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Effects of a Wrist Extension Splint on Muscle Power and Activities of the Forearm Muscles: Comparison of Day Versus Nighttime Wear Instructions

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Abstract

The objective of this study was to compare the differences on the activity and power of the wrist flexors and extensors in subjects before the use of a wrist extension splint, after nighttime wearing of the splint, and after daytime wearing of the splint. Ten healthy male and ten healthy female students (mean: 22.4±1.2 years old) volunteered to wear custom-made wrist splints either during the night or during the day. The hand force of the wrist flexor and extensor, and grip force were measured by PowerTrackⅡ and Dynatron, respectively. At the same time, the activities of the wrist flexor and extensor were recorded by surface electromyography. The maximal hand force and motor unit recruitment of the flexor carpi ulnaris (FCU) increased significantly ($p<.05$) when the subjects wore the wrist splints during the daytime, but the maximal hand power of the FCU decreased with nighttime use of the splints. The maximal hand power and motor unit recruitment of the extensor carpi radialis (ECR) and the ECR/FCU ratio decreased both during nighttime and daytime use. The decrement of the ECR/FCU ratio was significant ($p<.05$). Wearing a wrist extension splint during nighttime led to the maintenance of a lengthened position of the wrist flexor, resulting in the wrist flexor becoming weak. Wearing a wrist extension splint during the day induced the wrist flexors to be greater. In healthy people, the imbalance between the wrist flexors and extensors may be caused by the use of a wrist extension splint. This study indicates that therapists have to consider whether a splint will be effective, as well as the wearing time, when prescribing splints to people with problems of the musculoskeletal system.

Key Words: Muscle power and activities; Wrist extension splint; Wrist flexor and extensor.

Introduction

Cumulative trauma disorders (CTDs) caused by improper postures and great force during tasks or sport activities have proliferated (Armstrong, 1986). Lateral epicondylitis, or tennis elbow, which is an overuse injury of the soft tissue characterized by pain over the common extensor tendon with or without inflammation in the wrist extension, is a common example of a CTD (Assendelft et al, 2004; Peter and Baker, 2001). The main complaints of individuals with lateral epicondylitis are lessened grip force and pain, which could affect daily activities (Chard and Hazleman, 1989). Orthoses, such as elbow bands or forearm/hand splints of many therapeutic modalities, are used to rest the wrist extensors and to reduce the overload forces (Jansen et al, 1997). Biddulph (1981) showed that grip force increased and pain was relieved when people with a sprained wrist or joint trauma wore wrist orthoses.

Previous studies of wrist extension splints have investigated the difference of effects in hand function among several orthoses, and emphasized the elbow and shoulder joints, as well as the wrist

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joint, for hand function (Mell et al, 2005; Stern et al, 1991). However, when wearing a wrist splint, muscle activities surrounding the wrist and elbow increase (Adams et al, 2004; Bulthaup et al, 1999; King et al, 2003). Bulthaup et al (1999) found that the long type of wrist extension orthoses led to greater muscle activity for the wrist extensors of healthy people. It is also possible to prescribe wrist extension splints to reduce the force of the extensor carpi radialis brevis or acute tendon injury (Bulthaup et al, 1999; van Elk et al, 2004).

It is important that there is balance in the onset of activities in the wrist flexor and extensor during gripping and that the grip force is reduced as the wrist position changes from an extension of 30° to flexion (Bober et al, 1982; Neumann, 2002). The wrist extensors are not only the main stabilizers of the wrist joint, but also initiators of the stabilizing force during gripping, and they play a role in maintaining the optimal length of the finger flexors (Bober et al, 1982; Neumann, 2002).

Wrist splints are usually prescribed for nighttime wear, but are frequently used during daytime activities, due to the development of light thermoplastic splints (Walker et al, 2000). However, few studies have been conducted concerning the wrist flexors which are stretched and immobilized by wrist splinting, and about the most advantageous time for wearing the splint - day or night.

Therefore, the objectives of this study were to compare the effects of splinting on pre-wearing, day, and nighttime users and to identify the difference in muscle power and activity of the wrist flexors and extensors for holding the wrist in a 30° extension position after prolonged wearing of a splint and to determine the optimal wearing instructions in the use of wrist extension splints.

Methods

Subjects

Twenty healthy subjects who attended Inje University participated in this investigation. There were 10 male and 10 female volunteers (age: 22.4±1.2 years, height: 170.1±10.0 ㎝, weight: 61.9±13.8 ㎏) and all right-hand dominant. None of the volunteers had a history of radial nerve lesion or wrist joint or muscle injury, and none had current hand or upper extremity dysfunction.

Splints

Wrist extension splints, made out of thermoplastic for each subject in our laboratory, were used on the volar side of the subjects' non-dominant hand. The splints maintained the wrist in a 30° extension position, measured by a goniometer, and prevented further wrist flexion (Figure 1).

Hand Force Measurements

The hand force of the wrist flexor and extensor muscles was measured by PowerTrackⅡ[1]. For the wrist flexor examination, the subject was seated, with the forearm placed on a table in supination, and the wrist in flexion. The examiner placed the transducer on the midline of the palmar surface of the

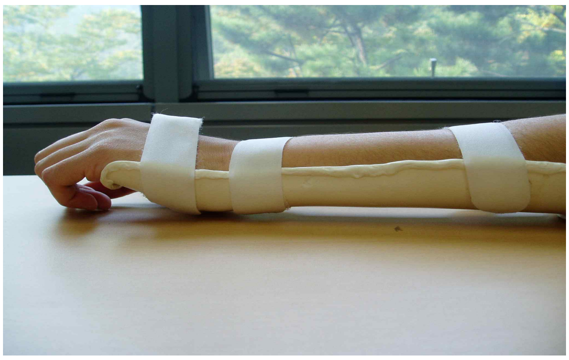

Figure 1. Wearing a wrist extension splint.

1) PowerTrackⅡ, JTECH Medical, Salt Lake City, Utah 84115, U.S.A.

hand, and broke wrist flexion. After five minutes of rest to recover from fatigue, the wrist extensor was measured, again with the participant seated, but with the forearm placed on a table in pronation, and the wrist in extension. The examiner placed the transducer on the midline of the dorsal surface of the hand, and broke wrist extension. The data were displayed and stored.

Grip Force Measurements

The grip force of the non-dominant hand was measured by Dynatron[2], with the participant standing with his/her elbow in 90° of flexion, and the forearm in a neutral position. The hand dynamometer was gripped with maximum isometric effort for five seconds. The measurer noted and recorded the notch mark on the scale.

EMG Measurements

The muscle activities of the wrist flexor (flexor carpi ulnaris; FCU) and extensor muscles (extensor carpi radialis; ECR) were recorded by an EMG system[3] and circular surface EMG disposable electrodes[4] with a diameter of 35 ㎜. The two electrodes for recording from the wrist flexor (FCU) were placed 3 to 4 ㎝ apart over the belly of the muscle in the direction of the muscle fibers. The two electrodes for recording from the wrist extensor (ECR) were placed 3 to 4 ㎝ in the center of the muscle mass that emerges, with the electrodes oriented on the muscle fibers. The ground electrode was placed over the left lateral epicondyle. The distance between the electrodes at each pair was 2 ㎝, and each pair was attached parallel to the muscle fibers (Cram et al, 1998). The EMG signals were sampled at 1000 ㎐, notch filtered at 60 ㎐, amplified, and then analyzed with the Acqknowledge 3.9.1 software (BIOPAC System Inc., CA., U.S.A.). The data were stored on a laptop computer after analog-to-digital conversion, and then averaged.

Test Procedures

This study consisted of hand force and grip force measurement with EMG. Participants were given verbal instructions before the measurements. The measurer selected muscles which exhibited prominently when the subjects extended and flexed their wrists, and marked the positions with a pen. Before placing the electrodes on the muscles, the skin of the left forearm was shaved and rubbed with alcohol to reduce electrical impedance. The electrodes were aligned at the marked positions previously described (Cram et al, 1998).

The non-dominant hand force of each subject was measured, then the measurer was instructed to encourage the volunteers to use maximal effort for five seconds (Figure 2). Muscle activities of the FCU and ECR were recorded simultaneously by EMG, which was checked before each measurement. Before each assessment, subjects rested for five minutes to lessen the effects of fatigue. Next, volunteers gripped the hand dynamometer with maximum isometric effort for five seconds. Muscle activities of the FCU and ECR were also recorded simultaneously by EMG, which was checked before each measurement (Figure 3). Three trials of each condition were performed and then averaged.

After all measurements, the experiment leader asked the volunteers to wear their splints for eight hours (12:00 AM to 8:00 AM) at night. The measurements as described above were again performed after the removal of the splints at 8:00 AM. After two days, all volunteers gathered to wear the splints for eight hours (9:00 AM to 4:00 PM) during the day. The measurements as described above were again performed after the removal of the splints at 4:00 PM. The experiment leader gave all subjects freedom to go about their usual routines, but they were forbidden from removing their splints without permission during the hours assigned to their use.

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2) Dynatron, Dynatronics, Salt Lake City, Utah 84121, U.S.A.
3) EMG MP150WSW, BIOPAC System Inc., CA, U.S.A.
4) EL503, BIOPAC System Inc., CA, U.S.A.

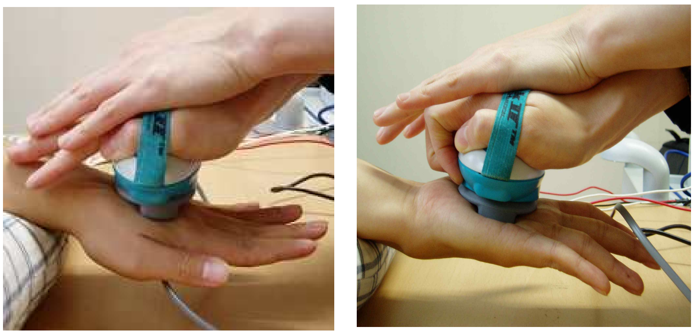

Figure 2. Hand force measurement methods of the wrist extensor and flexor.

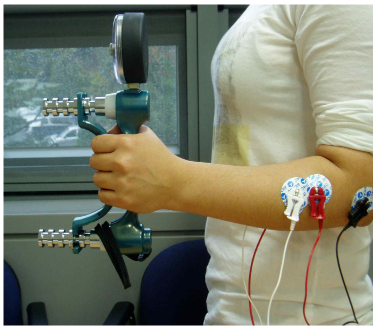

Figure 3. Grip force measurement method.

Statistical Analysis

The SPSS statistical package (SPSS version 14.0 software) was used to analyze differences in the ECR and FCU muscle activities. Repeated one-way ANOVA tests were used to compare the differences in each measurement of the pre-wearing, the day-wearing, and the nighttime-wearing conditions. A Bonferroni correction for post-hoc was done, with significance defined as being present when $p<.05$.

Results

Hand Force of the FCU and ECR

The maximal hand force of the flexor carpi ulnaris (FCU) increased significantly when the volunteers wore the splints during the day ($p<.05$). The maximal hand force of FCU decreased after nighttime use, but there was no significant difference. The maximal hand force of the FCU was 12.01±.93, 10.97±.80, and 13.25±1.20 in the pre-wearing, night, and daytime tests, respectively. The maximal hand force of the extensor carpi radialis (ECR) decreased when the volunteers wore the splints during the daytime and the nighttime, however there was no significant difference. The maximal hand force values of the ECR were 11.84±.63, 11.25±.61, and 11.03±.32 in the pre-wearing, night, and daytime tests, respectively (Table 1).

EMG Data of the FCU and ECR During the Hand Force Measurement

The EMG data for the FCU during hand force measurements increased significantly when the volunteers wore the splints during the daytime ($p<.05$). The maximal hand force of the FCU also increased after nighttime use, but there was no significant difference. The EMG data for the FCU during hand force measurements were 170.84±29.07, 173.97±28.95, and 249.12±35.97 in the pre-wearing, night, and daytime tests, respectively. The EMG data for the ECR during hand force measurements decreased when the volunteers wore the splints during the daytime and at night, however there was no significant difference. The EMG data for the ECR during hand force measurements were 201.51±26.61, 146.84±23.08, and 155.01±25.11 in the pre-wearing, night, and daytime tests, respectively (Table 2).

Difference of the ECR/FCU Ratio During the Grip Force Measurement

The ECR/FCU ratio decreased both after night and daytime use, however, there was a significant difference only after daytime use ($p<.05$). The means of the ECR/FCU ratios were 1.41±.26, .99±.17, and .62±.11 in pre-wearing, night, and daytime tests, respectively (Table 3).

Table 1. Hand force of the FCU and ECR (N=20)

Muscle Power (kg)	Pre-wearing	Nighttime	Daytime	F	p
FCU	12.01±.93[a]	10.97±.80	13.25±1.20	9.138	.002
ECR	11.84±.63	11.25±.61	11.03±.32	2.979	.076

[a]Mean±SD.

Table 2. EMG data of the FCU and ECR during the hand force measurement (N=20)

Muscle Activity (kg)	Pre-wearing	Nighttime	Daytime	F	p
FCU	170.84±29.07[a]	173.97±28.95	249.12±35.97	4.682	.023
ECR	201.51±26.61	146.84±23.08	155.01±25.11	3.541	.050

[a]Mean±SD.

Table 3. Difference of the ECR/FCU ratio during the grip force measurement (N=20)

Variable	Pre-wearing	Nighttime	Daytime	F	p
ECR/FCU ratio	1.41±.26[a]	.99±.17	.62±.11	4.115	.034

[a]Mean±SD.

Discussion

The present study explored the power and activities of the FCU and ECR muscles before the use of a long-type wrist splint, after wearing it at night, and after wearing it in the daytime. In this study, subjects maintained the wrist in a position of 30° extension, with the wrist flexor lengthened slightly for eight hours by wearing wrist extension splints that limited the use of the wrist flexor at night, weakening the FCU. The results showed that the FCU power decreased significantly after wearing the splint at night.

On the other hand, the EMG activity and the power of the FCU were significantly greater after wearing the splint during the day. The reason is that the FCU tended to increase its effort by straining opposite to the restriction given by wrist extension splints designed to limit wrist flexion (Bulthaup et al, 1999).

The EMG activity and the power of the ECR decreased by wearing the splint. This was similar to the result of van Elk et al (2004) where the reduction in the activity of the wrist extensor during gripping in healthy subjects caused the extension force to increase by application of an external wrist extension. Sustained specific joint movements and postures affect musculoskeletal and neural tissue and finally lead to unsuitable changes in the movement components (Sahrmann, 2002). McGill and Brown (1992) found that a prolonged flexion position for 20 minutes is capable of causing creep in soft tissues. Kendall and McCreary (1993) showed that muscles in a prolonged elongated position during rest or inactivity became stretched and weakened.

The wrist extensor activated much more than the flexor while gripping because the maximal grip force and wrist torque were the largest when the wrist was extended. In the present study, the normalized EMG data ratio between the ECR and FCU while gripping decreased significantly. The balance of ECR and FCU may have been destroyed because wearing a wrist extension splint weakens the extensor and strengthens the flexor. Hägg and Milerad (1997) found that the wrist extensors caused more static load patterns compared to the flexors during gripping. Moqk and Keir (2003) found that activity of the wrist extensor was greater than activity of the flexor during low to mid-range force levels and a flexed wrist produced only 50∼60% of maximal grip force. The wrist extensors should be initiated to counteract the wrist flexion torque to maintain a neutral wrist (Snijders et al, 1987). The function loss in the wrist and finger extensors causes the hand to destroy the reciprocal tenodesis action and lose wrist stability (Colditz, 1984).

A wrist extension splint, a therapeutic intervention for effective hand function, may actually lead to worsening of muscle balance, particularly if it is worn while working. Therefore, in the treatment of musculoskeletal disorders, we recommend that it is more effective to wear a wrist extension splint during the nighttime hours. When prescribing wrist extension splints, therapists should consider the individual patient's condition and direct the time that the splint is used.

There are some limitations to this study. The non-dominant hand of all subjects was selected our data were acquired over a short period of time; and it was impossible to continuously monitor the subjects while they were wearing their splints. In the future, it would be interesting to conduct a longer-term investigation to identify the effects of wearing wrist splints on muscle power and activity. Further studies should also be done on patients with neurological injuries, as well as musculoskeletal disorders.

Conclusion

The purpose of this study was to compare the differences on the activities and power of the wrist flexors and extensors in subjects before the use of a wrist extension splint, after nighttime use, and after daytime use. Wearing a wrist extension splint, which limits wrist flexion, maintained the lengthened position of the wrist flexors during the nighttime hours, so that the muscles remain inactive, inducing weakness to the overstretched wrist flexor. Wearing a wrist extension splint during the day strengthened the wrist flexor, because wrist flexion limitation in healthy subjects had an effect on resistance exercise. It is concluded that wearing a wrist extension splint in the workplace during the day can increase muscle power and EMG activity of the wrist flexor, and imbalance between the wrist flexor and extensor during gripping activity in healthy people.

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