptive stimuli, a mixture of internal and external focus of attention via self-controlled learning and shaping (Wulf et al., 2010; Cauraugh and Kim, 2003; Krakauer, 2006; Bund and Wiemeyer, 2004; Taub and Crago, 1994).

Altogether, this approach resulted in improvements that exceeded either the minimal detectable chance (MDC) and/or the minimal clinically important difference (MCID) of the monitoring tools used, indicating a meaningful improvement.

The ROM improvement exceeded the MCID of 11^0-16^0 as defined by Muir et al. (2010). The pain outcome exceeded the MCID of 2.17 (21.7) points on the NPRS (Michener et al., 2011). The PSFS exceeded the MDC of 1.2 (Hefford et al., 2012), as did the ASES which has a MDC of 9.7 (Michener et al., 2002). The SPADI also improved beyond the MDC of 18 points (Breckenridge and McAuley, 2011). The ASES and SPADI outcomes also exceeded the MCID of respectively 6.4 and 13.1 (Roy et al., 2009). The follow-up (T2) outcomes indicate possible motor learning effects since the effects of the outcome measures were retained or even further improved, although the follow-up (T2) was only four weeks (Wulf et al., 2010, 2016).

Given the study design of a single case report (N = 1), there are limitations from this report to generalize the effects on a total population of patients diagnosed with SIS. Nevertheless case studies seem to be the appropriate study design for explaining the use of a comprehensive approach (Smedes et al., 2016). The different components of the strategy used, in this case the PNF-concept, can be specifically described in a case report. Researchers often have to narrow down the variability that physical therapy provides, to study a single component for its specific effect. Those study designs do not represent the way therapy is provided

in daily practice. Therefore, the choice of this case study seems to be suitable for the objective of testing the feasibility of the PNF-concept. The results of this case report should not be generalized to patients with SIS in general. Rather, this case report should be used as an inspiration and motivation for further research in larger groups to determine the effectiveness of the PNF-concept in treating patients with SIS.

6. Conclusion and take-home message

The provided therapy in this specific case was successful in regards to changing patient's abilities in ADL. The results exceeded the MDC and/or the MCID of advocated monitoring instruments. Therefore, the specified PNF-based therapy with a focus on motor learning effects was shown to be a feasible option for physical therapy interventions.

The clinical reasoning in activity limitations and underlying impairments (ICF) was essential in determining a therapy approach that was supported with external evidence. Further research to determine the efficacy of a PNF-based rehabilitation approach is warranted.

Declaration of competing interest

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