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A Dynamic Extensor Brace Reduces Electromyographic Activity of Wrist Extensor Muscles in Patients With Lateral Epicondylalgia

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Study Design: Semiexperimental study.
Objective: To investigate the effect of an external wrist extension force on extensor muscle activity during hand gripping in patients with lateral epicondylalgia.
Background: Lateral epicondylalgia or "tennis elbow" is a common, often disabling ailment affecting millions of people. An optimal treatment strategy remains to be identified. The use of an external wrist extension force may reduce the extensor muscle activity during gripping in these patients.
Methods: Muscle activity of the extensor carpi radialis brevis (ECRB), extensor digitorum communis (EDC), and extensor carpi radialis longus (ECRL) was measured using surface EMG. Subjects gripped at an intensity of 10%, 20%, and 30% of the maximum voluntary contraction (MVC) force with and without the dynamic extensor brace and with and without an applied external wrist extension force of 1%, 2%, and 3% of MVC.
Results: At all levels of MVC gripping, the EMG signal of the ECRB and EDC were significantly lower for gripping with than without brace. An extension force of 3% of the MVC force significantly reduced the EMG signal of all muscles in almost all measurement conditions.
Conclusions: The results of this study indicate that the dynamic extensor brace as well as the external extension force significantly reduced the EMG signal of the wrist extensor muscles during gripping in patients with lateral epicondylalgia. Based on these results, the dynamic extensor brace could be a promising new intervention for lateral epicondylalgia. *J Orthop Sports Phys Ther 2006;36:170-178.*

Key Words: *electromyography, hand grip, isometric force, tennis elbow*

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Lateral epicondylalgia or "tennis elbow" is a common, often disabling ailment affecting millions of people. The pathoetiology of lateral epicondylalgia is not clear.[14,17] An overload injury seems to affect the wrist extensor muscles, specifically the extensor carpi radialis brevis (ECRB), at its insertion on the lateral humeral epicondyle.[9,20,26] With an incidence between 4 and 7 per 1000 patients per year in general practice and an annual incidence of 1% to 3% in the general population, it is a frequent complaint in primary care.[22] Untreated, the complaint is estimated to last from 6 to 24 months.[22,25] Several treatment options are available, including corticosteroid injections, surgery, and physiotherapeutic interventions, but there is insufficient evidence for success of any specific intervention approach.[1,10,11,20]

Another widely applied treatment strategy is the use of orthotic devices. A recent review article showed no advantages in pain, grip strength, and subjective outcome measures when using counterforce braces or wrist splints in the treatment of lateral epicondylalgia.[22] The theoretical basis for the orthosis is to provide rest and thereby a reduction in muscle activity of the wrist extensor muscles during functional activities. This would theoretically allow the pathological changes in the muscle and tendon to heal.[7] A recent retrospective cohort study revealed that, although splinting patients with epicondylalgia may cause acute relief, it does not necessarily lead to better outcomes and, in fact, may have adverse effects on rates of limited duty, treatment duration, and medical costs.[5] The only orthosis used to treat lateral epicondylalgia that has been shown to significantly reduce EMG signal of the ECRB muscle is a semicircular wrist orthosis. The reduction in EMG, however, was only seen during lifting tasks.[7]

A dynamic wrist extensor splint used to treat extensor tendon injuries induces an external extension torque on the wrist. Using this splint, Newport and Shukla[13] showed a reduction in the EMG signal of the extensor digitorum communis (EDC) muscle during active wrist flexion. An external extension force applied to the palm of the hand has also been shown to significantly reduce EMG signal in the ECRB and EDC muscles in 20 healthy individuals during hand gripping.[24] It was hypothesized that the production of the wrist extension moment required during a gripping task was partially provided by the externally applied force. The principle of an external wrist extension force applied to the palm of the hand might be useful in the treatment of lateral epicondylalgia. Based on this principle, a dynamic extensor brace for treatment of lateral epicondylalgia has been developed (Carp-X; Somas, Sint Anthonis, The Netherlands) (Figure 1). The brace applies a continuous extension force to the palm of the hand over the full range of wrist motion.

FIGURE 1. The dynamic extensor brace.

Activation of the extensor muscles differs with respect to health status.[3,8] During simulated tennis play, subjects with lateral epicondylalgia employed greater, earlier, and longer activation of the forearm extensor muscles than a healthy age-matched control group.[3] Therefore, patients suffering from lateral epicondylalgia may have altered muscle mechanics during gripping compared to healthy subjects. As a consequence, a significant reduction in EMG signal found in the wrist extensor muscles of healthy subjects while using an extension force[24] may not be seen in patients with lateral epicondylalgia.

The main purpose of this study, therefore, was to assess the effect of an external extension force exerted by the newly developed dynamic extensor brace on extensor muscle activity during gripping in patients with lateral epicondylalgia. In addition, the effect of an external extension force applied to the palm of the hand on wrist extensor muscle activity in patients with lateral epicondylalgia was examined.

METHODS

Subjects

Nineteen patients participated in the laboratory setup tests and 11 patients performed the tests with the newly developed dynamic extensor brace. Inclusion criteria for the patients were: physician's diagnosis of lateral epicondylalgia; recurrence of symptoms after initial treatment; and persistent symptoms despite alternative treatments for lateral epicondylalgia. Exclusion criteria were: bilateral lateral epicondylalgia; symptom duration of less than 6 weeks; neurological or rheumatic disorders to the forearm or wrist; and a history of muscular, neural, or bone injuries of the forearm apart from lateral epicondylalgia. Final inclusion criteria, which were checked prior to the first measurement, were: pressure pain at the lateral epicondyle of the elbow; no pain during palmar flexion of the wrist against resistance; a positive Mill's test; and pain on the lateral aspect of the elbow during extension of the wrist against resistance. All patients gave written informed consent. Characteristics of the subjects are shown in Table 1. The study was approved by the Hospital Ethical Committee of Human Research (CMO) of Arnhem en Nijmegen.

Study Protocol

Subjects were asked not to perform any strenuous exercise for the 24 hours before and on the day of the measurements. Surface EMG electrodes (Biomedical Engineering Department, University of

TABLE 1. Subjects characteristics.

Variables	Laboratory Setup (n = 19)	Dynamic Extensor Brace (n = 11)
Male/female (n)	10/9	6/5
Affected arm R/L (n)	19/0	9/2
Duration of symptoms (mo)	45.3 (3-192)*	16.2 (2-89)*
Age (y)	51 (34-63)*	48 (38-65)*
Use of analgesics (n)	5	7
VAS score		4.1 (2.9-7.3)*
PRFEQ score		5.0 (2.8-7.5)*

Abbreviations: VAS, visual analogue scale; PREFQ, Patient-Rated Forearm Evaluation Questionnaire.
* Mean (minimum–maximum).

Nijmegen, The Netherlands), with a diameter of 5 mm, were placed over the ECRB, EDC, and the extensor carpi radialis longus (ECRL) with a 2-cm interelectrode distance. Electrodes were applied on the forearm after scrubbing the area and properly cleaning the skin with alcohol. During the tests with the dynamic extensor brace only the EMG signal of the EDC and ECRB was measured, because in a similar study with healthy subjects the most significant results were seen in the EDC and ECRB.[24] Electrodes location was determined using palpation while the subjects were alternatively activating and relaxing their extensor muscles. Electrodes were placed on the thickest part of the muscle belly in accordance with Merletti et al.[12] The earth electrode was placed just above the elbow on the upper arm (Figures 2 and 3). The surface EMG signals and the grip force were recorded during every measurement. One person conducted all EMG electrode applications, assessments, and analyses to exclude intertester variability.

Procedure Laboratory Setup

After testing the electrodes, subjects were asked to place their forearm on a plate with their elbow between 60° and 90° of flexion, the forearm in neutral position between pronation and supination, and the wrist in neutral radial/ulnar deviation. The forearm was fixated at the distal end with a strap to a vertical bar attached to the plate. Proximally, the forearm was held against a vertical plate located on the medial side of the forearm (Figure 2). The position of the arm and wrist in the laboratory setup was chosen as indicated in studies by Fong and Ng[6] and Barr et al.[2] Grip force was assessed using a hand grip dynamometer manufactured at the University of Nijmegen (Biomedical Engineering Department, University of Nijmegen, The Netherlands).

First, grip maximum voluntary contraction (MVC) force was measured 3 times for 2 to 3 seconds, with the wrist in 15° of extension. A 1-minute rest was given between measurements. Verbal encouragement was given to ensure maximum effort. If the achieved MVC levels differed by more than 10% from each other, an extra trial was executed. The trial with the highest score was used as the MVC. Next, subjects were asked to grip at approximately 10%, 20%, and 30% of their MVC for 5 seconds using a monitor to display the grip force as visual feedback. These levels of MVC were chosen because they represent the effort typically performed during most daily activities.[4,15]

After a 20-second rest, a strap used to apply the wrist extension force was placed over the palm of the subjects' hand. The extension force was applied by weights, pulling via a cable at an angle 90° with the hand. Three different extension forces were used: 1%, 2%, and 3% of the individual MVC. This was approximately 3.2, 6.5, and 9.7 N for men and 2.2, 4.5, and 6.7 N for women. These levels of force were chosen because they overlap with the amount of extensor force provided by the dynamic extensor brace (Carp-X). Subjects were asked again to grip at 10%, 20%, and 30% of their grip MVC for 5 seconds, with their wrist still in 15° of extension as a force equal to 1% of their MVC was pulling the wrist in extension. Testing was then repeated with the exten-

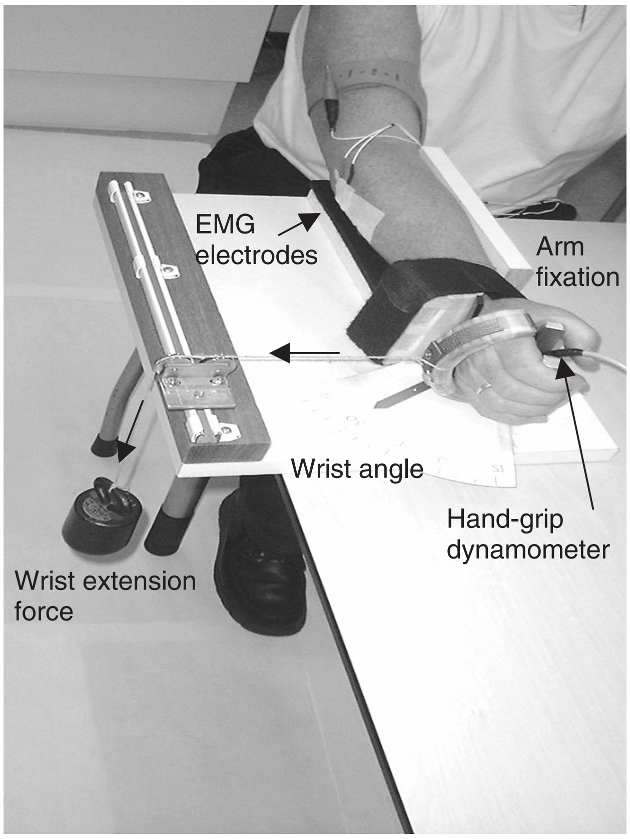

FIGURE 2. Test position of the arm in the laboratory setup. The angle of the wrist can be securely positioned and reproduced. The arm is stabilized at the wrist. The wrist extension force is applied by a mass, which is attached via a cable to a strap around the palm of the hand at an angle of 90° (by adjusting the position on the rails).

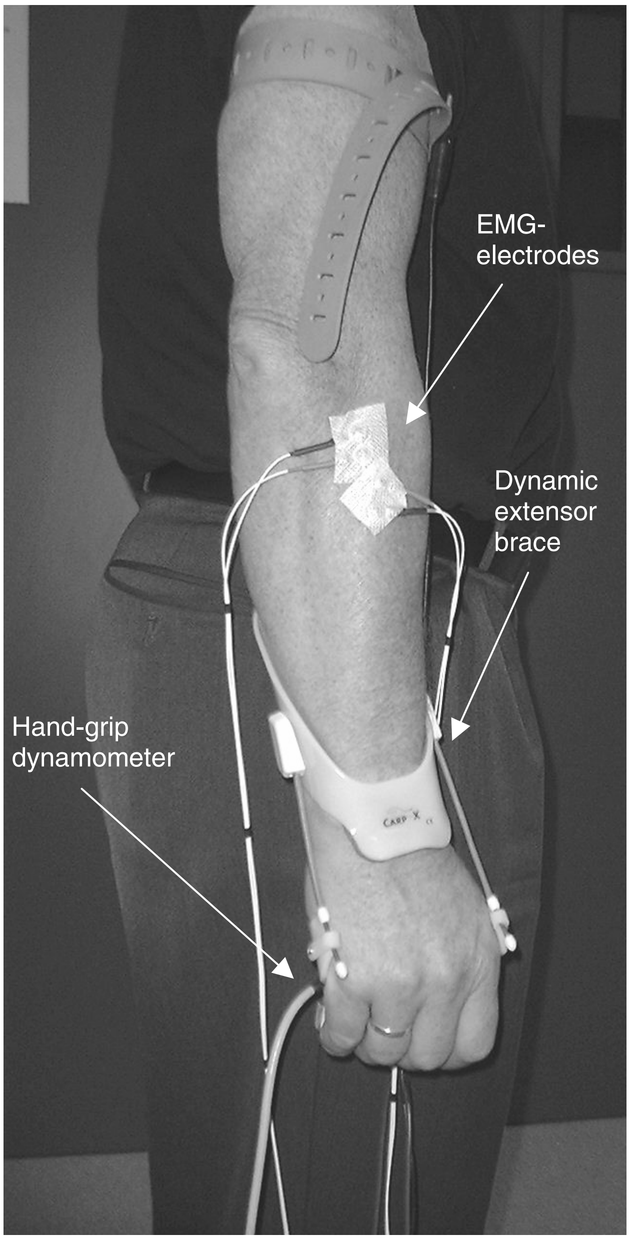

FIGURE 3. Position of the arm during the gripping test with the dynamic extensor brace with the wrist in neutral position. Subject is wearing the brace.

sion force set at 2% and 3% of the grip MVC. The total procedure was repeated twice thereafter, once with the wrist in 30° of extension and once with the wrist in neutral (0°) position. The surface EMG signals and the grip force were recorded during every measurement. For each gripping intensity and wrist angle 1 trial was collected and all subjects were tested following the exact sequence just described. In a previous study, with healthy subjects using the same laboratory setup, the measurements were proven to be reproducible; coefficient of variation in root-mean-square (RMS) EMG was 10.5% and the correlation coefficients (*r*) for the measurements of ECRB, ECRL, and EDC EMG activity were 0.84, 0.73, and 0.66, respectively.[24]

Procedure Dynamic Extensor Brace

This test was completed in a single 2-hour session and was divided into 2 stages: (a) fabrication of the dynamic extensor brace and (b) assessment of muscle activity during gripping.

Fabrication The brace consists of 2 shells (1 applied at the palm of the hand and 1 on the dorsal side of the forearm just proximal to the wrist) made of the thermoplastic polyester PET-G. Two springs made of memory metal (nickel-titanium alloy) connect the 2 shells. Two sets of springs are available: 1 version in which the external extension force varies from 5 to 9 N and another in which it varies from 7 to 12 N within the range of 30° wrist extension to 30° wrist flexion. The brace is available in 3 sizes. Depending on the maximum voluntary contraction (MVC) force and hand size, the proper brace size and springs were selected. Trained and experienced orthopaedic technicians fitted the braces for each patient according to an in-house protocol (custom-made brace). By heating the shells it was possible to shape them to the contours of the palm of the hand and the wrist to make sure the braces fitted comfortably. The basic position of the brace is at 30° wrist extension.

Testing Before measuring the grip forces, subjects were asked to fill in the Patient-Rated Forearm Evaluation Questionnaire (PRFEQ [score, 0-10]), which assess the functionality of the arm,[16] and a questionnaire about the use of analgesics. A horizontal 10-cm visual analogue scale was used to measure the amount of pain each subject had prior to the study (Table 1).

During the test, subjects were standing and looked straight ahead with the elbow in extension and the shoulder and radioulnar joint in neutral rotation (Figure 3). The position of the arm was based on the study by Wuori et al.[26] MVC and pain-free grip strength were measured with and without the subjects wearing the brace. MVC was measured according to the protocol used with the laboratory setup. For pain-free grip strength each patient performed 3 trials with a 1-minute rest between each trial. Between the 2 types of grip strength assessments a 5-minute rest was provided. Pain-free grip strength and MVC were calculated as the average of 3 trials and the best of 3 trials, respectively. After another 10-minute rest the subjects gripped without the brace at 10%, 20%, and 30% of their MVC for 5 seconds with visual feedback. A 1-minute rest was given between measurements. After a 5-minute rest the subjects repeated the task, wearing the dynamic extensor brace (Figure 3). Surface EMG signals were recorded during each measurement. While gripping, with or without the brace, the subjects were instructed to keep the wrist in neutral position.

EMG and Grip Force

Bipolar surface tin EMG electrodes were connected to an amplifier with a common-mode rejection ratio of approximately 80 dB, a gain of about 5000, and a first-order analogue passive filter with a low-pass cut-off frequency of 250 Hz and a high-pass cut-off frequency of 10 Hz. Data were recorded with a sampling rate of 1000 Hz on a computer using a Keithley DAS-1602 ADC-board and Poly software (Inspector Research Systems BV, Gouda, The Netherlands). Matlab, Version 6.1 (The Math Works, Natick, MA) was used to perform RMS processing of the raw EMG signal,[12] as well as for analyzing the grip force signal. Both signals, EMG and force, were analyzed for 1 second at the same time interval. During every 5-second measurement, a 1-second RMS value (the 1-second in which the produced strength values were similar with and without an extension force) was used for data analysis, because that represented the 5 seconds accurately (pilot study, data not shown).

Statistical Analysis

EMG data are presented as the percentage RMS value of gripping with an extension force compared to gripping without an extension force for the same wrist angle and percentage gripping force [(RMS with extension force ÷ RMS without extension force) × 100%], with 95% confidence intervals (CIs). If 100% (which represents muscle activity without extension force) is outside the range of the 95% CI, changes are considered to be significant. Paired *t* tests were used to compare the MVC and pain-free grip strength with and without brace.

Pooled SD of grip strength was calculated to verify that there were no grip strength differences between gripping without and with an extension force, and with and without the brace. Pooled SD values below 1 N, indicating a less than 5% difference in gripping strength between measurements, were considered acceptable.

Furthermore, to evaluate the effects of the gripping MVC conditions, the wrist angle, and the degree of extension force on the EMG signal, a repeated-measures analysis of variance (ANOVA) was applied. The variables for the repeated-measures ANOVA were gripping MVC condition with 3 levels (10%, 20%, and 30% MVC), the wrist angle with 3 levels (0°, 15°, and 30°), and the degree of extension force with 3 levels for the laboratory setup (1%, 2%, and 3% MVC). Only for significant effects post hoc *t* tests were performed. Effects and differences were considered significant at $P < .05$.

RESULTS

Laboratory Setup

The extension force had a significant effect on the EMG signal of the ECRB and EDC muscles ($P < .0001$). EMG signal of the ECRB and EDC declined with increasing extension force.

The repeated-measure ANOVA showed a significant effect of the wrist angle on EMG signal ($P = .016$). The EMG signal at 15° extension was significantly lower for all muscles compared to 0° and 30°, but no significant difference was found between 0° and 30°. No significant interactions between wrist angle, extension force, and MVC gripping condition were found.

Because the data were normalized to the control condition, the ANOVA did not evaluate differences between the control condition (the condition without the extension force) and other conditions, which can be detected by using the 95% CIs. Significant effect of the extension force is noted when 100% is not included within the CI.

ECRB At 2% and 3% extension force almost all RMS values at each wrist angle were significantly lower with than without the extension force. At 1% extension force only the 10% MVC gripping condition at a 15° wrist angle showed a significantly lower RMS value (Table 2).

EDC At 2% and 3% extension force almost all RMS values at all wrist angles were significantly lower with than without an extension force. At 1% extension force half of the tests showed significantly lower RMS values (Table 3).

ECRL The effect of an extension force on RMS values of the ECRL was inconsistent. The 1% extension force tended to increase RMS values, whereas at a force equal to 2% and 3% MVC less than half of the conditions showed a significantly lower RMS value when the extension force was applied compared to no extension force condition (Table 4).

Dynamic Extensor Brace

The brace had a significant effect on the EMG signal of the ECRB and EDC muscles ($P < .0001$). There was no significant effect of the MVC gripping condition (angle and %MVC) on the EMG signal of the ECRB and EDC, as revealed by the repeated-measures ANOVA.

At all levels of MVC gripping the RMS values of the ECRB and EDC were significantly lower for gripping with the brace than without (Table 5).

Pain-free gripping with the dynamic brace resulted in a higher pain-free grip strength comparing to gripping without the brace ($P = .031$) (Figure 4). No difference in MVC with or without the brace was found.

To verify that there were no differences in grip strength between gripping with and without an extension force and with and without the brace at the different MVC levels (10%, 20%, and 30%) the pooled SD was calculated. All values remained under 0.9 N, indicating that grip strength remained the same among the different tests.

TABLE 2. Percentage (mean [95% CI]) of EMG signal of the extensor carpi radialis brevis (ECRB) during gripping with a wrist extension force applied to the palmar aspect of the hand, in comparison to the same test without extension force. Shaded areas indicate significantly lower EMG root-mean-square values compared to a trial performed at the same wrist angle and grip strength without the extension force. Significant differences are present when the 95% CI does not include 100% (the value of the control condition).

Wrist Extension Angle/Grip Strength	Extension force (% MVC)		
	1%	2%	3%
0°			
10% MVC	96.7 (81.4-112.0)	89.6 (79.3-99.9)	65.7 (51.6-79.8)
20% MVC	103.6 (94.8-112.4)	88.1 (79.4-96.8)	74.8 (63.3-86.3)
30% MVC	97.3 (89.8-104.8)	94.0 (87.0-101.0)	76.7 (65.9-77.5)
15°			
10% MVC	88.6 (79.8-97.4)	73.7 (63.2-84.2)	68.1 (55.3-80.9)
20% MVC	93.2 (83.1-103.3)	75.1 (66.9-83.3)	73.2 (62.9-83.5)
30% MVC	101.8 (91.9-111.7)	87.0 (80.6-93.4)	81.2 (89.8-72.6)
30°			
10% MVC	102.1 (87.3-116.9)	83.9 (70.8-97.0)	56.0 (44.8-67.2)
20% MVC	102.8 (89.5-116.1)	91.4 (81.9-100.9)	66.4 (55.2-77.6)
30% MVC	101.5 (92.1-110.9)	88.3 (80.7-95.9)	75.2 (64.9-85.5)

Abbreviation: MVC, maximum voluntary contraction.

TABLE 3. Percentage (mean [95% CI]) of EMG signal of the extensor digitorum communis (EDC) during gripping with a wrist extension force applied to the palmar aspect of the hand, in comparison to the same test without extension force. Shaded areas indicate significantly lower EMG root-mean-square values compared to a trial performed at the same wrist angle and grip strength without the extension force. Significant differences are present when the 95% CI does not include 100% (the value of the control condition).

Wrist Extension Angle/Grip Strength	Extension force (% MVC)		
	1%	2%	3%
0°			
10% MVC	96.4 (64.7-128.1)	87.4 (73.6-101.2)	87.8 (72.3-103.3)
20% MVC	83.2 (71.1-95.3)	74.5 (62.1-86.9)	72.4 (58.6-86.2)
30% MVC	100.2 (77.7-122.7)	75.8 (66.1-85.5)	71.4 (58.1-84.7)
15°			
10% MVC	82.0 (69.3-94.7)	74.2 (56.9-91.5)	68.4 (53.0-81.8)
20% MVC	87.9 (72.0-103.8)	72.0 (58.7-85.3)	70.0 (52.5-87.5)
30% MVC	85.2 (70.1-100.3)	78.5 (67.4-89.6)	66.8 (50.9-82.7)
30°			
10% MVC	90.6 (70.2-111.0)	76.9 (60.1-93.7)	62.4 (44.5-80.3)
20% MVC	84.5 (70.9-98.1)	79.0 (65.5-92.5)	62.6 (50.6-74.6)
30% MVC	82.0 (70.2-93.8)	74.0 (61.5-86.5)	62.8 (52.7-72.9)

Abbreviation: MVC, maximum voluntary contraction.

DISCUSSION

The results of this study show that the dynamic extensor brace as well as the external extension force applied by the laboratory setup significantly reduced the EMG signal of the wrist extensor muscles during gripping in patients with lateral epicondylalgia. The muscles showing the most significant changes, the ECRB and EDC, are the muscles that are affected the most in these patients. A higher extension force resulted in a greater reduction of muscle activity.

The decline in RMS values when applying an extension force was not the result of a difference in force generation, as shown by the low-pooled SD results. The decrease in EMG signal of the wrist extensor muscles during gripping with the dynamic extensor brace in the present study is comparable to the reduction in EMG signal of the EDC as seen in the study of Newport and Shukla.[13] In that study a brace based on a similar principle (an external extension force applied to the palm of the hand) was studied; however, the purpose of that brace was to treat extensor tendon injuries, and the reduction in EMG signal was only seen during a lifting task. Gripping, an important aspect of daily functional

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TABLE 4. Percentage (mean [95% CI]) of EMG signal of the extensor carpi radialis longus (ECRL) during gripping with a wrist extension force applied to the palmar aspect of the hand, in comparison to the same test without extension force. Shaded areas indicate significantly lower EMG root-mean-square values compared to a trial performed at the same wrist angle and grip strength without the extension force. Significant differences are present when the 95% confidence interval does not include 100% (the value of the control condition).

Wrist Extension Angle/Grip Strength	Extension force (% MVC)		
	1%	2%	3%
0°			
10% MVC	123.2 (85.5-160.9)	109.6 (95.1-124.1)	92.5 (71.6-113.4)
20% MVC	107.8 (87.7-127.9)	98.2 (90.7-105.7)	82.2 (64.9-99.5)
30% MVC	110.9 (91.7-130.1)	101.7 (90.4-123.0)	87.1 (76.0-98.2)
15°			
10% MVC	107.3 (80.1-134.5)	81.2 (69.5-92.9)	66.3 (56.5-76.1)
20% MVC	98.6 (80.6-116.6)	83.7 (76.2-91.2)	68.4 (57.1-79.7)
30% MVC	93.6 (86.0-101.2)	84.9 (79.3-90.5)	70.4 (61.8-79.0)
30°			
10% MVC	107.8 (97.9-117.7)	90.5 (77.0-104.0)	76.4 (50.9-101.9)
20% MVC	104.7 (93.1-116.3)	94.0 (82.5-105.5)	73.3 (58.3-88.3)
30% MVC	113.3(103.1-123.5)	104.8 (92.6-117.0)	85.9 (74.1-97.7)

Abbreviation: MVC, maximum voluntary contraction.

activity, is most often negatively affected by lateral epicondylalgia.[26] Because an improvement in grip strength measurements reflects good treatment outcome,[18] most randomized clinical trials studying strategies to treat lateral epicondylalgia use grip strength to evaluate efficacy of a treatment. Gripping, which activates the flexor muscles, creates a flexion moment about the wrist joint and, as a result, the extensor muscles are coactivated, creating an extension moment that stabilizes the wrist joint.[19] Snijders et al[21] showed, using EMG, that the ECRB, EDC, and ECRL muscles are all activated during gripping.

It has been shown that activation of the extensor muscles differs with respect to health status.[3,8] We expected that patients suffering from lateral epicondylalgia, compared to healthy subjects, might have altered muscle mechanics during gripping. However, the results of this study show that an external extension force significantly reduces the EMG signal of the wrist extensor muscles during gripping in patients similarly to what was previously shown in healthy subjects.[24] Moreover, the brace had an immediate effect on the patients, demonstrated by an increase in pain-free grip strength compared to gripping without the brace. Apparently, by passively assisting the extensor muscles during gripping, pain-free grip strength improved. This may have important implications for brace wearing and functionality during daily life.

The results of this study show that a greater passive wrist extension force applied to the palm of the hand in a laboratory setup results in a higher reduction in muscle activity. The flexion moment produced by the flexor muscles when gripping is counterbalanced by

TABLE 5. Percentage (mean [95% CI]) of EMG signal of the extensor carpi radialis brevis (ECRB) and extensor digitorum communis (EDC) during gripping with the dynamic extensor brace (force, 5-12 N) with the wrist in neutral position, in comparison to the same test without the brace. Shaded areas indicate significantly lower EMG root-mean-square values compared to a trial performed at the same grip strength without the brace. Significant differences are present when the 95% CI does not include 100% (the value of the control condition).

Grip Strength	Brace	
	ECRB	EDC
10% MVC	74.5 (53.4-95.7)	65.1 (49.9-80.3)
20% MVC	78.0 (58.8-97.2)	72.4 (55.3-89.4)
30% MVC	68.8 (48.7-88.9)	71.6 (59.6-83.5)

Abbreviation: MVC, maximum voluntary contraction.

an extension moment normally produced by the extensor muscles.[23] Therefore, increasing the external force results in a reduction in the extensor muscle force that is needed to balance the wrist flexor moment.

Another interesting finding was that grip intensity also affected the results. If the flexion moment is increased due to a higher gripping intensity, then the extension moment has to increase as well to maintain equilibrium in the wrist.[21] Because the extension force is constant, only the muscle force can increase to maintain that equilibrium in the wrist. This means that a higher gripping intensity results in more muscle activity when a constant extension force is applied to the hand. Therefore, the highest decreases in EMG signal are to be expected at lower grip intensities, as was generally observed.

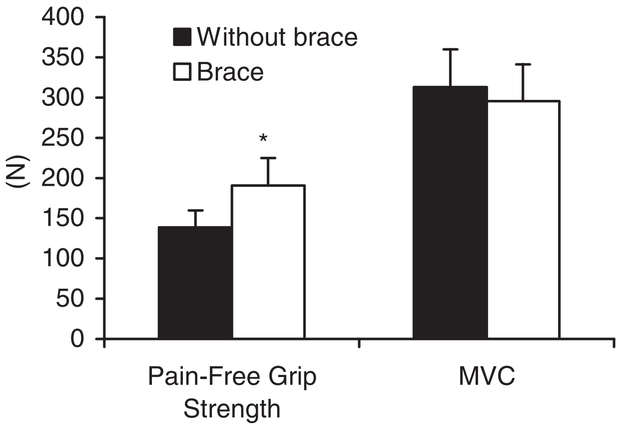

FIGURE 4. Pain-free grip strength and MVC with and without the dynamic brace in 11 patients. Mean (SD).* Pain-free grip strength with the brace significantly higher than without the brace *P* = .031.

Gripping with the wrist in 15° of extension showed the highest decrease in muscle activity for the ECRB and EDC, probably because 15° best approaches the normal functional wrist angle. This observation is of importance for the application of the dynamic extensor brace utilized to treat patients with lateral epicondylalgia.

The influences of the extension force, grip intensity, and wrist angle on EMG signal of the wrist extensor muscles in this study are in agreement with those seen in healthy subjects.[24] Based on these results, a dynamic extensor brace, used at the correct angle and extension force, could be a promising new treatment for lateral epicondylalgia. An evaluation in a clinical trial is needed.

CONCLUSION

The results of this study show that the dynamic extensor brace, as well as the external extension force applied by the laboratory setup, significantly reduced the EMG signal of the wrist extensor muscles during gripping in patients with lateral epicondylalgia. In addition, a higher extension force resulted in a greater reduction in muscle activity.

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