ORIGINAL ARTICLE

Training Mode–Dependent Changes in Motor Performance in Neck Pain

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ABSTRACT. O'Leary S, Jull G, Kim M, Uthaikhup S, Vicenzino B. Training mode–dependent changes in motor performance in neck pain. Arch Phys Med Rehabil 2012;93:1225-33.

Objective: To determine whether changes in motor performance after a course of exercise in patients with mechanical neck pain (MNP) were dependent on the primary behavioral demand of the exercise performed.

Design: Randomized controlled trial.

Setting: University laboratory.

Participants: Volunteers (N=60; 35 women, 25 men; mean age, 37.9y) with chronic MNP participated in the study.

Intervention: Exercise targeted to improve cervical motor performance including endurance training (ETr; n=20), coordination training (CTr; n=20), and active mobility training (n=20).

Main Outcome Measures: Changes in the cervical motor performance domains of strength, endurance, coordination, and active mobility were evaluated immediately after the 10-week training program, and at a 26-week follow-up.

Results: Between-group comparisons revealed significantly greater gains in endurance ($P<.02$) by the ETr group, and significantly greater gains in coordination ($P<.01$) by the CTr group. All 3 groups had improvement in pain ($P<.01$) and disability ($P<.01$).

Conclusions: Changes in motor performance in individuals with MNP in response to an exercise program were dependent on the specific mode of exercise performed, with minimal improvement in other domains of motor performance.

Key Words: Exercise therapy; Neck muscles; Neck pain; Rehabilitation.

A FEATURE OF THE HUMAN motor system is its plasticity and capacity to adapt to changing functional demands including those that are exercise induced. The process of exercise-induced adaptation of the motor system is multifactorial including neuronal[1] and muscle changes.[2] Adaptations to training appear to be specific to the mode of exercise training. Specific neuronal, muscle, and functional changes in motor output (changes in strength, endurance, and skill) in response to exercise appear to be dependent on the mode (primary behavioral demand) of training undertaken.[1-4] As such, it is recommended that exercise to train motor performance is prescribed specific to the desired enhancement in motor performance.

One area of rehabilitation where exercise is commonly prescribed with the intent of improving motor performance is in the management of chronic mechanical neck pain (MNP).[5,6] This practice is underpinned by evidence of an association between aberrant motor performance and chronic MNP,[7-10] and further justified by the demonstrated efficacy of cervical motor training in the management of MNP.[5,11,12] However, despite the general acceptance of motor training as a legitimate management strategy for MNP, its optimal implementation in the management of these disorders is still unclear. One challenge is the myriad of motor impairments reported in this patient group. Studies indicate that chronic MNP disorders may be associated with alterations in cervical motor behavior (timing and activation)[7,8,13-16] and changes in muscle structure (cross-sectional area, fatty tissue, fiber type),[7,9,17-20] as well as functional deficiencies in strength,[10,21,22] endurance,[10,22,23] precision and acuity,[10,24-26] and sensorimotor function.[27,28] What is unclear at this point is whether each of these various impairments requires specific retraining in patients with MNP. Moreover, it is unclear whether there is adequate improvement between the different domains of motor performance that would justify not having to address each motor impairment separately in the management of a patient with MNP.

Cervical spine studies that have investigated exercise-induced changes in motor performance between different domains of motor function in patients with MNP have shown mixed findings. Studies that have investigated the effects of a low-load craniocervical flexion training protocol (large element of coordination/skill training)[29] have shown this mode of exercise to also improve proprioceptive acuity of the neck[30] but to result in negligible improvements in flexor activation during a functional activity[31] or in flexor muscle strength.[32] Similarly, a specific flexor strength training protocol was shown not to

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List of Abbreviations

AS	anterior scalene
CTr	coordination training
ETr	endurance training
MNP	mechanical neck pain
MTr	mobility training
MVC	maximal voluntary contraction
NDI	Neck Disability Index
RMS	root mean square
SCM	sternocleidomastoid
VAS	visual analog scale

improve flexor muscle activation during a test of low-load craniocervical flexion.[33] While all trained motor behaviors may contain multiple elements of enhanced performance (improved strength, endurance, and skill) developed through extensive practice,[1] these studies to date suggest that exercise-induced changes in motor performance in patients with MNP are mostly specific to the mode of the exercise protocol. These findings have prompted us to perform further studies in an attempt to better inform exercise prescription for the management of chronic neck disorders.

We compared 3 different modes of cervical motor training (endurance, coordination, mobility) in patients with MNP to investigate whether changes in cervical motor performance are dependent on the primary behavioral demand of the exercise performed. Specifically, we hypothesized that changes in cervical motor endurance, coordination, and mobility will be specific to the mode of exercise training (ie, endurance, coordination, and mobility training, respectively). Because of the diverse motor impairments observed in patients with neck pain, we anticipate that the findings of this study will further inform clinicians as to the expected motor behavior outcomes of specific training protocols when managing these patients in the clinical setting.

METHODS

Study Design

A randomized trial with blinded outcome assessment compared the immediate (10wk) and midterm (26wk) effects of 10 weeks of cervical endurance training (ETr), coordination training (CTr), and mobility training (MTr) on cervical motor performance.

Participants

Participants for the study were recruited from the university and general community. Participants were eligible if they were aged 18 to 55 years, reported a history of neck pain of greater than 6 months' duration, scored between 10 and 15 points out of a possible 50 points on a Neck Disability Index (NDI),[34] and demonstrated positive findings on a physical manual examination of the cervical spine (altered joint motion and painful reactivity to palpation).[35] Only participants determined to have mild neck disability as rated using the NDI (participants' scores <15 points of a possible 50 points)[34] were included to avoid potential aggravation of neck symptoms from the exercise programs. Participants were excluded if they had specifically trained their neck muscles in the preceding 6 months, if they experienced neck pain or headache from nonmusculoskeletal causes, demonstrated neurologic signs, or had any other medical disorder contraindicating physical exercise. Participants within an age range of 18 to 55 years were accepted for both groups to ensure skeletal maturity and to minimize any confounding effects of advanced degenerative changes in the cervical spine.

If deemed eligible to participate and after consent, participants were randomly assigned to 1 of the 3 exercise intervention groups by a computer-generated randomization schedule by an independent investigator.

Ethical clearance for the study was granted by the university's medical research ethics committee, and the study was conducted in accordance with the Declaration of Helsinki. All participants received verbal and written information about the study and signed a consent form.

Cervical Motor Performance Measurements

Strength and endurance measurement. Isometric craniocervical flexor strength and endurance were measured in a neutral flexion/extension position (Frankfort plane) in sitting using the NeckMetrix dynamometer.[36-38,a] This dynamometer resists participants' flexion efforts at the undersurface of the mandible, recording craniocervical flexion torque in newton meters about an axis aligned to the axis of rotation of the C0/1 motion segment (concha of the ear). Torque recordings from the dynamometer are displayed via a computer equipped with a custom-written Labview data acquisition program.[b] During testing, standardized visual feedback (display graph that elevates as torque increases) and verbal encouragement were provided to the participants. The participant's thorax was secured posteriorly by the seat of the dynamometer and anteriorly by a belt around the upper chest secured to the seat. During testing, the arms were placed by the participant's side to further minimize trunk motion during testing.

In the first instance, recordings were made of the participants' maximal isometric craniocervical flexor strength (maximal voluntary contraction [MVC]). Participants first performed a standard warm-up of 3 submaximal repetitions, which was followed by 3 trials of maximal contractions with 60 seconds of rest between each trial. The maximal torque value of the 3 trials was recorded as the participant's MVC score. Five minutes of rest was allowed before the commencement of the endurance test. For the endurance test, participants were required to sustain a craniocervical flexion effort at 50% of their MVC until they could no longer sustain the contraction (task failure), at which point the test was terminated. The duration of time that the participant sustained the contraction before task failure was recorded as the endurance measure (seconds).[10] These dynamometry measurements have been shown to have good test-retest reliability (intraclass correlation coefficient, .70–.94).[38]

An identical procedure was repeated at the 10- and 26-week follow-up sessions, with the exception that the endurance test was based on the MVC peak torque measurement from the pretraining baseline measure so that the measure could be compared under the same load challenge, and a direct analysis of performance change could be assessed.

Coordination measurement. Coordination (defined for the purposes of this study as muscle activity during a standardized task) of the cervical flexor muscles was assessed with surface electromyography during the low-load craniocervical flexion test in accordance with our established protocol.[39,40] This test is performed in 5 incremental stages of increasing craniocervical flexion range in the supine position. The subject was guided through the stages by feedback from an inflatable air-filled pressure sensor (Stabilizer[c]) placed behind the neck (pressure increases as the lordosis flattens with progressive craniocervical flexion). The pressure sensor was inflated to a baseline of 20mmHg, and the subject performed the 5 stages of the test (2-mmHg increments; range, 20–30mmHg). Participants were fully familiarized with the test. Pairs of Ag/AgCl surface electrodes[d] (11-mm disk, 3-mm diameter) were attached over the sternocleidomastoid (SCM; lower one third of the muscle) and anterior scalene (AS) muscles bilaterally.[8] The ground electrode[e] was placed on the upper part of the thoracic spine. Recordings of SCM and AS electromyographic activity were made as participants sustained an isometric contraction for 10 seconds at each stage of the test. There was a 10-second rest period between each stage of the test.

Electromyography signals were amplified (gain, 1mV), and band-pass filtered between 20 and 450Hz and sampled at