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The Immediate Effect of Orthotic Management on Grip Strength of Patients With Lateral Epicondylosis

Tennis elbow, or lateral epicondylosis, is a degenerative condition[3] associated with overuse of the wrist extensor muscles.[3,12,24,30,31,33] An incidence of 1% to 3% is reported in the general population,[1,2,17,26,30] but the prevalence is much greater in people undertaking activities involving repeated wrist and hand function such as gripping. The incidence is 40% to 50% in tennis players, for example.[3,5,23,33] Lateral epicondylosis is characterized by pain and tenderness over the lateral epicondyle of the elbow and decreased grip strength.[3,7] The pain is aggravated by resisted wrist extension[16,33] and forceful hand function performed during work or sporting and daily activities.[14] It typically affects the dominant arm in middle-aged individuals (those 40 to 60 years of age).[12,25,28]

STUDY DESIGN: Controlled laboratory study using a randomized crossover design.

OBJECTIVE: To determine the immediate effect of 3 common types of orthoses (2 elbow counterforce orthoses and a wrist splint) on grip strength in individuals with lateral epicondylosis.

BACKGROUND: Lateral epicondylosis is a common cause of pain and upper limb dysfunction. Although the effectiveness of orthoses has been reported, comparisons of effectiveness among orthoses are limited.

METHODS AND MEASURES: Fifty-two subjects with lateral epicondylosis were recruited (20 men, 32 women; mean $\pm$ SD age, 41 $\pm$ 8 years). Maximum and pain-free grip strength were assessed using a digital hand grip dynamometer immediately after the application of each orthosis. The 4 testing conditions included a placebo orthosis as a control condition, an elbow strap orthosis, an elbow sleeve orthosis, and a wrist splint. Data were analyzed using a 1-way analysis of variance for each outcome measure.

RESULTS: Pain-free grip-strength was greater when using the elbow strap or the elbow sleeve orthosis compared to when using the placebo control orthosis or the wrist splint ($P<.02$), but there was no difference between the elbow sleeve and strap orthoses ($P>.05$), nor between the wrist splint and placebo orthosis ($P>.05$). Maximum grip strength was less when using the wrist splint compared to when tested with the elbow sleeve or the elbow strap ($P\leqslant.003$). Use of the elbow strap, elbow sleeve, or wrist splint did not change maximum grip strength compared to the control placebo orthosis condition ($P>.05$). There was also no difference in maximum grip strength between the elbow strap and the elbow sleeve conditions ($P>.05$).

CONCLUSION: The use of the 2 types of elbow orthoses (strap and sleeve) resulted in an immediate increase in pain-free grip strength. No differences between the 2 orthoses were found, suggesting that either can be used. A wrist splint produced no immediate change in pain-free or maximum grip-strength, indicating that it should not be used as a first-choice orthosis based on those outcome measures.

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The cause is believed to be excessive loading of the aponeurosis of the common origin of the wrist extensors at the lateral epicondyle,[31,33] the area where the maximum tensile force occurs during wrist movements.[13,32] This particularly affects the extensor carpi radialis brevis (ECRB) tendon, which is located deep to the origin of the extensor digitorum communis.[18] Its insertion location proximal to the elbow axis causes shearing stresses, contact stresses, and abrasion against the lateral epicondyle during elbow motion.[2,13,32] The tendon is frequently and heavily loaded during many everyday upper-limb activities, as the ECRB acts as a stabilizer for gripping activity involving pronation and supination, and a prime mover for wrist extension.[8,22] An additional factor which makes it at risk of injury is its susceptibility to fatigue as a mismatch between the tendon's meta-

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bolic supply and the physiologic demand on the muscle has been found. Although the tendon can bear large loads of up to 10 times an individual's body weight, it receives only 13% of the oxygen supply provided to muscle.[13,32]

Elbow orthoses are frequently prescribed to produce a "counterforce" to reduce the load on the common extensor tendon and thereby reducing pain.[23,27,31] The mechanism for this is thought to be similar to the fret on a guitar. When someone applies finger pressure on a different place on the string along the neck of the guitar, it reduces the tension on the guitar string above the point of application. This may improve function, as reflected by measurements of pain-free grip strength by partially changing the point of force application from the tendon origin on the lateral epicondyle to the orthosis, thereby reducing the stress exerted proximal to the strap during muscle contractions.[10] A different type of orthosis uses a sleeve design that applies gentle compression over a wider area below and above the elbow joint. It is also thought to alter the point of force application by distributing it over a wider area, rather than specifically moving it distally. This orthosis is thought to enable the patient to contract more forcefully with less pain. An alternative orthotic approach is to use a wrist splint that holds the wrist joint in slight extension. Using an extension wrist splint is thought to alleviate pain by reducing stress on the common extensor muscles and especially the ECRB, by providing passive assistance to wrist extension that is necessary to counteract the wrist flexion forces that occur with gripping.[4,6]

There is conflicting evidence on the effects of counterforce orthoses on grip strength and pain. Several authors have reported increased grip strength and reductions in pain and disability,[9,10,26] while others have reported no significant differences in pain-free grip strength or pain.[33] Our aim was to compare the immediate effect of 3 commonly used orthoses (a counterforce elbow strap, a counterforce elbow sleeve, and a wrist splint) on grip strength of patients with lateral epicondylosis. Ultimately, this information will help health-care professionals make evidence-based choices when prescribing an orthosis.

FIGURE 1. The (A) placebo, (B) counterforce elbow strap, (C) counterforce elbow sleeve, and (D) wrist splint.

METHODS

Design

A RANDOMIZED CROSSOVER DESIGN was used. After informed consent had been obtained, the subjects were fitted and tested with each of the 3 common types of orthoses (2 elbow counterforce orthoses and a wrist splint) and the placebo control orthosis in a randomized order. The order of fitting and testing was decided by the participants selecting the order from concealed envelopes drawn from a hat. After fitting, the participants wore the orthosis, then their maximum and pain-free grip strengths were measured, as detailed in the section on outcome measures below. Testing of grip strength was conducted immediately after the orthoses were fitted. Participants rested for at least 5 minutes between testing for 1 orthosis and fitting of the next. Neither participant nor assessor could be blinded, as it was obvious which orthosis was being worn. Ethical approval for the study was obtained from the Orthotics and Prosthetics Department, Welfare and Rehabilitation Sciences University, Tehran, Iran.

Participant Recruitment and Selection

Adults with a history of lateral epicondylosis of at least 3 weeks were recruited from orthopaedic referrals to a specialist orthotics center (Behgam Orthotics and Prosthetics Center, Isfahan, Iran). Lateral epicondylosis was diagnosed using the following tests: (1) pain on palpation at the lateral epicondyle, (2) pain on resisted wrist extension, and (3) pain on resisted middle-finger extension. Subjects needed to test positive on all 3 tests to be included in the study. Patients with a history of fracture, dislocation, surgery, bilateral elbow pain, cervical dysfunction, osteoarthritis, or previous steroid injection to the elbow were excluded. The desired sample size of 52 subjects was calculated from the data obtained from a pilot study of 20 subjects, using a power of 0.70 at an alpha level of .05.

Orthoses

Three commonly prescribed orthoses to treat lateral epicondylosis were compared with a placebo control orthosis: a counterforce elbow strap, a counterforce elbow sleeve, and a wrist splint (**FIGURE 1**). A range of sizes of each orthosis was available to accommodate the size of all subjects.

The counterforce elbow strap was an 8-cm-wide neoprene band that incorporated a pressure pad and a red line to indicate the proximal end of orthosis fitting. A suitably sized counterforce strap was chosen by the examiner and positioned 2.5 cm distal to the lateral epicondyle. The subject made a fist and the strap was tightened. The orthosis was considered of suitable size if the subject was comfortable after the fist was released.

The counterforce elbow sleeve was made of neoprene and extended 15 cm above and below the elbow joint, and was fastened by one 5-cm-wide Velcro strap distal to the epicondyle. It also had a red line incorporated into the strap to enable proper fitting. Upper and lower elbow circumferences were measured by the examiner and an appropriate size was selected based on those measurements.

The wrist splint was also made of neoprene and incorporated a rigid polyethylene bar anteriorly to hold the wrist in 25° extension and prevent flexion or other wrist movements. It was applied to the palmar surface of the forearm, wrist, and hand, and extended from the metacarpophalangeal crease to two thirds of the way up the forearm and was fastened with 3 straps.

The placebo control orthosis consisted of a 5-cm-wide elastic neoprene strap placed 15 cm above the elbow. It provided tactile input to the area around the arm but provided no pressure on the forearm muscles.

FIGURE 2: Test position for grip strength testing.

Outcome Measures

Maximum and pain-free grip strengths on the involved side were recorded using a digital handgrip dynamometer (YDM-110D, No. 4200; Yagami Ltd, Tokyo, Japan). The participant stood with the shoulder in a neutral position; elbow extended and the forearm in neutral pronation/supination, holding the dynamometer (**FIGURE 2**).

To assess pain-free grip strength, participants were asked to slowly squeeze the dynamometer handle until they felt pain, and the force generated at that point was recorded. To assess maximum grip strength, they were asked to squeeze the dynamometer as hard as they could, regardless of any pain. Each test was repeated 4 times and mean values calculated. To familiarize the participants with the testing procedures, they initially practiced while holding the dynamometer in the uninvolved hand. During the practice trials on the uninvolved side, the position of the dynamometer handle was adjusted so that it comfortably accommodated the subject's hand size.

Data Analysis

A one-way, repeated-measures analysis of variance (ANOVA) was used to compare pain-free and maximum grip strength across the 4 testing conditions. If the ANOVA was determined to be statistically significant, a Bonferroni test was used post hoc to determine pairwise differences among the 4 testing conditions. All analyses were performed with SPSS, Version 16. Level of significance was set a priori at 0.05.

RESULTS

Fifty-two participants were recruited (20 men, 32 women). Their mean (SD) age was 41.2 (8.1) years and mean duration of symptoms was 18 (15) weeks for the men and 15 (14) weeks for the women. The right arm was affected in 35 (70%) of cases, and for 33 of these 35 participants this was the dominant arm. About 30% of participants played a sport, such as racket games. Thirty-one of the 32 women were housewives and 60% of men had heavy-labor jobs. The mean, SD, and ranges for the pain-free and maximum grip strength are presented in **TABLE 1**.

The 1-way ANOVA for pain-free grip strength indicated a statistically significant main effect for elbow orthoses conditions ($P<.001$). Post hoc pairwise comparisons between the elbow sleeve and strap orthoses was not significant ($P>.05$). There was no significant difference in pain-free grip strength between the wrist splint and the control conditions ($P>.05$) (**TABLE 2**). **TABLE 2** also shows that pain-free grip strength was significantly greater with the use of either of the elbow orthoses compared to the placebo or the wrist orthosis ($P<.02$).

The conducted 1-way ANOVA for maximum grip strength also indicated statistically significant differences among orthoses conditions ($P<.001$). Post hoc pairwise comparisons revealed a signifi-

TABLE 1 DESCRIPTIVE STATISTICS FOR PAIN-FREE AND MAXIMUM GRIP STRENGTH*

Orthosis	Pain-Free Grip	Maximum Grip
Placebo control	135 ± 77 (22-404)	161 ± 95 (28-510)
Elbow strap	156 ± 88 (20-466)	174 ± 97 (22-567)
Elbow sleeve	156 ± 91 (14-440)	175 ± 95 (22-484)
Wrist splint	129 ± 74 (17-387)	142 ± 73 (13-369)

* *Values are expressed as mean ± SD (minimum-maximum) Newtons.*

TABLE 2 COMPARISON PAIN-FREE GRIP STRENGTH BETWEEN GROUPS*

	Control	Elbow Strap	Elbow Sleeve	Wrist Splint
Control	...			
Elbow strap	0.021 (2 to 39)†	...		
Elbow sleeve	0.006 (4 to 37)†	1.000 (−15 to 15)	...	
Wrist splint	1.000 (−21 to 9)	0.001 (−44 to −10)†	0.001 (−44 to −9)†	...

* *Data are* P *values between conditions and 95% confidence intervals of the measured difference between conditions (in Newtons) in parentheses.*
† *A statically significant difference between groups (*$P<.05$*).*

TABLE 3 COMPARISON MAXIMUM GRIP STRENGTH BETWEEN GROUPS*

	Control	Elbow Strap	Elbow Sleeve	Wrist Splint
Control	...			
Elbow strap	1.000 (−15 to 42)	...		
Elbow sleeve	0.159 (−3 to 30)	1.000 (−25 to 26)	...	
Wrist splint	0.092 (−39 to 2)	0.003 (−56 to −8)†	0.001 (−51 to −14)†	...

* *Data are* P *values between conditions and 95% confidence intervals of the measured difference between conditions (in Newtons) in parentheses.*
† *A statically significant difference between groups (*$P<.05$*).*

cant difference between the elbow orthoses and the wrist splint conditions ($P\leqslant.003$) (**TABLE 3**). Use of the elbow strap, elbow sleeve, or wrist splint did not change maximum grip strength compared to the control placebo orthosis condition ($P>.05$). There was also no difference in maximum grip strength between the elbow strap and the elbow sleeve conditions ($P>.05$).

DISCUSSION

THE RESULTS OF THIS STUDY INDICATE that applying a counterforce orthosis at the elbow (either a strap or sleeve) improved pain-free grip strength in individuals with lateral epicondylosis when tested immediately after application. In contrast, a wrist splint did not change pain-free grip strength. There were no differences between the use of the elbow strap or the elbow sleeve in improving pain-free grip strength. These results are in agreement with those reported by Struijs et al,[26] who reported that orthotic treatment can be useful as an initial therapy for lateral epicondylosis. They compared the efficacy of a counterforce strap, physical therapy, and the combination of both, and found that a counterforce strap alone had a greater effect on activities of daily living than physical therapy alone. An elbow counterforce orthosis affects wrist joint proprioception and increases the pain threshold to passive stretching of the wrist extensors in subjects with lateral epicondylosis.[19]

The rationale for the study was based on Irani's theory[10] that counterforce orthoses have an immediate effect on pain by broadening the area of applied stress on the ECRB muscle. As a result, gentle compression of the musculotendinous region limits muscle expansion during muscle contraction, thereby eliciting less pain. Biomechanical studies have shown that a forearm orthosis can decrease the forces acting at the ECRB origin if the pressure pad is placed over the belly of the ECRB, but tends to be more effective if the pressure pad is positioned distal to the lateral epicondyle.[15,31] We provided this pressure using a double-layer pressure pad in the elbow strap. We also found that the sleeve, which gives generalized compression around the elbow area rather than specifically to the area distal to the lateral epicondyle, increased pain-free grip strength, suggesting that specific compression may not be necessary. However, the sleeve included a fixing strap that was positioned below the epicondyle and might have acted as pressure pad. Wuori and coworkers[33] also reported no significant differences in pain-free grip strength between a counterforce strap and a sleeve, although they used orthoses with slightly different designs.

Future studies should assess whether this strap is a necessary part of the sleeve design. Because there is no difference apparent at this time between either of the 2 counterforce orthoses, cost and patient preference should be used to make a final choice. In practice, it may be that the types of activities during which the orthosis would be used also might influence comfort and compliance.

Our results showed that the wrist splint was not effective in improving pain-free grip strength when compared to the placebo control orthosis. While the use of a wrist splint cannot be recommended on the basis of immediate change on pain-free grip strength, it is possible that it could be useful based on other outcome measures and functions that do not include gripping, such as typing on a keyboard. Previous studies have suggested that 25° of wrist extension is the optimal position to generate grip strength and that a wrist splint can alter electromyography activity of the wrist extensors while lifting.[11,21]

We also showed there was no significant difference between the strap, sleeve, or wrist splint compared with the placebo when measuring maximum grip strength. It could be that pain did not limit the ability to generate grip strength, and, therefore, no improvement could be expected from the use of any of the orthoses. Unfortunately, we did not measure the amount of pain perceived by the subjects during the testing of maximum grip strength. It is possible that the effect of the orthoses was to reduce pain during testing, without increasing the amount of strength. In the future, we suggest that a pain scale be used to determine the effect of the orthoses on the amount of pain during the testing of maximum grip strength, as this is a more likely effect than a change in strength.

Clinical applicability of the results is limited, as we have only assessed the immediate effects of wearing the orthoses on grip strength. Future studies should address the effectiveness of the sleeve and the strap on grip strength with prolonged use. Future research should also consider functional changes related to work, daily living, and sporting activities, and acceptability to patients and their preferences. Consideration should also be given to the occurrence of adverse effects with prolonged use and whether use of an orthosis can prevent recurrence.

The sample size for this study was calculated from pilot study data powered to detect a difference between each orthosis and the placebo control. It was not powered to detect a difference between the strap and the sleeve. However the differences found were very small, the *P* values of the comparison very high, and the confidence intervals very wide, supporting the conclusion that the lack of differences were not due to an inadequate sample size. Finally, the appropriateness of the randomized crossover design is based on the assumption that there was no longlasting effect from wearing the orthoses once they were taken off. Trossman and Li[29] have demonstrated that a 60-second rest is sufficient to produce consistent intertrial results when testing isometric grip strength performance, and we increased this period to 300 seconds for more confidence. So it is not an unreasonable assumption, although an interrupted time series design would be needed to confirm statistically.

CONCLUSION

Two types of elbow orthosis, a strap or a sleeve, produced an immediate improvement in pain-free grip strength in people with lateral epicondylosis. There were no differences between the 2 orthoses, suggesting that either can be used. A wrist splint had no effect on pain-free grip strength. Maybe the wrist splint is effective for other outcomes/functions that do not include gripping, such as typing on a keyboard. ◉

KEY POINTS

FINDINGS: The application of a counterforce elbow orthosis (sleeve and strap) has an immediate effect on improving pain-free grip strength in individuals with lateral epicondylosis.

IMPLICATION: The results of the present study support the use of a counterforce elbow sleeve or strap as a first choice to reduce pain during gripping activities.

CAUTION: Only the immediate effects on grip strength have been investigated; long-term effectiveness and functional effectiveness of the braces were not investigated.

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