Physiological, Sensory, and Functional Measures in a Model of Wrist Muscle Injury and Recovery

Peter M. Tiidus, Lindsay Brown, Aron Brant, Deborah L. Enns, and Pamela J. Bryden

ABSTRACT

Purpose: To evaluate the effectiveness of muscle rehabilitation modalities, it is first necessary to develop a model to test measures that would assess physiological, sensory, and functional muscle recovery. This study attempted to develop such a model for wrist injury.
Subjects: Healthy male and female adults ($n = 25$).
Methods: Subjects performed wrist muscle damage assessment, soreness, discomfort, difficulty, and functional motor task tests before and 1, 2, and 7 days after eccentric wrist muscle contractions. Wrist-related motor task tests, including the perception of discomfort and difficulty during performance, were also conducted.
Results: At 24 hours post–eccentric exercises, wrist extension and flexion force declined ($p < 0.05$) and soreness ($p < 0.05$) and circumference ($p < 0.05$) increased; all returned to normal by 7 days post-exercise. At 24 and 48 hours post-exercise, perception of discomfort and difficulty was elevated during performance of motor tasks ($p < 0.05$). The completion speed of motor tasks was unaffected at any time post–eccentric exercise ($p > 0.05$).
Conclusions: Loss of wrist muscle force, increased soreness, task discomfort, and difficulty were noted following eccentric exercise. However, subjects appeared able to compensate, such that the speed of completion of motor tasks was not slowed. Longer or more specific motor tasks may be necessary to mimic real work performance decrement and recovery.

Key words: discomfort, motor tasks, muscle damage, muscle function, muscle soreness

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RÈSUMÈ

Objectif: Pour déterminer l'efficacité des modalités de réadaptation musculaire, il faut d'abord élaborer un modèle d'essai de mesures qui peut évaluer le rétablissement musculaire physiologique, sensoriel et fonctionnel. Cette étude tente de créer un tel modèle pour une blessure au poignet.
Sujets: Des hommes et femmes adultes en santé ($n = 25$).
Méthodes: Les sujets ont fait une évaluation des dommages musculaires, douleurs, malaises et difficultés au niveau du poignet et des essais de tâches motrices fonctionnelles avant des contractions musculaires excentriques du poignet et un, deux et sept jours après. Des essais de tâches liés au poignet et incluant la perception de malaises et de difficultés pendant l'exécution ont aussi été effectués.
Résultats: 24 heures après les exercices excentriques, l'extension du poignet et la force de flexion ont diminué ($p < 0{,}05$), la douleur ($p < 0{,}05$) et la circonférence ($p < 0{,}05$) ont augmenté et tout est revenu la normale sept jours après l'exercice. 24 et 48 heures après l'exercice, la perception de malaises et de difficultés s'est élevée pendant les tâches motrices ($p < 0{,}05$). La rapidité d'achèvement des tâches motrices n'a été affectée en aucun moment après l'exercice excentrique ($p > 0{,}05$).

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The Human Ethics Research Committee of Wilfrid Laurier University, Waterloo ON Canada approved the study.

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Conclusions: Une perte de la force musculaire du poignet, une douleur accrue, des malaises et des difficultés pendant l'exécution de la tâche ont été notés après l'exercice excentrique. Cependant, les sujets semblaient aptes compenser de manière ne pas ralentir l'exécution des tâches motrices. Des tâches motrices plus longues et plus spécifiques peuvent s'avérer nécessaires pour imiter la diminution du rendement réel au travail et le rétablissement.

Mots clés: douleur musculaire, dommage musculaire, malaise, tâches motrices, fonction musculaire

Wrist movement–related injuries account for the greatest number of repetitive motion injuries in US workplaces.[1] Wrist injuries are common in highly repetitive, low-force-type work and account for a significant amount of lost work time for both male and female workers.[2,3] Along with repetitive motions, any exposure to extreme positions or high force is also an important risk factor in the development of wrist injuries.[4,5] Wrist injuries account for a significant number of lost work days consequent to injury: approximately 30% of wrist injuries require 31 or more days away from work, and only 10% of those sustaining wrist injuries return to work after only 1 day off.[1] The development of optimal physical therapies to reduce post-injury muscle recovery time, dissipate discomfort, and maximize recovery of the ability to perform work-related functional tasks optimally would benefit both workers and industry. Numerous mainstream and complementary/alternative therapies are currently employed or advocated by both licensed therapists and other health or alternative medicine practitioners for use in enhancing recovery and healing following muscular injury.[6] Few, if any, empirical data exist to validate the effectiveness of many of these potential therapies. In order to optimally assess various therapeutic approaches to maximizing wrist muscle recovery following injury, a valid and relatively simple model for inducing standardized wrist muscle injury and, more importantly, for subsequently assessing practical functional recovery, soreness, discomfort, and physiological indices of muscle repair first needs to be developed.

Previous studies have established a strong relationship between muscle damage and soreness and disruption of motor control.[7,8] Alterations in muscle length–tension relationships, disturbed proprioception, and altered force perception during arm movement with damaged muscles can account for much of the disruption in movement control and interfere with optimal completion of work-related and practical functional tasks.[7,9] Feelings of muscle soreness and discomfort during movement can also inhibit performance of work-related functional tasks and prevent workers from performing repetitive tasks optimally.[2,10] It is therefore plausible that the discomfort symptoms of wrist muscle damage and recovery would also be temporally related to decrement and recovery in the performance of wrist muscle–related functional motor tasks.

Several previous studies have also made attempts at assessing wrist muscle function and wrist discomfort during movement and following eccentric exercise.[5,10,11] Other studies have evaluated other work-related issues, such as immediate wrist muscle responses to modelled effects of power tool torques.[12] However, a model of wrist muscle function following standardized injury that incorporates measures of muscle damage/recovery, functional work-related task performance, and subjective feelings of soreness, discomfort, and task difficulty, and that can be used to assess the effectiveness of therapeutic interventions easily and objectively, has yet to be fully developed.

The study reported here was the first phase in the development of such an objective model of wrist muscle injury and recovery assessment, and the lessons learned from this study will aid in the further development, refinement, and validation of the model. For such a model to be viable, the intervention (eccentric exercise) must induce physiological changes (strength loss and muscle swelling), sensory discomfort (soreness), functional changes (impairment of functional task completion), and task discomfort (sensations of difficulty and discomfort while performing applied motor tasks) in muscle. Various therapeutic modalities could then be assessed relative to their ability to influence the full range of physiological, sensory, and functional measures in muscle that has been damaged using a validated protocol. It was hypothesized that the wrist exercise model employed would result in (1) initial loss of muscle force and subsequent recovery of force over 7 days; (2) increase and subsequent recovery in muscle soreness and forearm swelling; (3) increase in time to task completion, coinciding with increased muscle soreness and loss of muscle force, which would return to normal coincident with the recovery of muscle force and soreness reduction; and (4) increase in perception of task discomfort and difficulty, coinciding with increased muscle soreness and loss of muscle force, which would normalize coincident with the recovery of muscle force and decreasing soreness.

METHOD

Subjects

Twenty-five healthy subjects (mean age = 22.4 years, SD = 2; 8 male, 17 female) completed the study. As no a priori data were available for power calculations, sample size was determined by subject availability. Hence, it is possible that a larger sample might have resulted in a greater possibility of significant differences being found. All subjects were right-hand dominant; none had participated in systematic upper-body weight training within the past 6 months or had previous history of hand or wrist injury. None of the subjects was taking any pain or anti-inflammatory medication. The study was approved by the Wilfrid Laurier University Human Ethics Board, and informed consent was obtained from all subjects. Subjects were recruited from the university's undergraduate kinesiology student population by asking for volunteers. Subjects were randomly assigned by lot to either the exercise group or the control group. No differences in age, gender balance, or body weight were present between groups. Approximately twice as many subjects were assigned to the exercise group, since it was in this group that we anticipated demonstrating an effect of muscle damage on task performance and perception of task difficulty; hence, we wished to increase power primarily in this group. The control group was included to demonstrate a lack of variability or learning effect from task repetition, and, while between-group statistical analysis was carried out, the experiment was designed primarily to investigate differences within the experimental group over time.

Experimental Design

On each of pre-experiment days 1 and 2, subjects performed each motor task twice in an attempt to optimize performance of each task and minimize any learning effect on repeated task performance. Generation of maximum isometric wrist muscle forces (as peak torques) during flexion, extension, radial deviation, and ulnar deviation was also performed on each of the pre-experiment days to familiarize subjects with generation of maximum wrist muscle forces. Subsequent to the familiarization period, baseline data on performance of each motor task (as detailed below) and maximum wrist muscle forces (as detailed below) were collected for each subject. Only the right (dominant) hand/wrist was tested for each subject.

On experimental day 1, exercised subjects ($n = 17$) performed the eccentric exercise protocol (as detailed below) to induce wrist muscle disruption. Control subjects ($n = 8$) did not perform the eccentric exercise protocol but did complete all other wrist muscle force, soreness, task discomfort and difficulty, and motor task evaluations on the same schedule as the experimental subjects. Bouts of eccentric exercise similar to those used in this study have previously been reported to induce muscle force loss, soreness, and swelling lasting for more than one week and similar to that caused by overuse injury or unaccustomed exercise.[13–15] Performance data for each motor task, maximum wrist muscle forces, muscle soreness, perceived task discomfort and task difficulty (as detailed below), and wrist circumference (as detailed below) were determined immediately following the eccentric wrist exercise protocol and at days 1, 2, and 7 post–eccentric protocol. The time course for the study was based on previous research indicating this as a typical time course for muscle damage and recovery following a similar bout of eccentric exercise.[13,14,16,17]

Induction of Wrist Muscle Disruption with Eccentric Exercise

The eccentric wrist exercise protocol was performed using the CYBEX NORM apparatus (CSMi Sport Medicine, Stoughton, MA). Subjects in the exercised group performed a total of 300 maximum-effort eccentric contractions using wrist muscles, as groups of 100 contractions broken down into 2 sets of 50 contractions in each plane of movement: (1) flexion/extension, (2) pronation/supination, and (3) radial/ulnar deviation. There was a 2-second rest interval between contraction phases, a 30-second rest interval after 10 contractions, and a 2-minute rest interval after each fiftieth contraction. The rest intervals decreased fatigue and allowed maximal voluntary force to be used for each contraction. Eccentric contraction speeds were chosen following pilot work to minimize fatigue with each movement and consisted of 90°/s radial deviation, 110°/s ulnar deviation, 100°/s extension, 120°/s flexion, 135°/s pronation, and 145°/s supination. Participants were seated in an upright body position with hips at 90° flexion. A forearm stabilizer attached to the seat supported the right forearm and was individually height-adjusted for optimal alignment of the axis of rotation. In the wrist extension/flexion movement, the forearm was at 90° flexion with the hand supinated. In both the radial/ulnar deviation and the forearm pronation/supination movements, the forearm was flexed to 90° with the wrist semi-pronated. Work was performed through normal ranges of wrist motion (as individually determined in each subject) in all planes and maximum movement regulated by safety stops. Maximal effort was maintained by having subjects view a visual display of torque of successive efforts. Such feedback, combined with verbal encouragement, has been demonstrated to sustain maximal effort on the part of subjects.[8,18] Control subjects did not perform any eccentric wrist exercises.

Evaluation of Isometric Muscle Force

Loss and subsequent recovery of muscle force is commonly used to assess the degree of movement-induced muscle disruption and the rate of recovery.[18,13] Maximal isometric force generation, determined as peak torque and expressed as Nm/(kg body weight) in each of the movement directions described above—flexion/extension, radial/ulnar deviation, and pronation/supination—was determined prior to and immediately after eccentric exercise and at 1, 2, and 7 days post-eccentric exercise. The positions of the subjects' hands, wrists, and forearms were the same as the starting positions for the movements described above and coincided with some of the maximal peak torque wrist positions described by Marley and Thomson.[19] Three isometric peak torque measures were made in each movement direction, with up to 30 seconds' rest between attempts. The highest isometric force of the three attempts was recorded.

Evaluation of Muscle Soreness, Task Discomfort, and Task Difficulty

Muscle soreness is a common symptom of movement-induced muscle disruption, and it is commonly measured as a quantifiable indicator of muscle disruption and recovery.[13,20] Subjects rated their perceived muscle soreness, task discomfort, and task difficulty using a numeric rating scale[13,21] (1 = no soreness, discomfort, or difficulty; 10 = extreme soreness, discomfort, or difficulty). Soreness was rated following each series of isokinetic contraction tests in each movement range during each testing day as well as upon moderate palpation—about half of the subjectively determined maximal thumb adduction force of the experimenter—as applied by the experimenter.

Following the completion of each of the applied motor tasks on each testing day, subjects were also asked to rate their perceived difficulty in completing the task as well as the discomfort they experienced when completing the task (see descriptions below), using the numeric ratings scale described above.

Forearm Circumference Measures

Muscle swelling is a common symptom of muscle damage, and limb circumference has often been used as a gross measure of limb muscle swelling and its dissipation and, hence, as a gross measure of the progress of muscle damage and its repair.[13,14] It has previously been demonstrated that muscle swelling can be reliably determined by determining arm circumference using a tape measure.[13] Distal and proximal forearm circumferences were measured using a clinical tape measure with the forearm relaxed at 90° elbow flexion. Subjects were marked with indelible ink at sites approximately 5 cm distal to the lateral epicondyle of the humerus (distal) and approximately 5 cm proximal to the styloid process of the ulna (proximal) to ensure that measures on subsequent days were made at the same sites. Circumference was recorded to the closest millimetre and expressed as cm/(kg body weight) to standardize for body size.

Evaluation of Muscle Function and Post-Disruption Recovery with Applied Motor Tasks

Three non-forceful applied motor tasks that employed wrist muscles and could be considered movement relevant to repetitive tasks performed in industrial settings[2] were used to assess the influence of muscle damage and recovery on task performance. The tasks selected are from a standard battery of motor tests used to evaluate motor performance in healthy men and women. Participants were familiarized with the tasks on the two familiarization days and then tested prior to the eccentric exercise protocol, immediately post-exercise, and 1, 2, and 7 days post-exercise (as with the other tests described above). The applied motor tasks were completed in the same order on each testing day: (1) the Hand Tool Dexterity Test; (2) the one-hand-turning-and-placing (Manual Dexterity) component of the Complete Minnesota Manual Dexterity Test; and (3) the O'Connor Tweezer Dexterity Test (all from Lafayette Instrument Co., Lafayette, IN). All tests were scored by time to completion.

The Hand Tool Dexterity Test (Lafayette Instrument Co., Model 32521) was conducted with subjects seated in front of a table that held the test apparatus. Using appropriately sized wrenches, subjects removed nine nuts and bolts of three different sizes mounted horizontally in columns of descending size on a vertical block on their right side and remounted them in the same configuration and order on their left side. All bolts in each row had to be removed or remounted before moving on to the next row. Once the bolts had been loosened by the wrench, fingers could be used to further loosen and remove the nuts from each bolt. Each bolt had to be tightened by the wrench so that it could not be removed using the fingers alone. Timing began when the subject touched the tools and finished when the last bolt was tightened. Subjects were instructed and verbally encouraged to complete the task as quickly as possible.

The one-hand-turning-and-placing component (Manual Dexterity) of the Minnesota Manual Dexterity Test (LIC Model 32023A) was conducted with subjects standing before a table on which the test was situated. With the right hand, subjects individually picked up 60 disks, 4 cm in diameter, situated in four rows, working from right to left and from the top row to the bottom row on the top board. Each disk was turned over and placed in the corresponding open slot in the bottom board. Timing began when the subject touched the first disk and stopped when the final disk was turned over and placed in the appropriate slot. Subjects were instructed and verbally encouraged to complete the task as quickly as possible.

The O'Connor Tweezer Dexterity Test (LIC Model 32022) was performed with subjects seated in front of a table on which the test was situated. The test device consisted of a board approximately 15 × 15 cm with 10 rows of 10 holes spaced approximately 1.3 cm apart. The holes were approximately 0.16 cm in diameter and 2.5 cm deep. Using tweezers held in the right hand, subjects picked up blunt pins (5 cm long, 0.14 cm diameter) from a tray and placed them one at a time into the holes in the board, moving from left to right in each row and from the top row to the bottom. Timing began when the subject picked up the tweezers and finished when the last pin was inserted in the last hole. Subjects were instructed and verbally encouraged to complete the task as quickly as possible.

Data Analysis

The dependent measures were entered into a series of two-group (experimental, control) by four-time (pre-exercise and 1, 2, and 7 days post-exercise) repeated-measures mixed-model ANOVAs. Significance was set a priori at $p < 0.05$.

RESULTS

In all movement planes, isometric peak torque was significantly decreased ($p = 0.048$) at 1 and 2 days post–eccentric contraction, relative to pre–eccentric exercise peak torque, and was significantly lower ($p = 0.009$) than isometric peak torque values of the unexercised controls at the same time points. At 7 days post-eccentric exercise, isometric peak torque had returned to pre–eccentric exercise peak torque values in all movement planes, and no significant differences ($p = 0.84$) were evident between the exercised group and the unexercised controls. To avoid redundancy, only representative data, as isometric wrist extension and flexion peak torque values and as perceived soreness during isometric wrist extension and during palpation at pre–eccentric exercise and at 1, 2, and 7 days post–eccentric exercise time points, are presented in Figures 1a, 1b, 2a, and 2b respectively. All other wrist force and soreness data in other movement planes (as described above) reflected similar time courses, relative change, and statistical differences.

Muscle soreness in all movement planes and palpation-induced soreness were significantly higher ($p = 0.010$) for the exercise group at 1 and 2 days post–eccentric contraction relative to pre–eccentric exercise soreness perception and higher ($p = 0.001$) than in the unexercised controls at the same time points. At 7 days post–eccentric exercise, soreness was no longer significantly different ($p = 0.79$) from pre–eccentric exercise values or between the exercised and control groups.

Forearm circumference at proximal and distal locations is depicted in Figures 3a and 3b. Forearm circumference at both proximal and distal locations was significantly greater ($p = 0.034$), indicating wrist muscle swelling, at 1 and 2 days post–eccentric exercise than pre–eccentric exercise but returned to pre–eccentric exercise values at 7 days post.

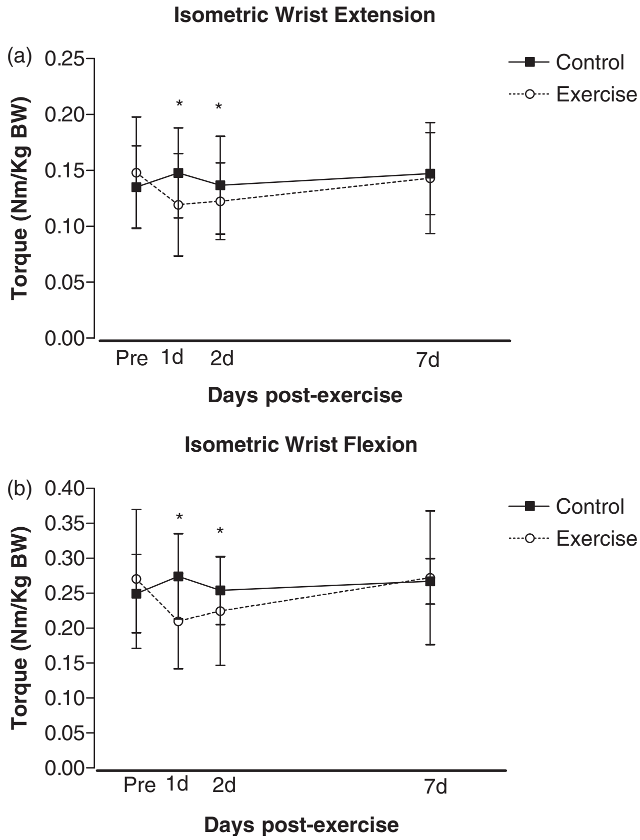

Figure 1 Isometric wrist extension (a) and flexion (b) peak torque prior to and at days 1, 2, and 7 post–eccentric muscle contractions in exercise and control groups. * Exercise group post-exercise values significantly ($p = 0.048$) less than pre-exercise values and significantly ($p = 0.009$) less than unexercised controls at the same time points. Data presented as means ± SD.

Performance on the Hand Tool Dexterity Test, measured as time to completion, perceived discomfort during performance of the test, and perceived difficulty in completing the test, is depicted in Figure 4. There were no significant differences ($p = 0.18$) between the exercised and control groups at any of the time points in time to complete the test (Figure 4a). At 1 day post–eccentric exercise, perceived discomfort during the test was significantly higher ($p = 0.029$) in the exercised group than in the unexercised control group (Figure 4b). Perceived difficulty in completing the dexterity test was also significantly greater ($p = 0.002$) at 1 and 2 days post–eccentric exercise in the exercised group than in the control group (Figure 4c). Because the tasks were not easy to perform, some discomfort was noted for most of these tasks even before the eccentric exercises were performed and muscle soreness developed.

Performance on the Manual Dexterity Test as time to completion, perceived discomfort during the performance of the test, and perceived difficulty in completing

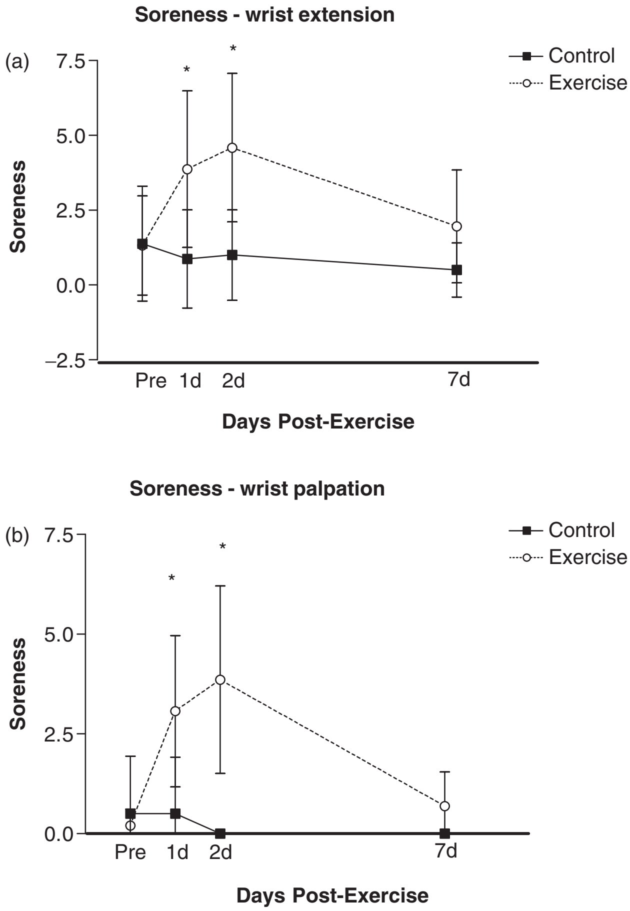

Figure 2 Wrist muscle soreness during wrist extension (a) and wrist palpation (b) prior to and at days 1, 2, and 7 post–eccentric muscle contractions in exercise and control groups. * Exercise group post-exercise values significantly ($p = 0.010$) greater than pre-exercise values and significantly ($p = 0.001$) greater than unexercised controls at the same time points. Data presented as means ± SD.

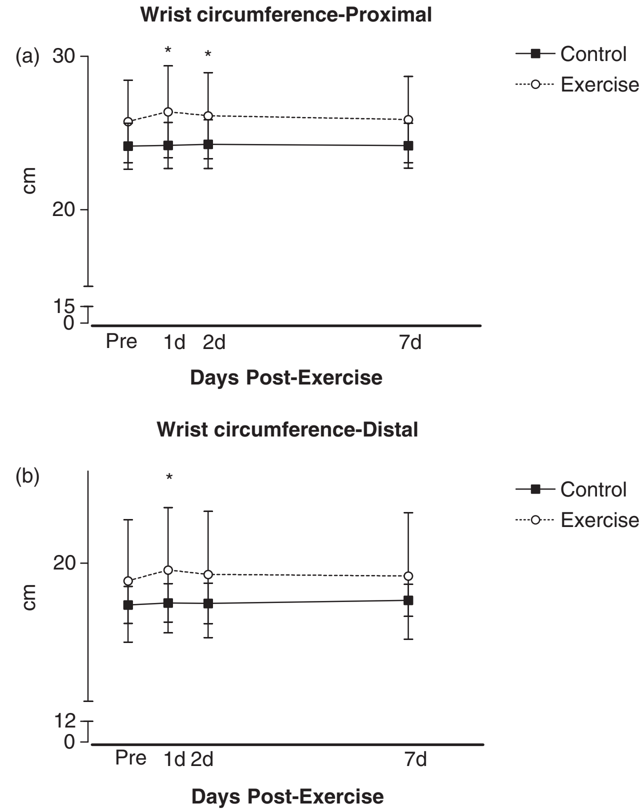

Figure 3 Wrist circumference at proximal (a) and distal (b) locations prior to and at days 1, 2, and 7 post–eccentric exercise in exercise and control groups. * Exercise group post-exercise values significantly ($p = 0.034$) greater than pre-exercise values. Data presented as means ± SD.

the test is depicted in Figure 5. There were no significant differences ($p = 0.07$) between exercised and control groups at any point in the time to complete the test (Figure 5a). Perceived discomfort during the Manual Dexterity Test was significantly higher ($p = 0.044$) at 1 and 2 days post–eccentric exercise in the exercised group than in the unexercised control group (Figure 5b). Perceived difficulty in completing the test was also significantly greater ($p = 0.019$) at 1, 2, and 7 days post-eccentric exercise in the exercised group than in the control group (Figure 5c).

Performance on the O'Connor Tweezer Dexterity Test as time to completion, perceived discomfort during performance of the test, and perceived difficulty in completing the test is depicted in Figure 6. There were no significant differences ($p = 0.11$) between exercised and control groups at any of the time points in time to complete the test (Figure 6a). At 1 and 2 days post–eccentric exercise, perceived discomfort during the test was significantly higher ($p = 0.030$) in the exercised group than in the unexercised control group (Figure 6b). Perceived difficulty in completing the test was also significantly greater ($p = 0.020$) at 1 and 2 days post-eccentric exercise in the exercised group than in the control group (Figure 6c).

DISCUSSION

The eccentric wrist exercise was successful in inducing significant reductions in peak torque in various planes of wrist movement, significant wrist muscle soreness, and significant wrist muscle swelling for at least 2 days subsequent to the exercise. These symptoms are typically reported in the presence of exercise- or overexertion-induced muscle damage[13,15] and indicate that the protocol for wrist muscle disruption used in our model was successful in inducing typical eccentric exercise–induced muscle damage.

This is also the first study to report that this type of muscle damage is temporally associated with increases in the perception of difficulty and discomfort in the performance of several wrist-associated, work-related

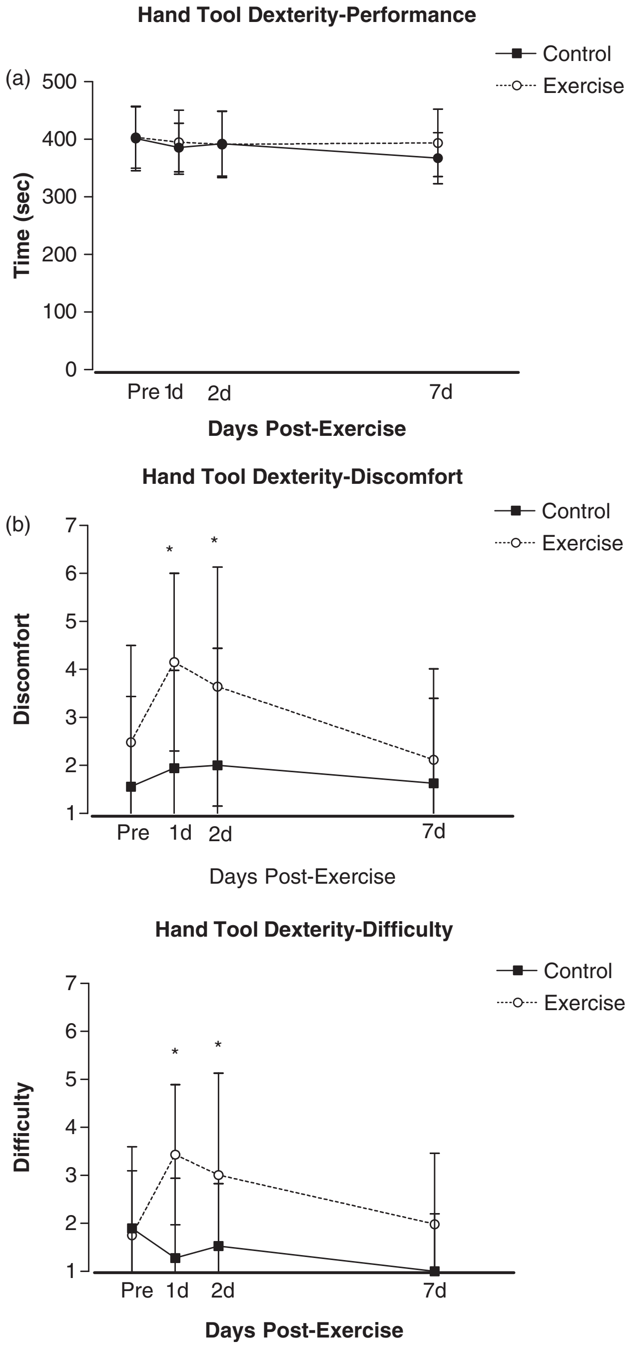

Figure 4 Hand Tool Dexterity Test: (a) time to completion, (b) discomfort during performance of test, and (c) difficulty in performing test prior to and at days 1, 2, and 7 post–eccentric exercise in exercise and control groups. * Exercise group post-exercise values significantly greater than pre-exercise values ($p = 0.029$, discomfort; $p = 0.002$, difficulty). Data presented as means ± SD.

movement tasks. Increased perception of task discomfort and difficulty is typically associated with decrements in task performance efficiency and task completion rates and with more awkward movements in task performance, which may predispose to further injury.[11,22] Hence it is somewhat surprising that the exercise subjects in our study did not manifest a decrease in task

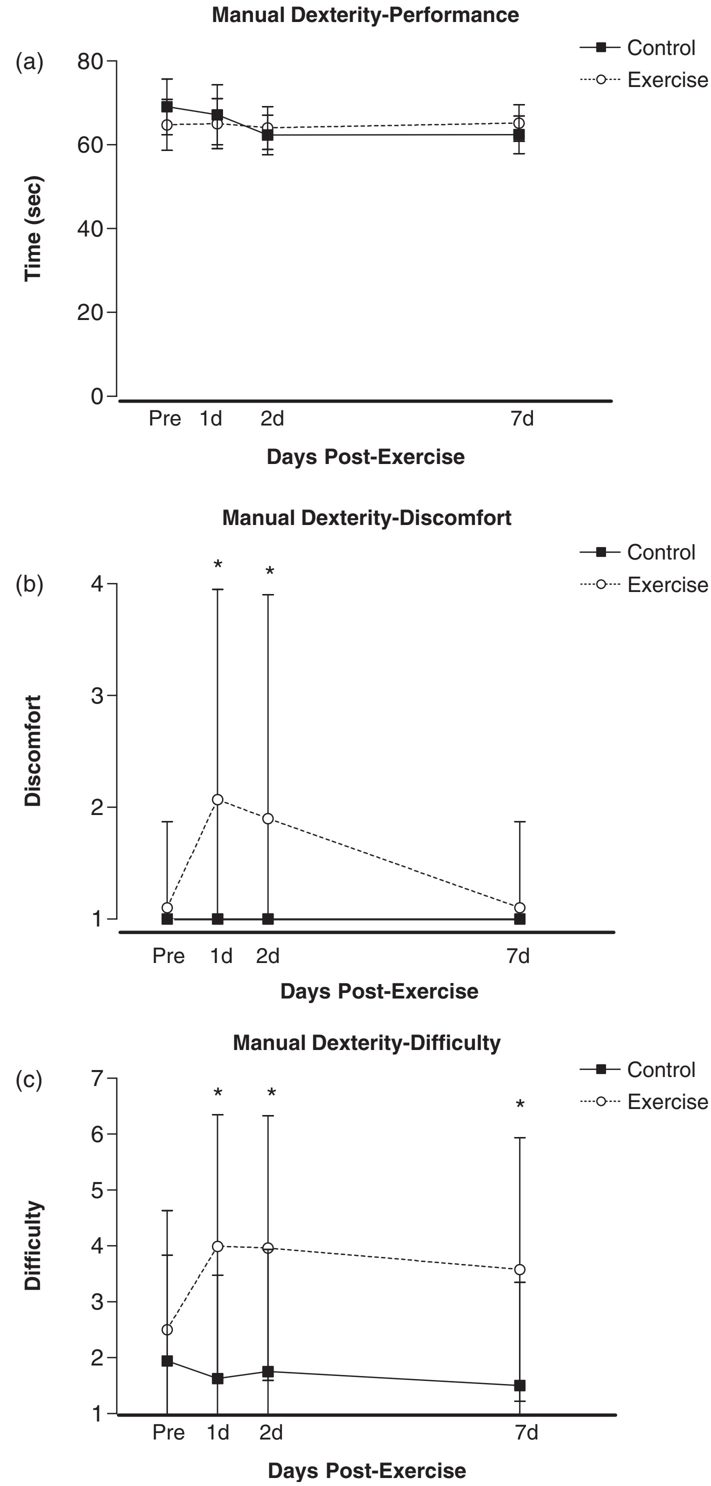

Figure 5 Manual Dexterity Test: (a) time to completion, (b) discomfort during performance of test, and (c) difficulty in performing test prior to and at days 1, 2, and 7 post–eccentric exercise in exercise and control groups. * Exercise group post-exercise values significantly greater than pre-exercise values ($p = 0.044$, discomfort; $p = 0.019$, difficulty). Data presented as means ± SD.

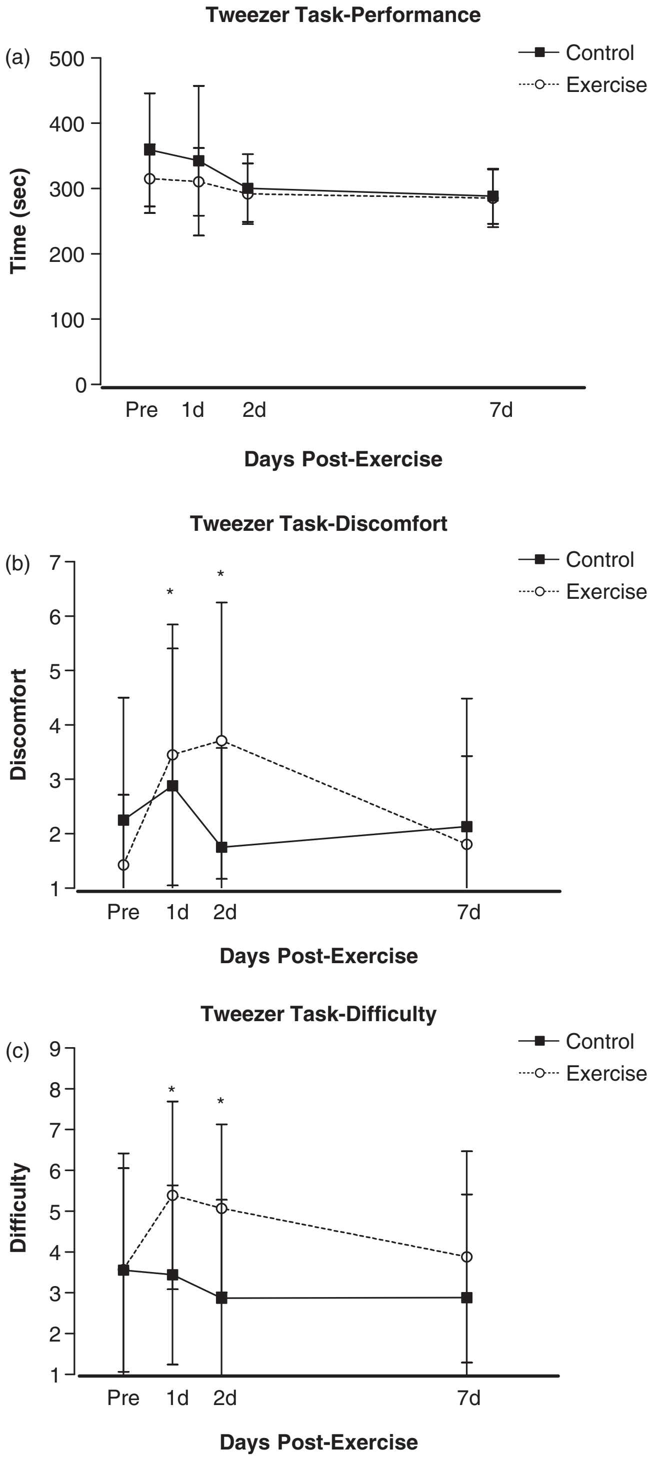

Figure 6 O'Connor Tweezer Dexterity Test: (a) time to completion, (b) discomfort during performance of test, and (c) difficulty in performing test prior to and at days 1, 2, and 7 post–eccentric exercise in exercise and control groups. * Exercise group post-exercise values significantly greater than pre-exercise values ($p = 0.030$, discomfort; $p = 0.020$, difficulty). Data presented as means ± SD.

performance in the days following eccentric wrist exercise, as evidenced by a lack of decrement in time to task completion. This is also surprising, since, in addition to the increased perception of task difficulty and discomfort, the exercised subjects also experienced typical symptoms of muscle damage, including loss of maximal force and increased muscle swelling and soreness, as noted above. While it is possible that a Type 2 error may account for this lack of significant difference, the number of subjects used and the consistency of this finding across several tests suggest that other factors are more likely to have accounted for the lack of difference between groups.

It is possible that the relatively minor muscle injury induced by this model may not have been severe enough to produce the anticipated loss in performance. However, ethical considerations limit the severity of experimenter-induced muscular injury in human models.

It is also possible that motivated subjects were temporarily able to overcome or ignore sensations of discomfort and difficulty experienced during task performance and thus to maintain task completion times in the short term. However, since the tasks were experienced as significantly more difficult and uncomfortable, it is possible that movement and efficiency compromises were made during task performance in order to maintain speed. These compromises could lead to greater long-term fatigue and inefficiency, increased injury potential, and longer-term task performance decrement.[11] Hence, in the further development of this type of model for assessing treatment options, longer-term tasks should be tested to determine whether they might be more successful in illustrating work-related functional decrements incurred by wrist muscle injury.

Previous studies have also used various means to model different forms of work-related wrist discomfort. For example, Slater et al.[8] used saline injection to model lateral epicondylalgia-like discomfort along the same time course as employed in our study. One other study has also shown wrist muscle soreness and strength loss following eccentric wrist muscle extension contractions, with results and time courses similar to those reported in this study.[10] Furthermore, previous studies have employed eccentric exercise–induced muscle damage to evaluate the potential effectiveness of interventions such as ultrasound treatment[16] and massage therapy[17] on the physiological symptoms and sensory perceptions of muscle damage and soreness in the upper arm. However, these studies did not evaluate the effects of these therapeutic interventions on functional task performance. The present study is the first attempt to develop a comprehensive model of wrist muscle injury that would evaluate physiological and sensory responses as well as applied and functional task responses to the injury. Development and validation of such a model would allow its use in a more comprehensive and applied evaluation of the potential effectiveness of various treatment modalities in enhancing the recovery in workers experiencing overuse- or overexertion-induced muscle injuries and their ability to regain full function in their wrist muscles. This study has provided further information for such development and demonstrated that eccentric wrist exercise, as employed in this study, will induce wrist muscle strength loss, swelling, and soreness, as well as increase functional task discomfort and difficulty, for several days following the exercise. However, it appears that the functional tasks used in this study may not have been of sufficient duration to mimic realistic workplace conditions adequately and hence may not have been successful in demonstrating impaired functional task ability, in spite of other indicators of muscle damage. Interestingly, this study also highlighted the ability of motivated subjects to temporarily overcome soreness, discomfort, and muscle strength loss to maintain performance. Since task performance with the above symptoms likely involves detrimental changes in movement patterns, this could indicate that motivated workers may predispose themselves to further injury if they attempt to continue working while experiencing muscle discomfort. Nevertheless, further refinement of this model is required before it can serve as a means of evaluating the potential effectiveness of various therapeutic modalities in inducing muscle healing and functional recovery.

CONCLUSIONS

This preliminary study has demonstrated the potential for eccentric wrist exercises, as described above, to induce the type of muscle damage, task discomfort, and difficulty that could eventually serve as a valid model for such evaluations. The current model is readily standardized and thus could serve as an example of short-term muscle injury and recovery that will affect perception of task discomfort and difficulty as well as muscle soreness and loss and recovery of muscle force. A more severe injury model combined with longer task performance, however, could be a more valid model of actual workplace injury and recovery and more readily affect task performance measures.

KEY MESSAGES

What Is Already Known on This Subject

It is well established that muscle injury, damage, and soreness disrupt motor control of movement and can inhibit work-related functional tasks. Therapeutic interventions may be able to speed recovery of injured workers. However, objective and workplace-valid assessment of the effectiveness of various therapies requires the development of a model of muscle function following standardized injury, incorporating measures of muscle damage and recovery, work-related task performance, and subjective feelings of discomfort and work difficulty.

What This Study Adds

The model developed in this study can be readily standardized as a model of short-term injury and recovery that will induce muscle soreness, strength loss, and increase perception of work-related task discomfort and difficulty.

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