ORIGINAL ARTICLE

EFFECT OF USING WRIST ORTHOSES ON FOREARM FLEXOR AND EXTENSOR MUSCLE ACTIVATION

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ABSTRACT

Objective: To investigate the effect of using wrist immobilization orthoses made from different materials, on activation of the flexor and extensor musculature of the forearm while performing specific tasks. Methods: Twenty-six adults, with an average age of 26.2 years, underwent the Jebsen-Taylor functional hand test and the grip strength test (Jamar® dynamometer) under three conditions: free hand, wearing a composite orthosis and wearing a thermoplastic orthosis. The tests were carried out using the dominant hand only. During the tests, surface electrodes were attached to the flexor and extensor muscles of the forearm to record the muscle electrical activity. The results obtained under the three conditions were compared and analyzed using the Wilcoxon statistical test. Results: Significant differences in muscle activation were found between using the free hand and using any of the orthoses. There was no significant difference in muscle activation between the two types of orthosis. A decrease in activity of the extensor muscles of the forearm was observed during all the tasks, as well as an increase in activation of the flexor muscles with the use of the orthoses. Conclusion: These results are important for defining whether an orthosis should be prescribed during the rehabilitation process for a wide range of disorders, such as tendinitis of the flexors and extensors of the wrist and fingers, as well as for predicting the length of time for which these devices should be used.

Keywords - *Orthopedic devices; Wrist; Electromyography*

INTRODUCTION

Assistance technology has been used as an alternative to intervention, with the aim of increasing patients' functional ability during self-care, work and leisure activities$^{(1)}$, as well as to support life and participation in the community$^{(2)}$. Among the various types of assistance technology, orthoses stand out as an important resource in the rehabilitation process.

Because of each client's specific features, this device can be characterized for different objectives: protection for structure healing; maintenance or promotion of the range of motion of a given joint; replacement or augmentation of a function; prevention or correction of deformities; provision of repose for a joint; reduction of pain; or serving as the foundation for self-help accessories, among others$^{(3,4)}$. Thus, the model and construction of orthoses used in different rehabilitation processes may range from simple to complex$^{(5)}$, and the material used in making them must meet the complexity requirements of each of these devices.

Many questions have been raised regarding the influence of these devices on the functional use of the hand, especially in relation to wrist immobilization orthoses. This type of orthosis, which is widely indicated for treating people with various conditions, has the aim of protecting the healing of tissues or structures$^{(6)}$ while allowing the manual function needed to perform everyday activities$^{(7,8)}$. One frequently discussed issue is the influence of orthosis use on the degree of forearm flexor and extensor muscle activation while performing daily tasks. The wrist is a strategic joint in the kinetic chain that regulates the efficiency of finger movements, among hand functions$^{(9)}$. It is the wrist position that maintains the extrinsic muscle-tendon unit in critical tension, and wrist range of motion defines the set of functional movements that the hand can produce$^{(9)}$. While executing the hand's

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We declare that there is no conflict of interest in this paper functional movements, the wrist muscles are responsible for promoting stability for this joint, increasing the grip strength and positioning the fingers(10).

To maintain wrist stability, it is necessary to have co-activation as well as individual activation of the wrist flexors and extensors(11). Specifically, the wrist extensors have a double role of concomitantly inhibiting and stabilizing forces during the grip movement(12,13). In the specific case of wrist extensor tendinitis or lateral epicondylitis, the basic premise for indicating orthoses for immobilization of wrist extension is the need to provide repose for the wrist extensor muscles during functional activities. In this case, the hypothesis is that immobilizing the wrist in relation to extension, through using orthoses, will reduce the activity of the extensor muscles while performing daily tasks. It is believed that this reduction will occur because the use of this device replaces the primary action of the extensors (i.e. the action of wrist extension) and keeps the muscle shortened. The objective of this study was to investigate whether using orthoses to immobilize the wrist during extension, constructed with different materials, would enable reduction of wrist extensor muscle activation while performing daily tasks.

METHODS

Sample

A quasi-experimental study was carried out, in which 26 adults (19 women and 7 men) of mean age 26.2 years participated as volunteers. None of them presented abnormalities of the upper limbs. The inclusion criteria were: age between 20 and 50 years, absence of neuromusculoskeletal disorders in the upper limbs and absence of pain in the wrist region during the last two weeks.

The sample size calculation used in this study was based on a similar situation documented in the literature by Johansson *et al*(13). Based on the results from their study and considering a non-directional analysis with significance level of $\alpha = 0.05$, for a statistical power of 0.99 and an expected effect of magnitude $d = 1.97$, the sample needed for the present study was determined as $n = 20$, in accordance with a table also in the literature(14), to which 30% was added as a safety margin.

Before inclusion in the study group, all the participants were duly informed about the intended objectives and the procedures that would be performed, and then were asked to sign the free and informed consent statement approved by the Research Ethics Committee of the Federal University of Minas Gerais (opinion no. ETIC 017/05).

PROCEDURES

Each participant underwent two evaluations: the first, for an initial interview and manufacture of the custom-made orthoses; the second, to assess the influence of using the orthoses the activation of wrist flexor and extensor muscles. Each evaluation was previously scheduled according to the volunteer's availability. At the time of the initial interview, two orthoses were custom made for each of the participants: one, using composite sandwich material that was developed by the authors in a previous study(15); and the other was made of thermoplastic material that is available on the market (*Ezeform*®; gold standard). *Ezeform*® was chosen as the gold standard because it is part of the main group of materials used in clinical practice to manufacture orthoses, since it has great rigidity and can therefore be used to construct various orthotic devices(16).

The device tested was an immobilization orthosis for wrists in extension, as shown in Figure 1. This type of orthosis was chosen because it is frequently prescribed for treating various sequelae from neuromusculoskeletal disorders, such as hemiparesis of the hand(17), carpal tunnel syndrome(18,19), quadriplegia(20) and lateral epicondylitis(21,22).

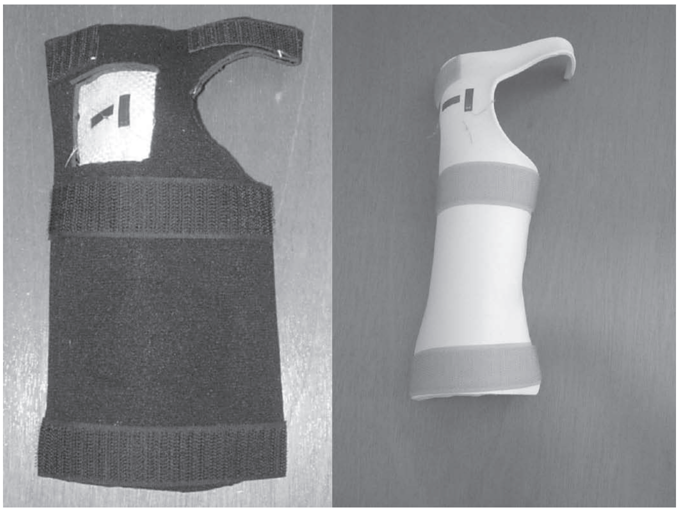

Figure 1 – Immobilization orthosis for extended wrist – A) composite material, B) thermoplastic material

The orthoses were constructed with the wrist at a 15º angle of extension, such that all the other upper-limb joints remained free. This was chosen based on studies by Callinan(6), Bulthaup *et al*(8) and Stern *et al*(23), who recommended the use of this angle to evaluate the long-term efficacy of using wrist orthoses among patients with various neuromusculoskeletal disorders. Moreover, as Jansen *et al*(7) mentioned, a 15º angle is ideal for patients to continue performing both their daily work activities and their leisure activities while using the orthosis.

The devices were manufactured in the prescribed position, taking every care to ensure that the medial palmar crease, distal palmar crease and thenar were free, so that the thumb and finger movements remained unimpeded while carrying out the tests. As proposed by Jansen *et al*(7), the orthosis length was taken to be twice the distance in centimeters from the distal palmar crease to the proximal crease of the wrist, measured towards the forearm. The orthosis was fixed to the body by means of Velcro strips positioned on the back of the hand, on the wrist and on the proximal third of the forearm.

The volunteers were invited to participate in a new session, in which they underwent an evaluation to measure the activation of the wrist flexor and extensor muscles. The activation level of the two wrist muscle groups (flexor and extensor) was monitored by means of an *MP100WSW* electromyograph (Biopac Systems, Inc., Goleta, USA), which was able to detect sample frequencies of up to 1,000 Hz, with entry impedance of 1 GΩ, high-pass filter of 10 Hz to eliminate noise, low-pass filter of 500 Hz and common-mode rejection capacity of 2 MΩ. Active surface electrodes (Ag/AgCl), with a diameter of 11.4 mm, were used to gather electromyographic data from the wrist flexor and extensor muscles. A reference electrode (earth/ground) from the same electromyograph manufacturer was fixed to the acromion on the non-dominant side, so as to avoid discomfort for the participants and possible complaints of pain while performing the movements.

Initially, the participants were instructed to remove any clothing that could make it difficult to place the electrodes and to sit on a chair to undergo skin preparation and for the region of greatest muscle contraction to be located, in accordance with the procedures described by Cram *et al*(24). Once this had been done, the participants were asked to contract the muscle groups that were to be analyzed, by means of flexion and extension movements of the wrist, and, through palpation, the location of greatest muscle volume was defined for each volunteer(24,25). This form of monitoring was chosen because, according to Cram *et al*(24), the placing of general electrodes assesses the general level of muscle tension in a given muscle group and is widely used clinically to study the general tension of the body segment, especially of muscle groups in the forearm, to evaluate the treatment of pain reported in this region, such as repetitive strain injuries.

Before affixing the electrodes, to ensure the validity and precision of the electromyography signals, the skin was shaved locally using disposable material, and was then cleaned by rubbing it with a sterile gauze soaked in alcohol(24). The electrodes were also cleaned with a sterile gauze and alcohol before they were placed on the skin.

After due preparation, the detection electrodes were positioned over the desired muscle groups, as previously identified, by means of palpating the muscle belly and following the muscle fiber orientation(24,26). For the flexor muscle group, the electrodes were positioned on the ventral region of the forearm and, for the extensor muscle group, on the dorsal region of the forearm. In both cases, they were positioned approximately 3 cm below the head of the radius(7).

Following this, all the electrodes were attached to the skin using double-sided adhesive tape and hypoallergenic surgical tape, for better adherence and to facilitate adequate pickup of electromyography signals. After placing and attaching the electrodes, wrist flexor and extensor muscle contraction against resistance was performed to verify the absence of interference in the corresponding signals and to ensure signal quality for all the muscle groups to be analyzed. Next, the attachment of the electrodes was reinforced, over their entire length, with a second layer of surgical tape. To ensure consistency in the procedures, the same electrodes were used for each muscle group evaluated and were also systematically placed by the same evaluator. The specifications for gathering electromyographic data were determined in accordance with the procedures described by Teixeira da Fonseca *et al*(27).

To compare the electromyography (EMG) data within and between subjects, the data were normalized using the percentage of the maximal voluntary isometric contraction (MVIC) from the muscle group of interest(28). The electromyography data from each muscle group analyzed, referenced in terms of the MVIC, were gathered while the individual was positioned and stabilized. The MVIC reference protocol was explained to all the participants and, if there were no questions about it, the MVIC for each of the muscle groups investigated was performed for six seconds, under verbal stimulation commands from the evaluator, for the contraction to be as intense as possible. For each movement, the procedure was repeated three times, with one-minute intervals(24,27).

The root mean square (RMS) EMG values were normalized using the highest RMS observed during the MVIC test, for each muscle group(29,30). To process the electromyography data, the *Acqknowledge* software was used, as well as computational routines developed in *MatLab* exclusively to meet the objectives of the present study.

The evaluation of the wrist flexor and extensor muscle activity began with the participants performing the grip strength test and the Jebsen-Taylor hand function test (J-T), in this order, in three situations: without the orthosis, with the composite sandwich orthosis and with the *Ezeform*® orthosis. The test sequence, i.e. with or without the orthosis, was defined by means of a draw. In both situations, muscle activity was monitored for 30 seconds, which was considered to be enough time to perform each test.

The Jebsen-Taylor hand function test (J-T) is standardized(31,32) and consists of seven functional subtests: (1) writing; (2) turning cards; (3) holding small objects; (4) eating; (5) piling blocks; (6) holding large light objects; and (7) holding large heavy objects. According to Jebsen *et al*(33) and Stern *et al*(34), these subtests are used to stimulate functional, manual and unilateral activities. This test was chosen because it enables objective measurement of standardized tasks and evaluation of the hand functions commonly used for activities of daily living (ADLs)(10,33,34).

While undergoing the J-T, each participant remained seated in a chair of approximately 46 cm in height, facing a table of 80 cm in height, in a well-lit room. The seven subtests were given to the participants always in the same sequence(33) and were carried out only with the dominant hand.

To ensure test accuracy and consistency among the participants' procedures, general instructions were given out by the evaluator before every session, to settle any questions. The volunteers were instructed to begin the test as soon as the evaluator gave the word and to perform the task as quickly as possible and as close to the way in which they would perform the same kind of activity on a day-to-day basis. In the event of mistakes, such as letting a piece fall or becoming distracted or confused, etc, a correction was made and the procedure was immediately repeated(10).

The *Jamar*® dynamometer was used to measure the manual grip strength. To do so, the individual remained seated comfortably, with the shoulder in adduction, elbow flexed at 90º and forearm and wrist in a neutral position. All the participants were instructed to apply strength smoothly, without any quick or abrupt movements. In the present study, wrist extension reaching a maximum of 30º while exerting maximum force was deemed acceptable, as recommended by ASHT(35) and SBTM(36). Also as recommended by ASHT(35), the second pickup position of the dynamometer was taken.

Statistical analysis

An inferential analysis was carried out based on measurements of the percentage of wrist flexor and extensor muscle activation while performing the tests without orthoses and with the composite and *Ezeform*® orthoses. The results obtained without the orthosis were compared with those obtained when using the composite orthosis and the *Ezeform*® orthosis, which were also compared between one another. The significance of all observations was statistically evaluated. The Shapiro-Wilk test was used to investigate whether the data presented normal distribution and the Wilcoxon signed-rank test was used to evaluate the significance of data obtained from comparing the groups. For all the analyses, the *SPSS for Windows* statistical software, version 13.0, 2004, was used and the significance level was taken to be $\alpha = 0.05$.

RESULTS

Tables 1 and 2 present the statistical results from the inferential analysis on the amount of activation of the wrist flexor and extensor muscles, respectively, normalized by means of the MVIC while carrying out the tests.

The means of all the variables relating to the amount of activation of the wrist flexor muscles when using the experimental and *Ezeform*® orthoses were 40% greater than the values used in the normalization with MVIC. The activation of the wrist flexor muscles was up to five times greater without using orthoses than with orthoses.

Table 1 – Mean values (± standard deviation) for the amount of wrist flexor muscle activation evaluated for each analysis variable

Flexor muscle activation				
Subtest	n	Without using orthosis	With use of composite orthosis	With use of thermoplastic orthosis
Eating	26	0.084 ± 0.044$^{a.b}$	0.433 ± 0.171^{a}	0.423 ± 0.164^{b}
Piling blocks	26	0.088 ± 0.053$^{a.b}$	0.521 ± 0.194^{a}	0.513 ± 0.190^{b}
Turning cards	26	0.190 ± 0.117$^{a.b}$	0.486 ± 0.200^{a}	0.480 ± 0.190^{b}
Writing	26	0.164 ± 0.089$^{a.b}$	0.407 ± 0.159^{a}	0.398 ± 0.153^{b}
Holding small objects	26	0.142 ± 0.087$^{a.b}$	0.479 ± 0.184$^{a.c}$	0.459 ± 0.175$^{b.c}$
Holding light objects	26	0.141 ± 0.104$^{a.b}$	0.544 ± 0.211$^{a.c}$	0.516 ± 0.191$^{b.c}$
Holding heavy objects	26	0.161 ± 0.104$^{a.b}$	0.540 ± 0.208$^{a.c}$	0.521 ± 0.198$^{b.c}$
Grip strength	26	0.356 ± 0.135$^{a.b}$	0.738 ± 0.260$^{a.c}$	0.693 ± 0.259$^{b.c}$

Note: Same letters indicate significant difference ($p < 0.05$) between the respective experimental conditions

Table 2 – Mean values (± standard deviation) for the amount of wrist extensor muscle activation evaluated for each analysis variable

Extensor muscle activation				
Subtest	n	Without using orthosis	With the use of composite orthosis	With the use of thermoplastic orthosis
Eating	26	0.159 ± 0.068$^{a.b}$	0.141 ± 0.068^{a}	0.143 ± 0.089^{b}
Piling blocks	26	0.165 ± 0.071$^{a.b}$	0.138 ± 0.070^{a}	0.131 ± 0.059^{b}
Turning cards	26	0.215 ± 0.093$^{a.b}$	0.168 ± 0.080^{a}	0.164 ± 0.074^{b}
Writing	26	0.211 ± 0.092$^{a.b}$	0.184 ± 0.110^{a}	0.190 ± 0.116^{b}
Holding small objects	26	0.207 ± 0.096$^{a.b}$	0.152 ± 0.077^{a}	0.146 ± 0.071^{b}
Holding light objects	26	0.202 ± 0.089$^{a.b}$	0.135 ± 0.063^{a}	0.132 ± 0.063^{b}
Holding heavy objects	26	0.284 ± 0.115$^{a.b}$	0.192 ± 0.070$^{a.c}$	0.176 ± 0.068$^{b.c}$
Grip strength	26	0.731 ± 0.265$^{a.b}$	0.602 ± 0.178$^{a.c}$	0.534 ± 0.179$^{b.c}$

Note: Same letters indicate significant difference ($p < 0.05$) between the respective experimental conditions

In relation to the amount of extensor muscle activation, the means of all the variables when using the experimental orthosis were 20% lower than the values in the normalization with MVIC, except regarding activation when testing the use of grip strength, which was 60%. The reduction in extensor muscle activation ranged between 10% for eating and writing activities and 38% for holding heavy objects.

Statistically significant differences were found in the results from the J-T and grip strength test, between nonuse and use of orthoses (either experimental or *Ezeform*®) for the actions of both the flexor and the extensor muscles (p value < 0.05).

Comparing the activation results with the use of different orthoses, there was slightly greater flexor activation when using the *Ezeform*® orthosis. However, this difference was not considered to be significant, except for the subtests that consisted of holding light objects ($p = 0.029$) and holding heavy objects ($p = 0.01$) and for the grip strength test ($p = 0.015$). On the other hand, the wrist extensor muscle group had a slightly greater reduction in action when using the *Ezeform*® orthosis instead of the experimental orthosis, but this difference was not considered to be significant, except for the subtest of holding heavy objects and the grip strength test ($p = 0.011$).

DISCUSSION

Many studies have sought to evaluate whether the use of wrist orthoses could generate passive stabilization of the wrist by reducing the extensor load of the wrist muscles. This would be an important result for defining whether orthosis use should be indicated within the rehabilitation process in relation to various musculoskeletal disorders(13). In other words, this would show whether, by using a simple orthosis, it would be possible to prevent of wrist flexion or reduce the severity of inflammatory processes of the wrist extensors, among other muscle stress conditions.

The results obtained in this study differ partially from those found in the literature, which have generally reported that the use of orthoses does not alter(37) or increase the action of the extensor muscles of the forearm(8,13). Only Jansen *et al*(7) and Roy *et al*(38) observed reductions in extensor activity.

This study showed that using an orthosis interfered with the electrical activation of the wrist flexor and extensor muscles. It was observed that the use of immobilization orthoses for extended wrists (15 degrees), regardless of which of the tested devices it was, caused a decrease in wrist extensor muscle action and increase in flexor muscle action while performing the grip strength and manual function tests.

Regarding the extensor musculature, this study indicated that using the orthoses that were tested reduced the extensor load while performing the tasks. It was observed that, when carrying out the tests, both orthoses (composite and *Ezeform*®) recruited significantly less wrist extensor muscle activity than did the free hand.

The findings from this study indicate that the orthosis replaced the primary action of the wrist extensor muscles (joint extension) and kept the muscles shortened, thus decreasing the activity of this muscle group. According Jansen *et al*(7), wrist extension orthoses limit the passive stretching of extensors, consequently decreasing the muscle activity during functional tasks. It is known that wrist extensors promote stability against the strength of the finger flexors to prevent the wrist from flexing, which would occur simultaneously with finger flexion during grip actions(10,13,39). To maintain this stability while gripping, co-activation and individual activation of the wrist flexors and extensors is fundamental(11). Moreover, because of passive insufficiency of the extrinsic finger extensors and active insufficiency of the extrinsic flexors, these have a containing action and prevent simultaneous flexion of the wrist and finger joints(40). This mechanism suggests that the wrist extensors have a double role of inhibiting and stabilizing forces during the grip movement(12,13).

Also in relation to activation of the extensor musculature, it was observed that the reduction in activation of this musculature was proportionally smaller in the activities of eating and writing than what was observed in the other tests. This reaction may have been related to the small range of motion of the wrist that is needed to perform these activities. In these tasks, the wrist extensor musculature essentially works to keep this musculature in a given position in order to enable the fingers to function.

On the other hand, a greater reduction in the activation of the wrist extensor musculature was observed while activities requiring a greater degree of grip strength or greater wrist and finger range of motion were being performed. This may indicate that using wrist immobilization orthoses may be more effective in such cases. For example, it is known that the symptoms of epicondylitis may be worsened with extreme use of the hand and forearm, and in situations of greater physical load requirement(41). It seems that orthosis use may provide good results for individuals who present such work characteristics.

With regard to increased flexor muscle activity while performing tasks using orthoses, the present study seems to corroborate the findings of Bulthaup *et al*(8). These authors took the view that orthoses for immobilizing wrist extension wrists were designed to limit joint movement and, in this case, in order to achieve grip actions, wrist flexors would need to have increased action in order to overcome the restriction imposed by the orthosis. In this study, Bulthaup *et al*(8) also suggested that a more restrictive orthosis would require greater muscle tension against the orthosis to enable movement closer to normal patterns. In this respect, in the present study, the *Ezeform*® orthosis could be considered to be more restrictive, in view of its rigidity (which was greater than that of the composite orthosis), which would imply greater activation of the flexors with its use. However, although inconclusive, the present study indicates the contrary. There was greater demand for activation of the flexors, comparing the use of *Ezeform*® orthoses with composite orthoses, albeit without significance. It seems that the use of different materials to manufacture orthoses does not interfere with the action of the wrist flexor or extensor musculature. This suggests that the indication of the material for constructing the orthotic device should take into account the greatest comfort and best adaptation for the individuals concerned.

Another matter to be considered is in relation to the degree of wrist extension used for constructing the orthoses. The results from the present study related to an extension angle of 15 degrees, but angles differing from this could generate different results. It is known that individuals each perform their daily tasks in their own manner, with different requirements for wrist range of motion, which might indicate other wrist angles for constructing orthoses.

The present study showed that using orthoses significantly interfered with the action of the wrist flexor and extensor muscles. Use of orthoses reduced the activation of the wrist extensor muscles while certain tasks were being performed, but it also increased the activation of the flexor muscles. The findings indicated that the use of orthoses for immobilizing wrist extension provided passive stabilization of the wrist, thereby reducing the extensor load of the wrist muscles. On the other hand, this use generated an increase in the activity of the wrist flexor muscles, which indicates that the device restricted movement and that this musculature needed to be activated to a greater degree to overcome this restriction. This is an important result for defining whether orthoses should be indicated within the rehabilitation process for various disorders, among which tendinitis of wrist and finger flexors and extensors, and for predicting the length of time for which such devices should be used. In particular, the present study draws attention to the greater effectiveness of wrist extension orthoses for reducing the wrist extensor musculature while carrying out tasks that require greater degrees of muscle strength (picking up heavy objects and muscle strength tests). It also draws attention to wrist positioning (15 degrees) and to the fact that there needs to be better evaluation of indications of different materials for orthosis construction.

The divergences between other studies that we evaluated and the present study may be explained by the methodological differences between them, such as the types of tasks performed, the type of orthosis used and the type of subject studied. These differences indicate that there is a need for further studies in this field, in order to seek scientific evidence regarding the real appropriateness of using orthoses (or not using them) for rehabilitation of such disorders.

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