Original Article

CLINICAL REHABILITATION

Clinical Rehabilitation
1–10

DOI: 10.1177/0269215516687613
journals.sagepub.com/home/cre
SAGE

Activity- vs. structural-oriented treatment approach for frozen shoulder: a randomized controlled trial

Renata Horst[1], Tomasz Maicki[2,3], Rafał Trąbka[2,3], Sindy Albrecht[4], Katharina Schmidt[5], Sylwia Mętel[6] and Harry von Piekartz[7]

Abstract

Objective: To compare the short- and long-term effects of a structural-oriented (convential) with an activity-oriented physiotherapeutic treatment in patients with frozen shoulder.

Design: Double-blinded, randomized, experimental study.

Setting: Outpatient clinic.

Subjects: We included patients diagnosed with a limited range of motion and pain in the shoulder region, who had received a prescription for physiotherapy treatment, without additional symptoms of dizziness, a case history of headaches, pain and/or limited range of motion in the cervical spine and/or temporomandibular joint.

Interventions: The study group received treatment during the performance of activities. The comparison group was treated with manual therapy and proprioceptive neuromuscular facilitation (conventional therapy). Both groups received 10 days of therapy, 30 minutes each day.

Main measures: Range of motion, muscle function tests, McGill pain questionnaire and modified Upper Extremity Motor Activity Log were measured at baseline, after two weeks of intervention and after a three-month follow-up period without therapy.

Results: A total of 66 patients were randomized into two groups: The activity-oriented group ($n = 33$, mean = 44 years, SD = 16 years) including 20 male (61%) and the structural-oriented group ($n = 33$, mean = 47 years, SD = 17 years) including 21 male (64%). The activity-oriented group revealed significantly greater improvements in the performance of daily life activities and functional and structural tests compared with the group treated with conventional therapy after 10 days of therapy and at the three-month follow-up ($p < 0.05$).

[1]Private Practice and Institute for Further Education for Medical Professions, Ingelheim, Germany
[2]Clinic of Rehabilitation, Jagiellonian University, Cracow, Poland
[3]Cracow Rehabilitation Center, Cracow, Poland
[4]Leuphana University, Lüneburg, Germany
[5]Department of Sports Medicine, Goethe-University, Frankfurt am Main, Germany
[6]Department of Physical Medicine and Biomedical Renewal, University of Physical Education in Krakow, Cracow, Poland
[7]University of Applied Science, Hochschule Osnabruck Fakultat Wirtschafts- und Sozialwissenschaften, Osnabrueck, Germany

Corresponding author:
Renata Horst, Private Practice, Stiegelgasse 40, Ingelheim 55218, Germany.
Email: info@renatahorst.de

Conclusions: Therapy based on performing activities seems to be more effective for pain reduction and the ability to perform daily life activities than conventional treatment methods.

Keywords
Shoulder, pain, manual therapy, proprioceptive neuromuscular facilitation, neuro-orthopaedic activity-dependent plasticity, motor learning

Received: 30 August 2015; accepted: 11 December 2016

Introduction

Patients with frozen shoulder generally suffer a great deal of pain, which often causes prolonged limitations in performance of daily activities and in participation in socio-cultural life. The prevalence of frozen shoulder is estimated to be 2% to 5% of the general population. It is more prevalent in women and middle-aged to older people, and the non-dominant shoulder is slightly more likely to be affected. In general, the term frozen shoulder is used for both primary adhesive capsulitis as well as secondary frozen shoulder.[1]

Feeling pain, often accompanied with fear of pain or body injury, causes activity avoidance (non-use) or 'freezing' of the shoulder. One underlying clinical hypothesis is that pain causes learned non-use, which entails changes in the brain and therefore, even after healing of periphereal structures has occurred, the brain may not be able to organize voluntary actions owing to the induced central changes.[2,3] This raises two questions for orthopaedic patients: (1) whether changes in peripheral structures alone or also central changes in cortical representation may be responsible for limitations, and (2) whether interventions, which incorporate treatment of body structures during the performance of activities, may be more effective for long-term effects and memory than physical therapy, which emphasizes treatment at the structural level alone.

Conventional methods for treatment of neuromusculoskeletal disorders primarily focus on the functioning of body structures, assuming that if joint play is restored and if stiff or contract muscles are relaxed and weak muscles strengthened, the ability to perform activities is automatically recovered.[4,5] A total of 26 trials were included for a meta-analysis and published in a Cochrane review, which showed that the efficacy of conventional physiotherapy, as the first line of treatment for shoulder pain, has not been established.[6] Passive mobilization techniques may even be harmful for the glenohumeral joint.[7] Up to now, studies comparing two different physiotherapeutic interventions have not been able to demonstrate significant differences in outcomes. Short-term increases in range of motion did not correlate with improvement in quality of life. No studies have been found that included the patient's subjective evaluation. Consequently, no conclusions can be drawn pertaining to cost-efficiency for any specific intervention.[8]

Numerous studies have shown that learning depends on experience and it is assumed that practise that enables experience changes the nervous system.[9–13] How practise is structured determines if consolidation, which is the basis for long-term learning, will result.[14,15] Activity-oriented movement strategies depend on cognitive aspects, such as memory, experience and intention, as well as feelings and emotions, which are essential for memory and learning.[16,17]

Considering these facts, the aim of this randomized trial is to compare the short- and long-term effects of a structural-oriented with an activity-oriented physiotherapeutic treatment.

Methods

This double-blinded, randomized, experimental study was approved by the Regional Medical Ethics Board of Physicians in Krakow, Poland (*pol. Okręgowa Izba Lekarska w Krakowie*) nr 18/KBL/OIL/2011. We only included patients who had been diagnosed with limited range of motion, pain in the shoulder region and had received a prescription for physiotherapy treatment at the Krakow Rehabilitation Centre in Krakow, Poland, by an orthopaedic specialist. The orthopaedic specialist had more than 20 years of experience in treatment of these patients. No limitations pertaining to age and gender were made.

Before being enrolled in the study, potential participants received oral and written information about the study and had to provide written informed consent. Following, patients were asked to complete a questionnaire describing their case history and symptoms to assess eligibility. Patients were excluded if they had additional symptoms of dizziness and a case history of headaches, pain and/or limited range of motion in the cervical spine and/or temporomandibular joint. Prior to the first treatment, participants were randomly assigned to one of the two treatment groups by drawing a sealed envelope, which entailed either an even or an odd number. Patients who drew an even number were assigned to the activity-oriented group. Those who drew an odd number were assigned to the structural-oriented group.

One blinded therapist, who had no knowledge of which intervention the patients received, performed all tests. Assessments were done at baseline (before the first intervention), after two weeks with ten physiotherapy sessions and after three-months follow-up without therapeutic intervention. Participants in both groups did not receive any information about the kind of intervention or treatment they were receiving.

Four therapists took part in the study. Two therapists treated their patients at an activity level and the other two therapists treated their patients at a structural level. All therapists had a minimum of four years practical experience as physiotherapists after having completed their Master Degrees at the University. The two therapists for the structural-oriented group had also been certified in further education courses as manual therapists and therapists in proprioceptive neuromuscular facilitation. The two therapists for the activity-oriented treatments had been trained in the methods described later in Table 2.

Table 1. Description of activities which were assessed.

Activity 1	Putting on and taking off a t-shirt with both hands.
Activity 2	Placing both hands behind the neck, as to fasten a necklace.
Activity 3	Placing both hands behind the back, as to tie an apron.
Activity 4	Lifting a bottle of 1 L contents onto a shelf of 145 cm height with the affected arm.
Activity 5	Lifting a case of water containing 9 L with both hands onto a height of 145 cm.

The McGill pain questionnaire and modified Upper Extremity Motor Activity Log were used for patient's subjective evaluation (see Appendix 1 and 2, available online).[18,19] The Upper Extremity Motor Activity Log, which was developed for assessing the capability to perform 30 different activities of daily living in patients following stroke, was modified to focus on five relevant daily life activities, which patients with frozen shoulder were not able to perform before therapy onset (Table 1).

Tests for range of motion were performed using a 12-inch plastic BASELINE goniometer, (Model 12-1000) Fabrication Enterprises (White Plains, New York) for all goniometric measurements.[20] The muscle testing procedures from Daniels and Worthingham were applied to assess strength of all major muscles of the shoulder. In this system, muscle strength is scored with a numerical grading system ranging from 0, indicating no muscle activation, to 5 for the best possible response to manual resistance in a shortened range of the muscle group performing the motion.[21]

All subjects received a total of 10 therapeutic sessions in a time period of two weeks for a duration of 30 minutes each. The activity-oriented group (study group) was instructed to focus on attaining a relevant goal during the manual guidance of the therapist with the aim to enable the best possible musculoskeletal situation for the required movements.[22] The structural-oriented group (comparison group) was treated at the structural level according to conventional physical therapy methods: Manual therapy and proprioceptive neuro-muscular facilitation techniques.[4,5]

Table 2. Comparison of methods applied in the activity-oriented treatment (study group) with the methods of the structural-oriented therapy (comparison group).

	Methods of activity-oriented therapy	Methods of structural-oriented therapy
1.	Randomized practise: For example, training external rotators of the shoulder in different situations, such as rolling from side-lying to supine, sitting back on the heels in quadriped, putting on a jacket, with only a few repetitions between the different activities.	Blocked practise: For example, practising a particular PNF pattern to train the external rotators of the shoulder until it can be performed before going on to a second pattern.
2.	Intrinsic feedback: For example, asking the patient how he thinks he could control his scapula to avoid pain.	Extrinsic feedback: For example, telling the patient how to control his scapula motion to avoid pain.
3.	External focus: For example, asking the patient to comb his hair.	Internal focus: For example, telling the patient to lift his arm.
4.	Mental and emotional involvement: For example, during sitting back on the heels in quadriped, the humeral head is actively mobilized in a ventral direction owing to eccentric activation of the *Musculus latissimus dorsi*.	Passive mobilization techniques: For example, the therapist mobilizes the humeral head in a ventral direction to increase external rotation.
5.	Influencing biomechanics during performance of activities: For example, rotating the clavicula dorsally and caudally during the activity of putting on a t-shirt over head to enable decompression of the acromo-clavicular joint.	Tactile input for movement initiation: For example, passive mobilization of the scapula in posterior depression to show the patient where to move with successive increase in resistance for the scapula depressors.
6.	Shaping according to individual potentials and needs: For example, beginning in standing if necessary to perform the activity of putting on a t-shirt or combing ones hair.	Fixed sequence of exercises: For example, beginning in lying positions and successively going into higher positions.
7.	Training distally organized movements together with subconsciously controlled proximal ones: For example, while the patient attempts to grasp an object over head the therapist enables joint stability by stimulating mechanoreceptors in applying pressure upon the humeral head towards the glenoid fossa.	Training proximal body parts cognitively and separately before distal ones: For example, the therapist gives traction to the humeral head and asks the patient to actively pull the humeral head into the glenohyoidal socket or gives resistance to the angulus inferior asking the patient to push it downwards.

PNF: proprioceptive neuromuscular facilitation.

Table 2 provides insight to the methods for both intervention groups. Both groups received the same additional treatment consisting of aerobic training, cryotherapy, laser therapy and resistance band exercises.

Categorical variables were described using counts and percentages. The quantitative variables were described using median and quartiles (Me [Q1;Q3]), mean and SD. The null hypothesis of no difference concerning changes in all study outcomes between groups was tested based on a comparison of change scores (ChS) using the Mann–Whitney test. For categorical variables, statistical significance of differences between groups was assessed using the Fisher's exact test. A p-value less than 0.05 was considered as an indication of a statistically significant result. No adjustment for multiple comparisons was made. All statistical analyses were performed using R 3.0.[23]

Results

The study was conducted between 2011 and 2012. A total of 66 patients were statistically analysed, six patients were excluded (Figure 1). The activity-oriented group ($n=33$, mean age = 44 years, SD = 16 years) included 20 male (61%) and 13 female (39%) patients. The structural-oriented group ($n=33$, mean age = 47 years, SD = 17 years) comprised 21 male (64%) and 12 female (36%) patients. At baseline, groups were comparable concerning

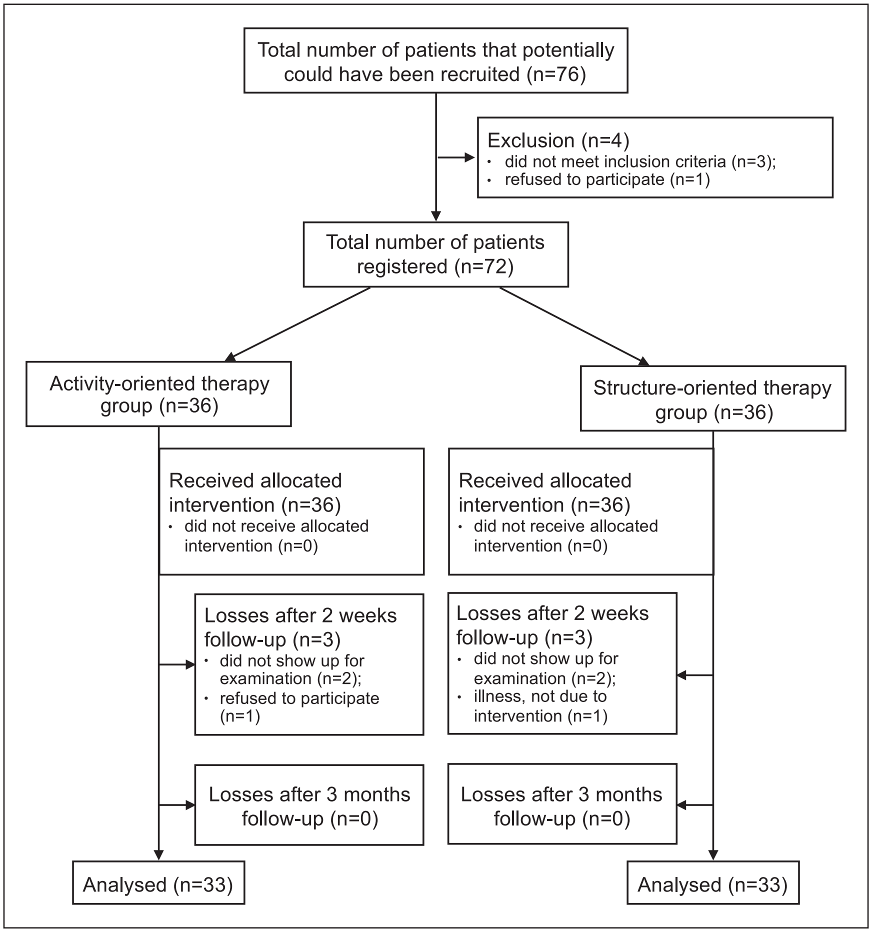

Figure 1. Flowchart of study participation.

age and gender distribution as well as all study outcomes ($p > 0.05$).

Table 3 and 4 display the changes in the outcome measures after two weeks of intervention (after 2) and after the 3-month follow-up (after 3). In more than half of the outcomes, the activity-oriented group experienced significantly greater improvements in comparison with the structural-oriented group.

Regarding the activities of daily living, a greater percentage of the activity-oriented group compared with the structural-oriented group was able to perform activities number 4 and 5 after two weeks of intervention and activities number 1, 3 and 5 at 3-month follow-up ($p < 0.05$) (Table 3). Concerning pain, the activity-oriented group had a significantly greater reduction from baseline to the 3-month follow-up than the structural-oriented group ($p < 0.05$). With respect to range of motion, significant group differences in favour of the activity-oriented group were found for changes in adduction, and external and internal rotation from baseline to the second and third assessment (Table 4). Changes in muscle strength of the flexors, adductors, abductors, internal rotators and external rotators from baseline to the end of the intervention and to the three-month follow-up were significantly higher in the activity-oriented group compared with the structural-oriented group ($p < 0.05$) (Table 4).

Table 3. Group comparisons for the treatment outcomes concerning activities of daily living. (Number and percentage of patients being able to perform the activity.).

	Activity-oriented group	Structural-oriented group	*p*-value
	n = 33	*n* = 33	
Activity no. 1			
Before	15 (45%)	12 (36%)	0.617
After 2	29 (88%)	22 (67%)	0.076
After 3	31 (94%)	22 (67%)	**0.011**
Activity no. 2			
Before	16 (48%)	17 (52%)	1.000
After 2	30 (91%)	27 (82%)	0.475
After 3	31 (94%)	28 (85%)	0.426
Activity no. 3			
Before	16 (48%)	11 (33%)	0.317
After 2	28 (85%)	21 (64%)	0.090
After 3	32 (97%)	24 (73%)	**0.012**
Activity no. 4			
Before	17 (52%)	10 (30%)	0.132
After 2	29 (88%)	21 (64%)	**0.042**
After 3	31 (94%)	25 (76%)	0.082
Activity no. 5			
Before	4 (12%)	3 (9%)	1.000
After 2	17 (52%)	6 (18%)	**0.010**
After 3	25 (76%)	6 (18%)	**<0.001**

Activity-oriented group (study group): patients receiving treatment during the performance of activities; structural-oriented group (comparison group): patients treated with manual therapy and proprioceptive neuromuscular facilitation.
Treatment outcomes– Before: baseline measurements; After 2: after two weeks of intervention; After 3: follow-up examination (after three months).
Bold values: $p<0.05$.

Discussion

The present randomized study compared the effects of a structural-oriented with an activity-oriented physiotherapeutic intervention. The results of this study indicate that influencing body structures during the execution of daily life activities is more effective than conventional physiotherapeutic methods and has both short-term and especially long-term effects for reducing pain and enabling the performance of activities of daily living.

These improvements were not only measured after 10 days of physiotherapy, but also continued during a follow-up period of three months without therapy. These findings suggest that consolidation may be significantly better when following an activity-oriented approach rather than a structural-oriented one. Evidence has demonstrated that experience-induced changes occur even after short periods of practise.[24] Therefore, it may not be necessary to mobilize joints passively and to strengthen muscles as a preparation for activities. Experiencing successful activities themselves may induce long-term structural changes and less pain perception. Since plasticity is dependent on experience and how treatment sessions are structured, practising relevant goal-oriented activities while ensuring the best possible musculoskeletal situation may enable the patient to perform these activities with less pain and herewith regain cortical representation.[9–13]

When injury occurs, it is a very effective strategy to ‘freeze’ the injured body part to enable wound healing to occur. For this, the sympathetic nervous system generates a cascade of biochemical

Table 4. Changes in study outcomes showing a comparison of the activity-oriented group with the structural-oriented group after two weeks of intervention and after three months of treatment compared with baseline measurements.

Outcome	Activity-oriented group	Structural-oriented group	*p*-value	95% CI:
	Median [Q1;Q3]	Median [Q1;Q3]		Differences between medians
Pain ChS				
After 2	−10 [−11;−6]	−7 [−9;−6]	0.083	(−4;1)
After 3	−15 [−17;−10]	−10 [−13;−6]	**0.005**	(−8;−1)
Range of motion				
Flexion ChS				
After 2	23 [6;39]	15 [12;24]	0.286	(−8;21)
After 3	32 [6;48]	18 [12;29]	0.338	(−11;27)
Extension ChS				
After 2	30 [10;40]	20 [0;30]	0.113	(0;20)
After 3	30 [20;50]	20 [0;30]	0.061	(0;40)
Rotation internal ChS				
After 2	29 [21;43]	14 [8;22]	**<0.001**	(8;24)
After 3	36 [22;57]	15 [7;36]	**0.003**	(4;31)
Rotation external ChS				
After 2	25 [17;34]	17 [8;25]	**0.025**	(0;16)
After 3	34 [25;59]	25 [16;33]	**0.017**	(0;25)
Abduction ChS				
After 2	24 [12;35]	18 [12;30]	0.700	(−8;14)
After 3	29 [12;47]	26 [15;38]	0.386	(−10;21)
Adduction ChS				
After 2	22 [15;41]	15 [11;20]	**0.009**	(0;17)
After 3	26 [15;52]	19 [15;27]	**0.024**	(0;23)
Muscle strength				
Flexion ChS				
After 2	30 [10;70]	5 [0;20]	**0.001**	(10;40)
After 3	40 [20;80]	10 [0;40]	**0.001**	(10;70)
Extension ChS				
After 2	30 [0;70]	20 [10;50]	0.990	(−25;20)
After 3	60 [10;80]	20 [10;70]	0.167	(−30;60)
Rotation internal ChS				
After 2	20 [10;70]	0 [0;10]	**<0.001**	(10;35)
After 3	40 [10;80]	0 [0;10]	**<0.001**	(15;70)
Rotation external ChS				
After 2	10 [0;30]	5 [0;10]	0.059	(0;15)
After 3	20 [10;70]	5 [0;10]	**0.001**	(5;35)
Abduction ChS				
After 2	20 [5;60]	0 [0;10]	**0.002**	(5;30)
After 3	20 [5;80]	0 [0;10]	**<0.001**	(10;80)
Adduction ChS				
After 2	20 [5;70]	10 [0;10]	**0.010**	(0;40)
After 3	55 [10;90]	10 [10;40]	**0.012**	(0;70)

Activity-oriented group (study group): patients receiving treatment during the performance of activities; structural-oriented group (comparison group): patients treated with manual therapy and proprioceptive neuromuscular facilitation; ChS: change score; CI: confidence interval.
Treatment outcomes – After 2: after two weeks of intervention; After 3: follow-up examination (after three months).
Bold values: p<0.05.

processes, such as protective muscle tone of muscles with primary tonic muscle fibres and contraction of myofibroblasts within connective tissues.[25] As long as injured body structures require immobilization, these protective mechanisms fulfil a meaningful task. If they are kept up longer than necessary, then this may lead to learned non-use, loss of cortical representation and finally to stiffness, which in turn may cause increased pain and again activates the sympathetic system. In order to stop this vicious circle, it appears reasonable that the patient needs to experience that these protective mechanisms are no longer necessary.

Application of external tactile stimuli by the therapist is fundamental to both, orthopaedic manual therapy and neurophysiological treatment concepts. However, conventional therapy concepts, which follow a stimulus-response approach using the hands as a tool to initiate movement or to prepare structures for activities, may not be as effective for long-term learning as structuring practise to enable the successful performance of various activities.[9,10,16,17]

In neurological rehabilitation, a great amount of research has been done within the past few decades, which has led to new clinical implications for neurological patients. Brain research may also help to better understand the mechanisms underlying the pathologies of orthopaedic patients. Since plastic changes within the capsule require sufficient force applied to tissues, perhaps stiffness and decreased range of motion were not primarily owing to capsule adhesions.[26] Since pain is considered to be subjective and dependent on individual experience, persisting even if structures are no longer affected or not even existent, the reduction of pain perception may not have solely been caused by treating peripheral body structures.[27] The experience that relevant goals were able to be attained with less pain by ensuring the best possible musculoskeletal situation during the performance of daily life activities may possibly explain the results of this study.

In summary, the clinical implication from these observations and knowledge from current evidence is that practising activities leads to better performance of these. Pain reduction, as well as increased range of motion, can also be influenced effectively by influencing body structures during the performance of activities rather than treating these alone. Brain plasticity may be the explanation for the positive treatment results rather than plasticity of peripheral structures alone.

A limitation to this study is that within the inclusion criteria no difference was made between patients with 'primary frozen shoulder' (spontaneous painful contracture of the glenohumeral joint with no distinct causes) and 'secondary frozen shoulder' (caused by rotator cuff ruptures, neurological impairments and metabolic disorders, associated with diabetes mellitus).[28] Even among the 'secondary frozen shoulder' patients, it may be worthwhile to study the differences in outcome regarding the different causes and stages of pathology. A patient with a metabolic disorder may not profit from treatment of the structures concerning the shoulder complex, whereas a patient with a rotator cuff rupture may.

The duration of therapy, which lasted for only 10 days for 30 minutes daily, was specific for the rehabilitation centre where the study was carried out. It may be helpful to gain more insight for general clinical implications by gathering information on outcomes for patients who remain in therapy for four weeks, with a therapy frequency of two to three times a week as well. A further limitation was owing to the fact that all patients had a medical prescription for physiotherapy. Consequently, it was not possible to assess a non-intervention control group, but we used conventional physiotherapy as standard treatment for the comparison group. Nevertheless, since the focus of the study group was at the activity level, it is possible that patients who do not receive physiotherapy and have to cope in activities of daily living may have improvements as well. Future studies may need to include patients who have had a case history of shoulder pain and limited range of motion of at least three months prior to baseline to rule out this assumption.

The question that may require further investigation is of how much importance it may be to influence body structures during the execution of voluntary goal-oriented activities to enable positive movement experiences and how relevant this may be for better performance of daily life activities. The consideration of positron emission tomography may be useful to identify potential changes in cortical representation before and after therapy. Future studies may help to gain insight as to how neuroplasticity may be influenced for better outcome in neuromusculoskeletal disorders and lead to better collaboration between musculoskeletal and neurological physiotherapists.

Clinical messages

- An activity-oriented therapy programme has a larger and much more prolonged beneficial effect than structurally oriented therapy.

Acknowledgements

I wish to thank Topschool Cracow and the staff of the Cracow Rehabilitation Center in Cracow, Poland, for providing patients for this study.

Conflict of interest statement

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

References

1. Kelley MJ, McClure PW and Leggin BG. Frozen shoulder: Evidence and a proposed model guiding rehabilitation. *J Orthop Sports Phys Ther* 2009; 39(2): 135–148.
2. Klug S, Anderer P, Saletu-Zyhlarz G, et al. Dysfunctional pain modulation in somatoform pain disorder patients. *Eur Arch Psychiatry Clin Neurosci* 2011; 261(4): 267–275.
3. Vartiainen N, Kirveskari E, Kallio-Laine K, Kalso E and Forss N. Cortical reorganization in primary somatosensory cortex in patients with unilateral chronic pain. *J Pain* 2009; 10(8): 854–859.
4. Kaltenborn FM. Teil 1 Extremitäten. 12. Auflage, Oslo: Norli, 2005: 203–229.
5. Buck M, Beckers D and Adler SS. PNF in der Praxis. 6. Auflage. Berlin-Heidelberg: Springer, 2010: 38–40, 43–44, 50–55, 85–86, 109–116, 240–242.
6. Green S, Buchbinder R and Hetrick SE. Physiotherapy interventions for shoulder pain. *Cochrane Database Syst Rev* 2003; (2). Art. No.: CD004258. DOI: 10.1002/14651858.CD004258.
7. Donatelli R, Ruivo RM, Thurner M and Ibrahim MI. New concepts in restoring shoulder elevation in a stiff and painful shoulder patient. *Phys Ther Sport* 2014; 15(1): 3–14.
8. Maund E, Craig D, Suekarran, et al. Management of frozen shoulder: A systematic review and cost-effectiveness analysis. *Health Technol Assess* 2012; 16: 11.
9. Kleim JA and Jones TA. Principles of experience-dependent neural plasticity: Implications for rehabilitation after brain damage. *J Speech, Lang Hear Res* 2008; 51(1): 225–239.
10. Dayan E and Leonardo LG. Neuroplasticity subserving motor skill learning. *Neuron* 2011; 72(3): 443–454.
11. Draganski B and May A. Training-induced structural changes in the adult human brain. *Behav Brain Res* 2008; 192(1): 137–142.
12. Lövden M, Wenger E, Mårtensson J, Lindenberger U and Bäckman L. Structural brain plasticity in adult learning and development. *Neurosci Biobehav Rev* 2013; 37(9 Pt B): 2296–2310.
13. May A. Experience-dependent structural plasticity in the adult human brain. *Trends Cogn Sci* 2011; 15(10): 475–482.
14. Kantak SS, Sullivan KJ, Fischer BE, Knowlton BJ and Winstein CJ. Neural substrates of motor memory consolidation depend on practice structure. *Nat Neurosci* 2010; 13: 923–925.
15. Cross ES, Schmitt PJ and Grafton ST. Neural substrates of contextual interference during motor learning support a model of active preparation. *J Cogn Sci* 2007; 19: 1854–1871.
16. Abe M, Schambra HM, Wassermann EM, Luckenbaugh D, Schweighofer N and Cohen LG. Reward improves long-term retension of a motor memory through induction of offline memory gains. *Curr Biol* 2011; 21(7): 557–562.
17. Pignatelli M and Bonci A. Role of dopamine neurons in reward and aversion: A synaptic plasticity perspective. *Neuron* 2015; 86: 1145–1157.
18. Melzak R and Katz J. Pain measurement in persons in pain. In: Wall PD and Melzak R (eds) *Textbook of pain*, 4th ed. Edinburgh: Churchill Livingston, 1999: 409–426.
19. Uswatte G, Taub E, Morris D, Light K and Thompson PA. Reliability and validity of the Motor Activity Log-28. Assessing use of the hemiparetic arm after stroke. *Neurology* 2006; 67: 1189–1194.
20. Kolber MJ and Hanney WJ. The reliability and concurrent validity of shoulder mobility measurements using a digital inclinometer and goniometer: A technical report. *Int J Sports Phys Ther* 2012; 7(3): 306.
21. Daniels L and Worthingham K. *Muscle testing – Techniques of manual examination*, 7th ed. Philadelphia, PA: WB Saunders Co., 2002.
22. Horst R. N.A.P. – Therapieren in der Neuroorthopädie. Stuttgart: Thieme, 2011: 12–48, 50–78.

23. R Development Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing, 2011.
24. Scholz J, Klein MC, Behrens TEJ and Johansen-Berg H. Training induces changes in white matter architecture. *Nat Neurosci* 2009; 12(11): 1370–1371.
25. Schleip R. Fascial plasticity – a new neurobiological explanation: Part 1. *J Bodywork Movement Ther* 2003; 7(1): 11–19.
26. Findley T, Chaudry H and Dhar S. Transmission of muscle force to fascia during exercise. *J Bodywork Movement Ther* 2015; 19: 119–123.
27. Melzak R. Introduction: The pain revolution. In: Melzak R and Wall PD (eds) *Handbook of pain management*. Edinburgh, Churchill Livingstone, 2003: 2–3.
28. Uppal HS, Evans JP and Smith C. Frozen shoulder: A systematic review of therapeutic options. *World J Orthop* 2015; 6(2): 263–268.