EUR J PHYS REHABIL MED 2014;50:255-64

Neurocognitive therapeutic exercise improves pain and function in patients with shoulder impingement syndrome: a single-blind randomized controlled clinical trial

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Background. **Traditional rehabilitation improves pain and function in patients with shoulder impingement syndrome. Neurocognitive rehabilitation has shown to be highly effective after surgical reconstruction of the anterior cruciate ligament. However, its effects in patients with shoulder impingement syndrome have not yet been established.**
Aim. **The aim of the study was to compare the effects of neurocognitive therapeutic exercise, based on proprioception and neuromuscular control, on pain and function in comparison to traditional therapeutic exercise in patients with shoulder impingement syndrome.**
Design. **Single-blind randomized, non-inferiority clinical trial.**
Setting. **Outpatient clinic of Geriatrics and Physiatrics, University Hospital.**
Population. **Forty-eight patients with shoulder impingement syndrome (Neer stage I) and pain lasting for at least three months.**
Methods. **Participants were randomly allocated (1:1) to either neurocognitive therapeutic exercise or traditional therapeutic exercise. Both treatments were provided one-hour session, three times a week for five weeks. The primary outcome measure was the short form of the Disability of the Arm, Shoulder and Hand Questionnaire (Quick-DASH questionnaire) for the assessment of physical ability and symptoms of the upper extremity. Secondary outcome measures: Constant-Murley shoulder outcome score for the determination of range of motion, pain and strength; American Shoulder and Elbow Surgeons Society standardized shoulder assessment form for the evaluation of physical ability in daily-living tasks; a visual analogue scale for pain assessment at rest and during movements; Likert score for the estimation of participant satisfaction. Endpoints: before treatment, end of treatment, 12 and 24 weeks after the completion of each intervention for all outcome measures, except for the Likert score that was evaluated only at the end of treatment. Follow-up: 24 weeks.**
Results. **At the end of treatment and at follow-up, both treatment groups experienced improvements in all outcomes measures relative to baseline values, except for the visual analogue scale at rest that was unaffected by traditional therapeutic exercise. For all outcome measures, changes over time were greater in the neurocognitive therapeutic exercise group relative to the traditional therapeutic exercise group. The level of satisfaction with treatment was higher for participants in the neurocognitive therapeutic exercise group.**
Conclusion. **Neurocognitive rehabilitation is effective**

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in reducing pain and improving function in patients with shoulder impingement syndrome, with benefits maintained for at least 24 weeks.

Clinical Rehabilitation Impact. **In patients affected by shoulder impingement syndrome, pain, range of motion, skills and function of the shoulder can greatly benefit from neurocognitive rehabilitation.**

KEY WORDS: Upper extremity - Proprioception - Shoulder pain - Tendinopathy - Rehabilitation.

Shoulder impingement syndrome (SIS) is the most common cause of shoulder pain, accounting for 44-65% of all shoulder complaints.[1] The syndrome is caused by the compression and mechanical irritation of the rotator cuff and subacromial bursa against the anterior undersurface of the acromion and coracoacromial ligament, especially during elevation of the arm.[2] SIS encompasses various pathological entities, such as subacromial bursitis, rotator cuff tendinopathy, partial rotator cuff tears and small full-thickness tears.[3] Clinical manifestations include pain with arm abduction and flexion that often occurs at rest, decreased active range of motion (ROM), and loss of arm strength and function.[1, 3]

The first-line management of SIS is represented by conservative treatment based on therapeutic exercises, application of physical agents (*e.g.*, electromagnetic fields, heat, and ultrasound), nonsteroidal anti-inflammatory drugs (NSAIDs), oral steroids and local injection of corticosteroids.[4] Several techniques of exercise have proven effective in SIS. Traditional therapeutic exercise (TTE) (*e.g.*, strengthening exercises with weights, stretching exercises for the anterior and posterior capsule, Codman's pendulum exercises, exercises against thera-band resistance) is commonly used in clinical practice and is effective in relieving pain, strengthening the rotator cuff and scapular stabilizing muscles, and improving ROM and muscle elasticity.[5-11] Nevertheless, a general agreement exists that higher quality studies are needed to provide a more accurate and standardized methodology and a clearer description of the exercises used.[12-14]

Neurocognitive therapeutic exercise (NCTE), the efficacy of which has recently been demonstrated in rehabilitation after surgical reconstruction of the anterior cruciate ligament,[15] is rarely used in SIS patients. NCTE is a rehabilitative approach based on the stimulation and the improvement of higher cortical functions such as attention, awareness, memory and language, which confer patients the ability to interact with the environment in order to know it and give it a meaning. The exercise is an activity planned by the therapist as a proprioceptive and motor problem-solving task that the patient has to resolve by utilizing higher cortical functions. The patient needs to select the most significant proprioceptive information from the interaction with specific instruments and use the cortical feedback to guide muscle contraction and organize the motor behavior. NCTE is a cognitive sensory motor training rehabilitation focused on sensory retraining, which is important for the execution of fine motor skills.[16, 17] During these activities, the hand can explore, recognize and discriminate the characteristics of objects also without visual input. During the execution of these guided somatosensory discrimination exercises, the spatial features of perceived objects are extracted and subsequently integrated by higher cortical functions in a mental representation of the object's shape.[18] This may be especially relevant to SIS rehabilitation, given the fact that patients with this condition often exhibit alterations in muscle activation with suppressed rotator cuff coactivation, humeral mover alterations during arm elevation, and increased middle deltoid and latissimus dorsi activity.[19, 20]

Based on these premises, the purpose of the present study was to evaluate the efficacy of neurocognitive rehabilitation on shoulder function and pain in patients with SIS in comparison to TTE.

Materials and methods

Participants

The study was designed as a single-blind randomized, non-inferiority trial and took place from April 2011 through May 2012. Participants were recruited from the outpatient clinic of Geriatrics and Physiatrics, "Agostino Gemelli" Teaching Hospital (Catholic University of the Sacred Heart, Rome, Italy), and the outpatient clinic of Physiatrics, "Sant'Andrea" Teaching Hospital (La Sapienza University of Rome, Rome, Italy). Men and women aged 18 years or older with shoulder pain lasting for at least three months as a consequence of SIS were eligible for inclusion. The diagnosis of SIS was established by clinical ex-

amination, including four isometric tests (abduction at 0° or 30°, external or internal rotation, positive Kennedy-Hawkins sign and positive Neer sign), X-ray in anteroposterior, axillary and outlet views, and magnetic resonance imaging (MRI) or echography of the affected shoulder. Subjects with Neer stage I SIS, degenerative rotator cuff tendinopathy without tendon tears and/or subacromial bursitis were included. Exclusion criteria were: inability or unwillingness to sign informed consent, rotator cuff and/or subscapularis tendon partial/full-thickness tears, capsulolabral pathology responsive to surgical repair, congenital abnormalities of the acromion, previous surgery on the affected shoulder, inflammatory or neurological (systemic or local) diseases involving shoulder girdles, cognitive or psychiatric disorders, local tumor metastasis or application of radiotherapy, acute infections or osseous tuberculosis. The study protocol was approved by the local Ethics Committees (ClinicalTrials.gov Identifier: NCT01785745).

Eligible participants were referred to a physician not involved in the study and provided with detailed information about the experimental protocol. Informed consent was obtained from each participant prior to treatment allocation. Patients were randomly assigned to either NCTE (group 1) or TTE (group 2) using a random sequence generator (www.random.org). Allocation concealment was performed using closed envelopes, and the assignment code of each patient revealed to the researcher who performed the treatment only at the beginning of the therapeutic protocol. Information pertaining to demographics, education, lifestyle habits, pain duration, emotional distress, comorbidities and medications was collected using a dedicated questionnaire.

Interventions

Both TTE and NCTE were administered by experienced physiotherapists. The rehabilitative aim of NCTE was to teach the patient how to control pathological elements (joint stiffness, pain, muscle contraction, and muscle atrophy) avoiding compensation and how to rebuild and recover movements in a smooth and functional way. Exercises involving specific instruments (inclined table with a board with five concentric circles, tangents in one place and with a radius which increases each time of 7 cm, checkerboard, tablet swinging in a lateral side way placed on the floor with rollers, sponges of various texture) were taught to promote the stimulation of higher cortical functions useful to select the most important proprioceptive information necessary to organize the motor behavior and recover fine motor skills. The execution of the exercises are facilitated by using motor imagery that the therapist can evoke in a correct way by making the patient feel, at first, a movement with the unaffected side and then by asking him/her to transfer motor imagery features to the affected side and make a comparison with what is actually perceived.[21]

The neurocognitive protocol contained 10 exercises. The first three, performed in the early stages of treatment, aimed at restoring shoulder fragmentation and counterbalance; the second set consisted of four exercises aimed at centering the humeral head in the glenoid fossa during active movements and introducing counterbalancing mechanism of the scapula during upper limb movements; the last three exercises aimed at recovering maximum ROM of the affected shoulder. The exercises were performed in three different modalities: in the first grade, the therapist performed the movement and the patient, with closed eyes, had to resolve the motor problem by the analysis of different sensory afferent information. In the second grade, the patient, with closed eyes, had to recruit motor units to solve the motor problem. Finally, in the third grade, the resolution of the motor problem required visual control.

Patients who could perform correctly the exercise in the first grade and acquired a sufficient control over pathological elements were challenged with more complex perceptive tasks. For example, the therapist could ask the patient to distinguish five different concentric circles placed on an inclined plane by touching the surface with a finger. The therapist varied the inclination and position of the plane according to joint movements. In another exercise, the patient was asked to recognize sponges of different texture placed in correspondence of the interscapular space, the medial border of the scapula, the spine of the scapula, the clavicle and the coracoacromial arch, checking the horizontality of the tablet in the different positions of flexion and extension of the shoulder. During the execution of this task, the patient sat with the elbow flexed and the forearm placed on a laterally swinging support, placed on the floor with rollers.

The rehabilitative aim of TTE was to restore mus-

cular deficits in strength, mobility and elasticity, reduce pain and promote functional recovery.[13, 14] The TTE protocol contained mainly strengthening exercises focused on the rotator cuff and scapular stabilizing muscles, stretching exercises, Codman's pendulum exercises and exercises against elastic band resistance.

Patients in the two groups received a total of 15 treatment sessions (three sessions a week for five weeks), each lasting approximately one hour, including 5-min warm-up and cool-down periods. Both NCTE and TTE were administered at the outpatient clinics of the two study sites. For the time between the start and the 24-week follow-up, participants were asked to refrain from any other treatment for pain management and from structured exercise programs.

Outcomes

Outcome measures were determined by an assessor blinded to participant allocation. The primary outcome measure was the short form of the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire (Quick-DASH).[22, 23] The 11-item disability/symptom component of the Quick-DASH was used, as previously detailed.[24] The questionnaire measures physical ability and symptoms of the upper extremity and explores the impact of functional impairment and pain on daily-living tasks, as well as on social and recreational activities, work and sleep. The score ranges from 0 to 100 points, with 0 reflecting no disability and 100 corresponding to the most severe disability.

Secondary outcomes were the Constant-Murley shoulder outcome score, a visual analogue scale (VAS), the American Shoulder and Elbow Surgeons (ASES) Society standardized shoulder assessment form, and the Likert score. The Constant-Murley score,[25] recommended by the European Society of Shoulder and Elbow Surgery (SECEC/ESSE) for assessing outcomes of treatments for shoulder disorders, is based on subjective (sleep, work, and recreational activities) and objective (ROM and strength) components, adjusted for age and sex, according to normative values reported by Yian *et al*.[26] The score ranges from 0 (worst result) to 100 (best result). A VAS was used for pain assessment at rest and during movements.[27] Patients were requested to mark on a 10-cm line the point corresponding to the perceived pain intensity, with 0 indicating the absence of pain and 10 the most severe pain. The ASES score is a 10-item region-specific tool for assessing the patient's physical ability in carrying out the activities of daily living.[28] The score for each item ranges from 0 (unable to perform the activity) to 3 (able to perform the activity without limitations). The summary score is comprised between 0 (worst result) and 100 (best result). Finally, the Likert score is a 5-item tool for assessing the degree of patient satisfaction with treatment.[29] The score ranges from 1 (not at all satisfied) to 5 (completely satisfied).

As a check on blindness, the assessor was asked to guess treatment allocation after the final outcome assessments were completed. The analysis of these guesses showed a correctness of approximately 30%, which is considered not better than chance.

Endpoints

All patients were evaluated before treatment (baseline, T_0), at the end of treatment (T_1), and at 12 (T_2) and 24 (T_3) weeks after the completion of each intervention for all outcome measures, except for the Likert score that was evaluated at T_1 only.

Statistical analysis

Sample size was calculated according to the primary outcome measure (Quick-DASH score), as described previously,[30] and considering a 10-point increase in the Quick-DASH score as the minimally clinical important difference (MCID).[31] We estimated that, if there were truly no difference between the two exercise modalities, 40 participants (20 per treatment arm) would be required to exclude a change in Quick-DASH score ≥10 points between the two groups, given an α of 0.05 and a power (1-β) of 0.80. The number of participants was increased to 24 per group to account for a 20% rate of loss at follow-up.

Statistical analysis

Statistical analysis was performed using SPSS Version 13.0 (SPSS Inc, Chicago, IL). For all variables, normality of data was ascertained by the Kolmogorov-Smirnov's test. Differences between groups in Quick-DASH, Constant-Murley, VAS and ASES scores over time were analyzed by analysis of covariance (ANCOVA) for repeated measures. Mod-

els were adjusted for age, sex, and baseline values. A two-factor (time and group) analysis was performed to evaluate the overall group effect, overall time effect, and the interaction between group and time. Multiple pairwise comparisons within groups were performed by means of paired t-test with Bonferroni's correction in order to determine the time-point at which the observed effect occurred. Comparison of Likert scores between groups was performed by unpaired t-test. For each variable, 95% confidence intervals for means differences were determined. For all tests, significance was set at $P<0.05$. Missing data at follow-up were managed by the Last Observation Carried Forward (LOCF) method. Analyses were performed according to the intention-to-treat principle. All tests were two-sided, with results presented as mean ± standard deviation (SD) for continuous variables and proportions for categorical variables.

Results

A total 76 patients were eligible for inclusion and 48 were randomized for the interventions (Figure 1). Baseline characteristics of participants in the two groups are shown in Table I. At T_0, patients assigned to the two treatment arms did not differ for any demographic parameter. Baseline values of all outcome measures were comparable between groups (Table II). All of the participants completed the treatment protocol. Two participants in the NCTE group and three in the TTE group did not attend the follow-up visit at T_2. Two participants in the TTE group did not attend the follow-up visit at T_3. No adverse events were observed in either treatment arm.

Effects of treatments on primary and secondary outcome measures

Descriptive statistics of primary and secondary outcome measures in the two treatment arms over 24 weeks of follow-up are shown in Table II. Over the follow-up, no significant differences in the Quick-DASH score were detected between groups at any time-point ($F=1.041$; $P=0.3136$). Quick-DASH scores showed a significant reduction after treatment in both groups ($F=34.25$; $P<0.0001$), with a significant time-by-group interaction ($F=11.11$; $P<0.0001$), due to a greater decrease of Quick-DASH scores in the NTCE arm relative to the TTE group. It is worth noting that only patients in the neurocognitive rehabilitation group experienced a clinically meaningful reduction in Quick-DASH scores over the 24-week follow-up (T_0-T_3=-11.4 points), which is indicative of a clinically relevant effect of this treatment modality.[31]

The analysis of Constant-Murley scores showed no differences between groups ($F=0.1972$; $p=0.6593$), with a significant score improvement after treatment in both arms ($F=36.39$; $P<0.0001$). A significant time-by-group interaction was observed as a result of a greater increase of the Constant-Murley scores over time in the NCTE group relative to participants who received traditional rehabilitation ($F=9.249$; $P<0.0001$). In the NTCE group, the average Constant-Murley score increased by approximately 18 points from baseline to T_3, while an average 7-point increase was observed in the TTE group. However, since no MCID has yet been defined for the Constant-Murley, it is not possible to determine whether changes induced by the interventions were clinically meaningful.

VAS scores at rest showed significant differences between groups over the follow-up, with a treatment effect in favor of NCTE ($F=8.760$; $P=0.0035$). In addition, a significant time effect ($F=3.557$; $p=0.0164$) and time-by-group interaction ($F=3.590$; $P=0.0157$) were determined. The reduction in VAS scores observed in the NCTE arm from T_0 to T_1-T_3 was greater than the MCID of this tool (*i.e.*, 1.3 points),[32] indicative of a substantial, long-lasting clinical benefit. In contrast, patients assigned to TTE did not experience significant changes in VAS scores at any time-point. VAS scores during movements were not different between groups at any time-point ($F=0.9160$; $P=0.3441$). A significant time effect ($F=17.53$; $P<0.0001$) and time-by-group interaction ($F=3.703$; $P=0.0136$) were observed, due to a greater score reduction in the NCTE group relative to the TTE arm. In both treatment groups, differences in VAS scores between T_0 e T_3 were clinically meaningful, and averaged 3.5 points in the NCTE group and 1.4 points in the TTE group.[32]

The analysis of ASES scores did not show significant differences between groups at any time-point ($F=0.4889$; $P=0.4883$), with a score improvement over time in both arms ($F=24.26$; $P<0.0001$). A significant time-by-group interaction was observed ($F=8.578$; $P=0.001$), due to a greater score increase in the NCTE

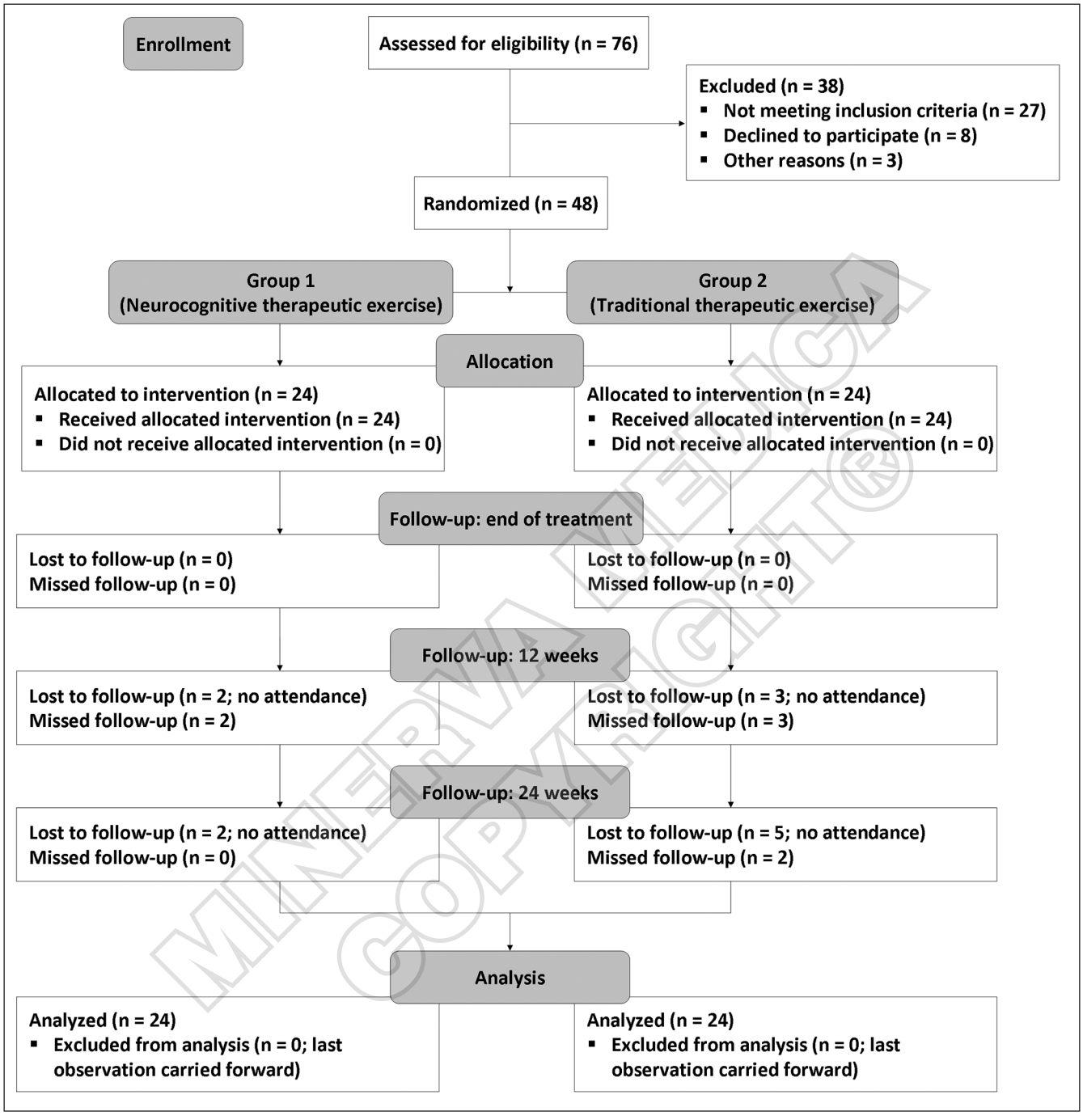

Figure 1.—Flowchart of the study.

group relative to participants who received TTE. In the NCTE, the ASES score increased by approximately 26 points between T_0 and T_3, which is greater than the MCID of this tool (*i.e.*, 12 points).[33] A statistically significant, but not clinically relevant 9.7-point improvement was observed in the TTE group.

TABLE I.—*Baseline demographic characteristics of the study population according to treatment allocation.*

	Traditional therapeutic exercise (N.=24)	Neurocognitive therapeutic exercise (N.=24)	P value
Age (years)	61.6±11.2	62.6±13.9	0.7927
Sex (M/F)	12/12	9/15	0.5604

TABLE II.—*Primary and secondary outcome measures at baseline (T_0), at the end of treatment (T_1), and at 12 (T_2) and 24 (T_3) weeks of follow-up in the two treatment arms.*

Outcome measure	Treatment		P	Difference between means	95% Confidence Interval	
	TTE (N.=24)	NCTE (N.=24)			Lower limit	Upper limit
Quick-Dash score						
T_0	28.41	25.67	0.3549	2.74	-4.72	10.21
T_1	23.24	19.41	0.1971	-3.83	-11.29	3.64
T_2	22.90	18.09	0.1054	-4.81	-12.28	2.65
T_3	22.48	17.00	0.0658	-5.48	-12.94	1.99
Constant-Murley score						
T_0	70.19	65.14	0.3228	-5.05	-17.93	7.82
T_1	74.57	75.50	0.8557	0.93	-11.94	13.80
T_2	74.57	81.00	0.2091	6.43	-6.44	19.30
T_3	76.95	83.27	0.2167	6.32	-6.55	19.19
VAS score (at rest)						
T_0	2.10	2.41	0.6410	0.31	-1.38	2.01
T_1	2.19	0.95	0.0676	-1.24	-2.93	0.46
T_2	2.14	0.68	0.0311	-1.46	-3.16	0.24
T_3	2.05	0.45	0.0189	-1.59	-3.29	0.10
VAS score (movement)						
T_0	5.36	4.71	0.4102	-0.65	-2.64	1.34
T_1	4.10	3.73	0.6405	-0.37	-2.35	1.62
T_2	3.76	2.46	0.0984	-1.31	-3.29	0.68
T_3	3.33	1.86	0.0634	-1.47	-3.46	0.52
ASES score						
T_0	66.52	57.27	0.1089	-9.25	-23.75	5.24
T_1	70.33	75.09	0.4084	4.76	-9.74	19.25
T_2	71.76	80.91	0.1129	9.15	-5.35	23.64
T_3	73.86	83.50	0.0949	9.64	-4.85	24.14

TTE: Traditional therapeutic exercise; NCTE: neurocognitive therapeutic exercise.

The overall greater benefits induced by NCTE are reflected by a higher level of satisfaction with treatment expressed by participants who received neurocognitive rehabilitation (Likert score: 4.3±1.2) relative to those treated with TTE (Likert score: 3.9±1.5; P=0.0393).

Discussion

The objective of the study was to evaluate the efficacy of neurocognitive rehabilitation in patients affected by SIS in comparison to TTE. Both treatments improved primary and secondary outcome measures relative to baseline values, with the exception of VAS at rest that was unaffected by TTE. Changes in Quick-DASH, Constant, ASES and VAS at rest and during movements over time were greater in the NCTE group relative to the traditional rehabilitation group. More importantly, in the NCTE arm, differences in all outcome measures from baseline to the end of follow-up were greater than the MCID thresholds, indicating that this treatment modality produces clinically meaningful effects.

To the best of our knowledge, this is the first trial testing the effects of a neurocognitive approach for the management of SIS. A very recent randomized controlled clinical trial has shown that a neurocognitive rehabilitative approach based on proprioceptive exercises and proper motor strategy choices amel-

iorates clinical outcomes after anterior cruciate ligament reconstruction.[15] In particular, a gradual improvement in the symmetrization of the static load, regain of gait fluidity, and reduction of pain and edema were observed following neurocognitive rehabilitation.[15]

The present findings together with those by Cappellino et al.[15] indicate that a neurocognitive rehabilitative approach is an effective rehabilitative strategy offering early and long-lasting benefits. In both studies, NCTE, by proposing exercises as cognitive problems, which requires the activation of higher cortical functions and the fractionation of some body segments, produced a reduction of pain and disability and an improvement of function, ROM and strength of the structures involved. It is important to notice that patients treated with NCTE experienced an amelioration of quality of life in terms of vitality, social function, pain, physical activities and functional impairment.

Any injury involving the shoulder structures deprives the joint of its informative function, leading to a partial deafferentation which results in disruption of afferent signals to the spinal cord and then to afferent neurons, subsequently altering the transmission to the central nervous system (CNS) and decreasing neuromuscular control.[34] These abnormalities eventually result in diminished joint position sense, kinesthetic awareness, abnormal humeral and scapular muscular firing patterns, and reduction in the ability to organize the fractionation of some body segments.[34, 35] This leads to an impoverishment of the information flow and, therefore, to a reduction of the capacity of the subject to know and use information from the periphery to direct actions and organize motor behaviors.[34, 35]

The correction of proprioceptive deficits and the restoration of neuromuscular control appear extremely important to enhance cognitive appreciation of joint position and movement, improve muscular stabilization, prevent disability of the shoulder joint, restore afferent pathways from the mechanoreceptors to the CNS, and facilitate supplementary afferent pathways.[36] The damage to the information structures also affects input signals passing from the muscle spindle to the CNS and directly to alpha motor neurons.[37] This proprioceptive input to the CNS results in joint movement and position sense, reflexive muscle contraction and regulation of muscle tone and stiffness.[37, 38] The proprioceptive information provided by musculotendinous, capsuloligamentous and cutaneous mechanoceptors plays a complementary role in movement and joint position sense. It follows that a damage to the joint information structures results in alterations of dynamic shoulder stabilizers and impairment of muscle contraction efficacy and coactivation.

Our findings indicate that neurocognitive rehabilitation is effective in restoring neuromuscular control, shoulder proprioception, stability and fragmentation. These effects are produced by the proper establishment of connections between the periphery and the CNS, which are essential for refining the movement pattern. Hence, our rehabilitation protocol restored proprioception and neuromuscular control, which translated into improved shoulder function and decreased pain, with benefits maintained for at least 24 weeks.

Results from our study also indicate that TTE is effective in the conservative management of SIS. This is in agreement with a vast literature on the subject. Indeed, numerous studies [5-12, 39-42] and systematic reviews [4, 13, 14, 43-46] are available in support of TTE for the treatment of patients with SIS. This exercise modality is effective in reducing pain, strengthening the rotator cuff and scapular stabilizing musculature,[5-10] restoring muscle elasticity, and decreasing capsular tightness. Many of these studies suggest the incorporation of other rehabilitation methods in the therapeutic protocol, such as joint mobilizations [5, 6, 13, 14, 39, 40, 47, 48] and physical therapies.[11] The association with manual therapy seems to increase the effectiveness of the rehabilitation program in terms of pain control and functional improvement. However, most of these studies suffer important methodological limitations. For instance, a clear description of exercises and the definition of criteria adopted for drafting the rehabilitation protocol are rarely provided. These limitations reduce the possibility of comparing the efficacy of the various protocols tested. Therefore, clinical trials of higher quality are needed to establish the true efficacy of the physical techniques employed in order to produce reliable clinical guidelines based on solid scientific evidence.[13]

Limitations

The major limitation of our study is the lack of a placebo control group. However, the effects of

NCTE were compared with those produced by a widely adopted exercise modality. The absence of a placebo group is also justified by the non-inferiority design of the trial. Another limitation resides in the lack of imaging examination at follow-up, which does not allow to infer about the effects of treatments on disease progression. On the other hand, the main objective of our investigation was to evaluate the effects of specific exercise modalities on clinical, rather than radiographic parameters. Further studies are needed to establish whether and to what extent the treatments tested in the present trial affect the progression of SIS. Finally, reasons for lack of follow-up participation were not recorded. However, only a few participants were lost at follow-up (10.4%) and dropouts occurred to a similar extent in the two treatment groups, which did not substantially affect the results. The impact of dropouts on the study findings was further minimized by the adoption of the LOCF method during data analysis.

Conclusions

Results of our study support neurocognitive rehabilitation as a valid treatment option in patients with SIS. NCTE provides an overall approach to the patient with a strong focus on the recovery of neural feedback between the peripheral receptor system and the CNS, usually compromised in musculoskeletal diseases. Starting from the neurophysiological assumption that the CNS knows nothing about muscles, it only knows movements,[49] it was possible to demonstrate the efficacy of the neurocognitive rehabilitation in a common orthopedic disorder such as SIS. These initial findings provide the groundwork for future studies aimed at testing whether neurocognitive rehabilitation retains its effectiveness in other orthopedic conditions.

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Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Received on June 6, 2013.
Accepted for publication on October 25, 2013.
Epub ahead of print on January 16, 2014.