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Effect of proprioceptive training on lower back muscle performance in patients with chronic non-specific low back pain: a randomized controlled trial

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Abstract

Introduction. This study was conducted to investigate the impact of proprioceptive training in patients with chronic non-specific low back pain on lower back muscle performance.

Methods. Overall, 43 participants of both genders (28 females and 15 males) with chronic non-specific low back pain aged 18–26 years were randomly assigned to 2 groups (A and B). Group A ($n = 22$) received proprioceptive training and conventional strengthening and stretching exercises 3 times per week for 8 weeks. Group B ($n = 21$) received conventional strengthening and stretching exercises 3 times per week for 8 weeks. To assess lower back muscle performance (peak torque) and the repositioning error of the lumbar spine, a Biodex System 3 Pro isokinetic dynamometer was used. A pressure pain algometer served to measure the pain level, and the functional level was evaluated with the Arabic version of Oswestry Disability Index. All subjects' outcomes were assessed before and after treatment. For statistical analysis, mixed ANOVA was conducted to investigate the effect of treatment.

Results. A statistically significant effect ($p < 0.0001$) of treatment and time was revealed in both groups for all measured variables. Between-group analysis implied a higher improvement in post-intervention results in group A ($p < 0.05$).

Conclusions. This study indicated improvement in both groups, but adding proprioceptive training to conventional therapy resulted in more improvement in all measured variables.

Key words: proprioceptive training, back muscle performance, isokinetic dynamometer, chronic non-specific low back pain

Introduction

Low back pain (LBP) is an extremely common problem [1]. It attacks, at least once in the lifetime, nearly 60–80% of all adults and the risk increases in older subjects. It can affect family and community life, life style, and business of the individuals [2]. In most of the cases, back pain is considered non-specific. It is called non-specific owing to the inability to determine a definitive diagnosis of the pain in relation to the involved anatomical structure, as well as the biomechanical point of view in orthopaedic medicine [3].

About 85% of LBP subjects present with this non-specific type [4]. Chronic LBP (CLBP) causes are complex and not yet fully understood. The trunk musculature may be involved as one of the possible reasons [5–7]. There is a delayed activation of the trunk muscles in individuals with CLBP [8]. This delay of activation has been ascribed to a defect in feedforward and feedback control mechanisms that are responsible for spinal muscle stability to control forces generated internally and externally during body movements [7, 9]. Also, the high prevalence of LBP conditions may be due to a deficit in the sensorimotor system [10].

Movement is a dynamic process in which the central processing system incorporates and processes information and the musculoskeletal system reacts to it [11]; dynamic and static senses of position (senses of proprioception) are known to keep the body stable and oriented during motion [12]. The existing methods of managing patients with LBP concentrate only on muscle strengthening and neglect the mobilization order and the coordination ability of muscles [13].

Proprioception can be defined as afferent information contributing to conscious muscle sense, segmental posture, and total posture [14]. Proprioceptive feedback controls the accuracy of movement, time of onset of motor commands, and adaptation to movement situations that require the use of non-preferred coordination patterns [15]. Maintaining proprioceptive integration in neuromuscular control of posture has been shown as a significant contributor to unimpaired and pain-free involvement in everyday activities [16].

Proprioceptive training reconditions the proprioceptive senses which augment the sensory input in various body parts, which leads to maximizing muscle adjustment ability [17–19]. Proprioceptive training is commonly used for prevention of injury or rehabilitation in various sports and rehabilitation settings [20]. The focus of many studies was to investigate the effect of proprioceptive training on pain and function; however, to our knowledge, there are few studies concerning its impact on lower back muscle performance and lumbar repositioning error in patients with CLBP. So, this study was conducted to assess the effect of proprioceptive training on lower back muscle performance and lumbar repositioning error in patients with chronic non-specific LBP.

Subjects and methods

Study design

The randomized clinical trial was conducted in accordance with the Declaration of Helsinki and the guidelines of Consolidated Standards of Reporting Trials [21] at the outpatient clinic of the Faculty of Physical Therapy, Cairo University, in years 2019–2020.

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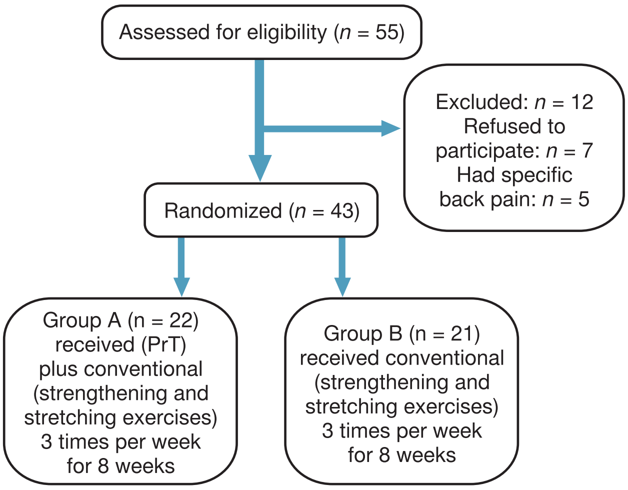
Sample size calculation

The G*Power software (Franz Faul, Universität Kiel, Germany) (version 3.1.9.2) was used to identify the sample size. In the *t*-test, the type I error rate equalled 5% ($\alpha = 0.05$); 0.85 was the primary outcome (peak torque) effect size, which was attained from a pilot study performed in 10 subjects. The type II error rate was 80%. The results indicated that 46 patients should be recruited but we could not reach the required sample size owing to laboratory technical problems and time constraint.

Subjects

The sample (55 subjects) was selected from among the students of the Faculty of Physical Therapy. During screening, 12 individuals were excluded: 7 refused to participate because they did not have time for the trial and 5 had specific back pain (Figure 1).



PrT – proprioceptive training

Figure 1. Flow chart of subjects included in the study

The subjects were randomly selected by using a random number generator; the patients were masked. All participants were informed about the procedures involved in this study but they did not know which group they would be assigned to. In total, 43 subjects (28 females and 15 males) were included. By creating a block randomization list with online sealed envelopes, the participants were randomly allocated to 2 groups. Subjects in group A received proprioceptive training and conventional physical therapy (strengthening and stretching exercises) 3 times per week for 8 weeks and those in group B received only conventional physical therapy (strengthening and stretching exercises) 3 times per week for 8 weeks.

The inclusion criteria were as follows: (1) LBP for not less than 3 months [22]; (2) ability to assume at least 40° of trunk flexion in order to apply the planned measurement tasks (30° trunk flexion) [22]; (3) age of 18–26 years.

The exclusion criteria involved: (1) any LBP due to a specific cause, such as arthritis, degenerative joint diseases, disc lesion, inflammation, or facet joint disease [23]; (2) history of head trauma or other neurological manifestation [24]; (3) current inner ear infection or vestibular problem [24]; (4) obesity with body mass index (BMI) above 29 [23].

Instruments

A Biodex System 3 Pro isokinetic dynamometer (Biodex Medical Systems Inc., Shirley, NY, USA) was used to measure muscle peak torque of trunk flexors and extensors and to estimate the lumbar repositioning error. It is a valid and reliable device applied to assess different variables, such as torque and position sense [25, 26].

A Commander algometer (JTECH Medical, Midvale, UT, USA) (Figure 2) served to assess the participants' pressure pain thresholds. An algometer is a handheld device that is used to evaluate pain intensity by producing a manual pressure stimulus. The instrument is valid and has been widely used to establish pain intensity [27].

To assess the functional level, a validated Arabic version of the Oswestry Disability Index was applied [28].

Figure 2. A Commander algometer

Procedure

For measuring the peak torque of trunk flexors and extensors, the Biodex system was calibrated before each assessment trial. The subject sat on the Biodex trunk chair, and by 2 curved anterior leg pads, the knee block angle was individually changed. The individual's both feet were kept in place without floor touch, 2 straps were used to stabilize both thighs, and lumbar pads were located against the lower lumbar spine [29].

The fulcrum of the actuator arm of the seat was changed to be in line with L5, S1 disc space. This was obtained clinically by palpating the most upper point of iliac crest, which is at the L4/L5 level, and then descending 2 cm. We entered the subject's data to a computer database, and a test protocol was set with the software – trunk flexion and extension in concentric mode at the angular velocity of 60° per second. The range of motion was set at 10° hyperextension and 80° flexion [29], as shown in Figure 3. The procedure was explained to the subjects; each patient was instructed to cross their arms over the chest. A total of 5 repetitions of trunk flexion and extension were allowed to be done before testing as warm-up; after a 30-second rest, the subject was instructed to perform maximal effort. The mean values of maximal voluntary contraction (peak torque) of the lumbar flexors and extensors were obtained [29, 30].

To assess the lumbar repositioning error, the system was calibrated before each assessment trial. The subject's position on the Biodex chair was adjusted as described above for peak torque measurement. The predetermined spinal range of motion, which was from neutral spinal position to 30° of lumbar flexion, was selected to be the target position for individuals while testing. To determine the maximum available lumbar range of motion, each participant was told to lean as far as they could into flexion to know whether they were able to do the experimental task. To ensure the same starting position in the 3 testing trials for all participants, the dynamometer was locked in the zero position [31].

Figure 3. Starting (A) and ending (B) position for measurement of muscle peak torque

Figure 4. Starting (A) and ending (B) position for measurement of lumbar repositioning error

Each person was allowed to do 3 repetitions of the test as a practice trial at the beginning of the procedures. Once the practice trial was completed, the individuals began the standard test session. The device moved each participant to a position of 30° flexion. The patients were asked to hold this position (30° lumbar flexion) for 3 seconds; then, they were asked to remain this position in the memory as they were instructed to perform the position again [32].

The participants then were returned to the starting position and reproduced the target position as accurately as they could as they were instructed (Figure 4). When they felt that they had reached the target position, they informed the tester. A hold button was pressed after the subject had reached the ending position and maintained it for 3 seconds and then the reproduced angle was registered. The test was repeated 3 times with a modified 10-second rest interval between the tests. The individuals received no verbal or visual feedback during testing. For the 3 trials performed by every subject, the absolute error values were reported concerning the 30° target position and then the mean difference was determined for each participant [24, 33].

To assess the pressure pain thresholds, we put the tip of the algometer on the paravertebral measuring points; those points were palpated and marked with a pencil at various levels of the erector spinae muscles, 5 cm from the spinal column at L1 and L3 levels and with a 4-cm distance at L5 level [34] (Figure 5). The pressure was increased by 1 kg/cm^2 per second. Once discomfort was felt, the pressure value was obtained in kg/cm^2. We repeated the procedure 3 times with a 1-minute rest between the measurements, and the average pressure value was calculated as the pressure pain threshold [35].

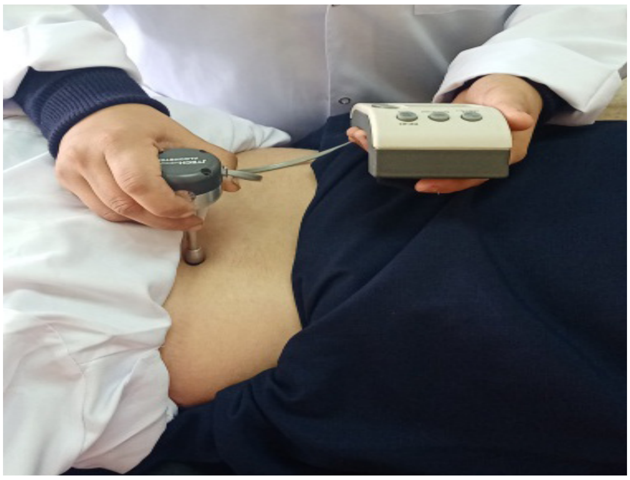


Figure 5. Pressure pain threshold assessment

The Oswestry Disability Index is composed of 10 items with appropriate statements for the subject to choose which express their ability to deal with pain during daily life. The items include pain intensity, personal care, lifting, walking, sitting, sleeping, sex life (if applicable), and social life. There are 5 answers to each question, so the score range is 0–5, with higher values indicating more severe impairment. The Oswestry Disability Index questionnaire, describing the patient's current functional level, was filled in by each subject. The total score was doubled and displayed as a percentage [28].

All variables were evaluated before and after the treatment programme.

Interventions

Group A received proprioceptive training and conventional strengthening and stretching exercises. Group B received only conventional strengthening and stretching exercises.

Proprioceptive training

A total of 6 types of exercises were performed on a mat for 40 minutes during each session, 3 times per week, for 8 weeks. All exercises were held for 3–5 seconds, with a rest of 5 seconds [36]. The exercises were as follows:

1. Hollowing exercise: from a quadruped position, the patient was instructed to contract the abdominal muscles and bring the centre of movement toward the navel.
2. Single leg raising in the quadruped position: the patient was asked to bring one leg up and hold it in a quadruped position, and perform the same movement with the other leg.
3. Contralateral arm and leg raising in the quadruped position: from a quadruped position, the patient was asked to raise one arm and the opposite leg at the same time and maintain them in that position; then, the same movement was performed on the opposite side.
4. Abdominal bracing: from a supine position, keeping the hip and knee joints at 90° and feet against the wall, the patient was instructed to raise the lower abdomen during breathing in, and bring the lower abdomen down during breathing out.
5. Holding a bridging position: the patient was asked to raise the pelvis while keeping both knees together.
6. Single leg raising in the bridging position: in a bridging position, the patient was instructed to extend one leg, maintain it, then perform the same movement on the other side.

Conventional treatment

This program, applied to both groups, consisted of stretching exercises and strengthening exercises.

Stretching exercises: Manual passive stretching to hamstring, iliopsoas, and low back muscles from supine, prone, and cross-sitting positions, respectively, was performed [37]. The stretching force holding time was 30 seconds, followed by a 30-second rest for each stretching procedure, with 3 repetitions for every session. The handling and procedures were done as previously mentioned in the literature [38].

Strengthening exercises: These were performed to strengthen the abdominal muscles and back extensors. They were carried out from crook lying and prone positions, respectively. The exercises were repeated 10 times for 1 set in the first week; then, the repetition number was increased gradually in accordance with the patient's response and fatigue to provide safety and adaptation to the change of muscle strength resulting from the exercises [38].

During the abdominal exercises, the patient was put in the supine position, with both hips and knees semiflexed and the feet fixed. The subject was asked to cross their hands over the chest and lift the head and shoulders off the bed before relaxing. To strengthen the back muscles, the participant's lower limbs and pelvis were fixed by the therapist from the prone position and then the patient was asked to lift the head and shoulders off the table and then relax [23].

Statistics

For the statistical analysis of the results, SPSS version 23 (IBM Corp., New York, USA) was used and the α value was set at 0.05. The data set was evaluated with the Shapiro-Wilk test for normality of distribution. All of the demographic data (age, weight, height, BMI) and the outcome measures (including peak torque of trunk flexors and extensors, lumbar repositioning error, pressure pain thresholds for both right and left sides at L1, L3, and L5, and functional level) were normally distributed. Therefore, a parametric *t*-test was used to detect the differences between demographic data (age, weight, height, and BMI) in both groups, and mixed model multivariate analysis of variance (MANOVA) was applied to detect the differences concerning time and treatment for all variables between subjects of both groups.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethical Review Committee of the Faculty of Physiotherapy, Cairo University (approval No.: P.T.REC/012/002347) and registered in the Pan African Clinical Trials Registry (registration No.: PACTR 202001519121833).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

Demographic data of subjects

The unpaired *t*-test used to assess the differences between the 2 groups in terms of age, weight, height, and BMI revealed no statistically significant difference between the groups (Table 1).

Table 1. Demographic data of subjects in both groups

Characteristics	Group A (mean ± *SD*)	Group B (mean ± *SD*)	*t*	*p*
Age (years)	20.73 ± 2.69	20.43 ± 2.50	0.38	0.71
Weight (kg)	66.55 ± 8.86	66.29 ± 6.70	0.11	0.91
Height (cm)	165.82 ± 7.16	166.62 ± 7.70	–0.35	0.73
BMI (kg/m^2)	20.03 ± 2.01	20.01 ± 1.55	0.04	0.97

BMI – body mass index

Within- and between-group analysis

The multiple pairwise comparison within the groups revealed that there was a significant difference in all variables in both groups ($p < 0.0001$), with more benefits in all variables in group A. Mixed ANOVA was conducted to detect the effect of treatment on all variables in general, and it was found that there were significant effects of treatment ($p = 0.000$, $f = 16.50$) and time ($p = 0.0001$, $f = 353.35$). Moreover, a significant interaction between time and treatment was indicated ($p = 0.0001$, $f = 47.67$) (Table 2).

Table 2. Pre- and post-treatment results of all measured variables in both groups

Parameters	Group A	Group B	*p* (between-group)
PTF (N · m)			
Pre-treatment (mean ± *SD*)	38.94 ± 6.58	37.74 ± 6.14	0.541[a]
Post-treatment (mean ± *SD*)	102.90 ± 7.60	67.99 ± 5.48	0.0001[b]
p (within-group)	0.000[b]	0.000[b]	
PTE (N · m)			
Pre-treatment (mean ± *SD*)	33.05 ± 2.97	32.50 ± 4.76	0.655[a]
Post-treatment (mean ± *SD*)	97.66 ± 8.86	62.60 ± 6.40	0.0001[b]
p (within-group)	0.000[b]	0.0001[b]	
LRE (°)			
Pre-treatment (mean ± *SD*)	6.30 ± 0.70	6.52 ± 0.77	0.324[a]
Post-treatment (mean ± *SD*)	3.35 ± 0.50	4.66 ± 0.65	0.0001[b]
p (within-group)	0.000[b]	0.000[b]	
PPT RL1 (kg/cm^2)			
Pre-treatment (mean ± *SD*)	0.61 ± 0.15	0.64 ± 0.14	0.446[a]
Post-treatment (mean ± *SD*)	1.20 ± 0.23	0.95 ± 0.11	0.000[b]
p (within-group)	0.000[b]	0.000[b]	
PPT LL1 (kg/cm^2)			
Pre-treatment (mean ± *SD*)	0.65 ± 0.12	0.69 ± 0.12	0.395[a]
Post-treatment (mean ± *SD*)	1.10 ± 0.16	0.92 ± 0.87	0.000[b]
p (within-group)	0.000[b]	0.000[b]	
PPT RL3 (kg/cm^2)			
Pre-treatment (mean ± *SD*)	0.60 ± 0.11	0.57 ± 0.10	0.318[a]
Post-treatment (mean ± *SD*)	1.14 ± 0.20	0.89 ± 0.13	0.000[b]
p (within-group)	0.000[b]	0.000[b]	
PPT LL3 (kg/cm^2)			
Pre-treatment (mean ± *SD*)	0.56 ± 0.11	0.60 ± 0.12	0.256[a]
Post-treatment (mean ± *SD*)	1.11 ± 0.19	0.89 ± 0.11	0.000[b]
p (within-group)	0.000[b]	0.000[b]	
PPT RL5 (kg/cm^2)			
Pre-treatment (mean ± *SD*)	0.55 ± 0.96	0.53 ± 0.11	0.586[a]
Post-treatment (mean ± *SD*)	1.02 ± 0.17	0.72 ± 0.16	0.000[b]
p (within-group)	0.000[b]	0.000[b]	
PPT LL5 (kg/cm^2)			
Pre-treatment (mean ± *SD*)	0.44 ± 0.09	0.43 ± 0.09	0.913[a]
Post-treatment (mean ± *SD*)	1.01 ± 0.11	0.70 ± 0.10	0.000[b]
p (within-group)	0.000[b]	0.000[b]	
FL (%)			
Pre-treatment (mean ± *SD*)	32.09 ± 9.72	33.54 ± 7.49	0.580[a]
Post-treatment (mean ± *SD*)	18.64 ± 8.44	28.57 ± 2.77	0.000[b]
p (within-group)	0.000[b]	0.000[b]	

PTF – peak torque of trunk flexors, PTE – peak torque of trunk extensors, LRE – lumbar repositioning error
PPT RL1 – pressure pain threshold of L1 spinal level of right side, PPT LL1 – pressure pain threshold of L1 spinal level of left side,
PPT RL3 – pressure pain threshold of L3 spinal level of right side, PPT LL3 – pressure pain threshold of L3 spinal level of left side,
PPT RL5 – pressure pain threshold of L5 spinal level of right side, PPT LL5 – pressure pain threshold of L5 spinal level of left side,
FL – functional level

[a] non-significant difference, [b] significant difference

Discussion

This study was carried out to assess the impact of proprioceptive training on lower back muscle performance in patients with chronic non-specific LBP. The outcome of the study indicated improvement in muscle performance (peak torque) of trunk flexors and extensors, lumbar position sense, pain level, and functional level in both groups, with more benefits in the group that received both proprioceptive training and conventional strengthening and stretching exercises.

Impairment and delay of trunk muscle activity and poor position sense are possible causes of LBP [5–7]. This delayed activation has been described as an important impairment of the 'neural control unit' of the stabilizing system of the spine [7]. Trunk muscles are crucial to provide spinal stability during functional activities and they work through feedforward and feedback control mechanisms that modulate the stiffness of the spinal muscles to control forces generated internally and externally during body movements [7, 9].

The group that received only conventional strengthening and stretching exercises showed improvement in muscle performance of trunk flexors and extensors, lumbar position sense, pain level, and functional level, probably owing to the fact that conventional strengthening exercises improve the mechanical effect of the efferent drive on the motoneurons, enhancing the rate of force development during maximal voluntary contraction [39].

The possible explanations of more benefits in the group that received both proprioceptive training and conventional strengthening and stretching exercises may be that proprioceptive training improves functional joint stability and postural stabilization [39]. It is suggested that the feedback of mechanoreceptors altered with proprioceptive training may lead to central nervous system reorganization processes in terms of sensorimotor integration and, subsequently, to motor response modifications (adaptations of neuromuscular control) [40], thereby increasing muscle plasticity, enhancing motor performance and position sense, and finally controlling pain [36, 41].

The results of this study are in agreement with research by Hadadnezhad et al. [41], who investigated the effects of sensorimotor training on proprioception and anticipatory postural adjustment of some trunk muscles in subjects with chronic non-specific LBP. The study found significant improvement in proprioception, which was measured with a goniometer, and muscle performance, measured by means of surface electromyography, in the group who received sensorimotor training.

Furthermore, Hwang et al. [36] presented the effect of sensorimotor training on anticipatory postural adjustment in CLBP patients. Their results revealed significant improvement in pain, function, and muscle performance in the group who received sensorimotor training.

In the same line, Gatti et al. [42] investigated the efficacy of trunk balance exercises in individuals with CLBP. They concluded that trunk balance exercises combined with flexibility exercises were more effective than a combination of strength and flexibility exercises in reducing disability and improving the physical component of quality of life among patients with CLBP.

Moreover, Marshall and Murphy [43] examined changes in electromyographic measures of deep abdominals in association with LBP. More rapid improvements in disability and feedforward activation of the deep abdominal muscles, leading to muscle performance enhancement, were identified in subjects who received proprioceptive training.

On the other hand, Johannsen et al. [44] studied the effect of coordination exercises on back muscles in patients with LBP. A total of 40 individuals were randomly assigned to 2 groups. One group received intensive training of muscle endurance and the other group received muscle training, including coordination. The study revealed that the groups equally improved with regard to isokinetic muscle strength, pain level, and functional level.

Also, Jull et al. [45] investigated the effect of 2 exercise regimes (conventional proprioceptive training and craniocervical flexion training) in retraining cervical joint position sense among people with persistent neck pain. No significant differences were observed between the 2 groups regarding cervical joint position error of the right side, neck pain intensity, or perceived disability.

Limitations

The limitation of this study was that it did not investigate the long-term influence of proprioceptive training in patients with chronic non-specific LBP.

Conclusions

The results of this study reported improvement in muscle performance of trunk flexors and extensors, lumbar position sense, pain level, and functional level in both groups, with more benefits in the group that received proprioceptive training and conventional strengthening and stretching exercises.

Recommendations

On the basis of this study, it is recommended that proprioceptive training should be applied as an essential component in treatment programs for chronic non-specific LBP. For future research, it is proposed that a study may be performed to investigate the long-term effects of proprioceptive training in subjects with chronic non-specific LBP.

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Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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