TECHNICAL NOTE

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Wrist Splint Effects on Muscle Activity and Force During a Handgrip Task

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Wrist splints are commonly prescribed to limit wrist motion and provide support at night and during inactive periods but are often used in the workplace. In theory, splinting the wrist should reduce wrist extensor muscle activity by stabilizing the joint and reducing the need for co-contraction to maintain posture. Ten healthy volunteers underwent a series of 24 10-s gripping trials with surface electromyography on 6 forearm muscles. Trials were randomized between splinted and nonsplinted conditions with three wrist postures (30° flexion, neutral, and 30° extension) and four grip efforts. Custom-made Plexiglas splints were taped to the dorsum of the hand and wrist. It was found that when simply holding the dynamometer, use of a splint led to a small (<1% MVE) but significant reduction in activity for all flexor muscles and extensor carpi radialis (all activity <4% maximum). At maximal grip, extensor muscle activity was significantly increased with the splints by 7.9–23.9% MVE. These data indicate that splinting at low-to-moderate grip forces may act to support the wrist against external loading, but appears counterproductive when exerting maximal forces. Wrist bracing should be limited to periods of no to light activity and avoided during tasks that require heavy efforts.

Keywords: wrist, splints, rehabilitation, electromyography, forearm, biomechanics

Wrist splints (or braces) are often prescribed during rehabilitation to limit wrist motion and provide additional support. Typically, these devices are prescribed for night use and/or during inactive periods but have become increasingly common in the workplace. Wrist splints are often applied to the dorsal aspect of the hand and should reduce extensor muscle activity by supporting the wrist joint thus reducing the need for muscular co-contraction to maintain posture. Without splinting, co-contraction of the flexor and extensor muscles must occur at the wrist to allow for the performance of finger flexion movements while maintaining wrist posture (Snijders et al., 1987). However, the effectiveness of splinting during active use is inconclusive. During active use, wrist splinting has been shown to decrease forearm extensor muscle activity (van Elk et al., 2004), have no beneficial effect (Johansson et al., 2004), or increase muscle activity depending on the type of orthosis (Bulthaup et al., 1999). Bulthaup et al. (1999) found that wrist extensor muscle activity was higher using a long splint versus a short splint, whereas flexor carpi radialis activity increased using either splint when compared with no splint. More recently, a commercially available soft brace was found to have no effect on forearm flexor or extensor activity, whereas a long stiff splint significantly increased both flexor and extensor muscle activity (Johansson et al., 2004). In addition, although finger dexterity may not be affected by all dorsal wrist orthoses, grip strength likely decreases (Stern, 1996).

The purpose of the current study was to examine the relationship between muscle activity and splinting under several postures and effort levels. Given that muscle activity is dependent on wrist posture and grip force magnitude (Cort et al., 2006, Mogk & Keir, 2003a), there is a need to examine the effects of splinting under a wide range of force levels that can be experienced in the workplace. In addition, while wrist splints are typically neutral or slightly extended, three wrist postures were used to evaluate whether the relationships would hold in

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varied postures. Specifically, the study was designed to test the hypothesis that a simple dorsal wrist brace would reduce the need for co-contraction for moment balance as evidenced by reduced wrist extensor muscle activity.

Methods

Ten healthy volunteers (five females and five males) participated in a right-handed gripping protocol. Nine participants were right-handed, with one female being left-handed. All participants were free of pain; had no history of hand, wrist, or forearm dysfunction; and provided informed consent before the study. Mean age, mass, and height for the participants were 22.6 (*SD* 2.8) years, 73.4 (11.0) kg and 173.5 (7.0) cm, respectively. The protocol has been outlined previously (Mogk & Keir, 2003a) and was approved by the university human participant research subcommittee.

A total of 24 experimental trials were randomized between two splinted conditions (with and without splint), three wrist postures (30° flexion, neutral, and 30° extension), and four grip effort levels (12.5, 25, 50, and 100% of maximum). Each trial was 10 s in duration and started with the participant holding the dynamometer in one of three experimental postures without exerting a grip force and then increasing to the target force. Three simple custom-made Plexiglas splints, each 12–15 cm in length and 4 mm thick, maintained wrist postures of neutral (0°), 30° flexion, and 30° extension (with neutral forearm posture and no radioulnar deviation). Each splint was affixed to the dorsal aspect of the hand and wrist with tape at the proximal end of the brace, just proximal to the wrist crease, and across the distal aspect of the palm. Grip force was measured using a grip dynamometer (MIE Medical Research Ltd., UK; 450 g / 4.4 N) set to a constant grip span of 50 mm using a power grip (all fingers and thumb). The forearm was supported in a midprone (thumb up) position, but the wrist, hand, and dynamometer remained unsupported, creating a small external ulnar moment. Neutral wrist posture was defined as the anatomical position of the wrist such that the dorsal surfaces of the hand and forearm formed a straight line and the third metacarpal was parallel to the lateral border of the radius. A mirror apparatus, angled at 45°, allowed radioulnar deviation and wrist flexion–extension angles to be recorded simultaneously with a single video camera to confirm postures (Mogk & Keir, 2003a).

Maximal grip force was determined in a neutral wrist posture, with maximal exertions performed until two grip forces were achieved within 5% of one another (three efforts were required by five subjects). The highest grip force was then used to set the relative target forces in the protocol by calculating the mean value over a 500-ms window centered about the peak force in the trial. Participants were given a minimum 1-min rest period between trials and were instructed to release the dynamometer and relax their hand while resting their forearm on the platform.

Surface EMG was collected from six muscles including flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), flexor digitorum superficialis (FDS), extensor carpi radialis (ECR), extensor carpi ulnaris (ECU), and extensor digitorum communis (EDC). Disposable bipolar Ag-AgCl electrodes (MediTrace 130, MA) were placed over the muscle bellies along the direction of the fibers using a 3-cm center-to-center distance after cleansing sites with alcohol. Placement of electrodes was determined through palpation and isolated resistance tests. EMG signals were differentially amplified (Bortec Biomedical Ltd., AB) and sampled with grip force data at 1,000 Hz. EMG was normalized to maximal voluntary electrical (MVE) activation determined by a series of trials in which subjects performed resisted movements of flexion and extension, radioulnar deviation, and circumduction, as well as maximal grip force. Bias was determined during a quiet trial and was removed before normalization.

Average, normalized EMG (AEMG) was calculated after the EMG signal was full-wave rectified and low pass filtered at 3 Hz (linear envelope signal). "Pre-exertion" AEMG was calculated over a 1.5-s window during which the subject was instructed to hold the dynamometer but before exerting the target grip force ("holding force"). The "target force" data were calculated over a 3-s window during which the target force level was maintained constant. For each muscle (and grip force), data were analyzed using 2 (splint) × 3 (posture) × 4 (force level) repeated measures ANOVA. Because there was pre-exertion data for each contraction level, pre-exertion AEMG was analyzed separately using 2 × 3 × 4 repeated measures ANOVAs (Statistica, Version 6.0, StatSoft, Inc., Tulsa, OK). Unless an F statistic is presented, all p values reflect those determined by post hoc tests.

Results

During the "pre-exertion" phase (before grip force production), holding (grip) force was significantly lower when splinted, $F(1, 9) = 11.5$, $p < .008$. Although an additional grip force was not required other than to hold the device, there was a significant effect of target force, $F(3, 27) = 23.0$, $p < .0001$. When gripping, a main effect of grip target force was found, $F(3, 27) = 333.0$, $p < .0001$. Posture also had a significant effect on target force, $F(2, 18) = 32.2$, $p = .0001$, with significantly lower forces being produced in flexion than neutral, which was significantly lower than extension ($p < .01$) during maximal grip force trials. This resulted in a significant interaction between posture and effort, $F(6, 54) = 38.3$, $p < .0001$ (Figure 1). Use of a splint did not significantly alter grip force at any target force level.

A main effect of posture was observed for FDS activity during the pre-exertion phase, $F(2, 18) = 5.6$, $p = .013$, resulting from significantly higher muscle activity with the wrist flexed than neutral ($p < .021$) or extended ($p < .0041$). In the pre-exertion phase, ECR, FCR, FCU, and FDS activities were significantly lower when splinted by 19.9%, 8.8%, 19.4%, and 20.5%,

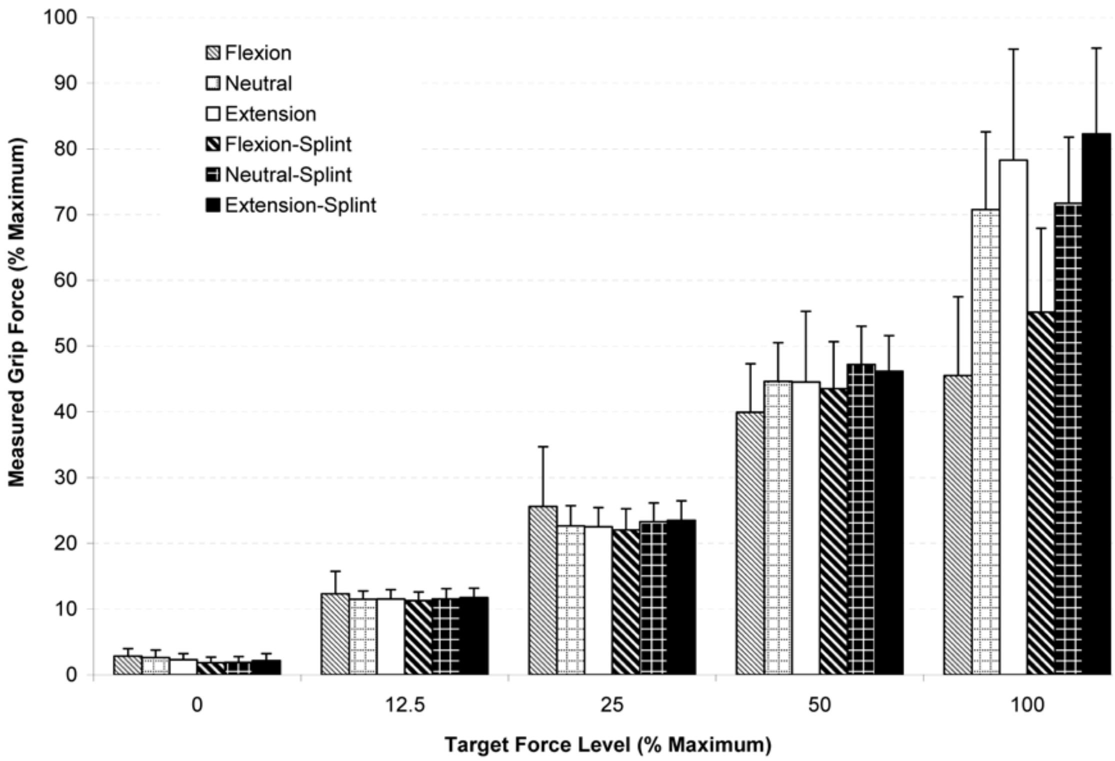

Figure 1 — Measured grip force achieved (% maximum, with *SD*) with and without splinting for each posture at "pre-exertion" (0), 12.5, 25, 50% and maximal (100%) target force levels.

respectively (0.2–0.7% MVE; all $F > 5.5$, all $p < .044$; Table 1). Although not statistically significant, ECU and EDC activities were also lower when splinted (0.9 and 0.3% MVE, respectively).

At low-to-moderate effort levels (12.5–50% maximum), muscle activity was not significantly altered with use of the splints. However, at maximal (100%) grip, muscle activity increased when splinted. Significant main effects of splinting were found for ECR, ECU, and EDC (all $F > 5.34$, $p < .05$; Table 1), with the increase ranging from 15.5 to 25.0% (6.4–7.6% MVE) for the extensors pooled over all postures (although the interaction with posture was not significant, the greatest changes occurred with flexion). Flexor muscle activity was also increased by 10.3–17.1% (2.4–5.8% MVE) at maximal grip but failed to attain statistical significance as the effect was mainly seen in the flexed and neutral postures (a trend existed for FCR activity, $p = .051$).

Discussion

The current study quantified forearm muscle activity with and without splinting while gripping using a total of four levels of isometric grip force, as well as a "pre-exertion" time period. In general, we found that dorsal wrist splinting was associated with forearm extensor, as well as flexor, muscle activity which was (i) lower when holding the dynamometer without exerting force, (ii) similar at low-to-moderate force levels (12.5, 25, 50% maximum), and (iii) higher during maximal efforts. Without additional grip production, the splints acted to support the wrist resulting in lower activity in all muscles during the pre-exertion phase partially due to a reduction in residual grip (holding) force (by less than 1 N). This effect was not noted at low-to-moderate force levels and activity was marginally increased at high grip force levels, indicating that the splint may be counterproductive given that the grip forces generated were the same with and without the splint.

During the (pre-exertion) phase before generating the additional grip force, the splint proved to be helpful in supporting the wrist joint against gravity as evidenced by lower muscle activity and slightly (yet significantly) lower residual grip forces (Figure 1 and Table 1). When the splint was used, there was a significant reduction in ECR and FCR activity. This was presumably due to participants' using the splint to support some of the load that would be expected in the radial muscles to counteract gravity given that the standard posture required a neutral forearm and no radioulnar deviation.

During gripping, significant increases in muscle activity were evident between splinting conditions only at maximal efforts. Thus, splinting as a component of wrist rehabilitation may be appropriate at rest and low-to-moderate force levels, but not when high forces are

Table 1 Mean Muscle Activity (AEMG in % MVE ± *SD*) With and Without Splint in Flexion; Neutral; and Extension During "Pre-Exertion" (0), 12.5%, 25%, 50%, and Maximal Grip (100%)

	Muscle Activity (% MVE)					
	Flexion		Neutral		Extension	
Muscle	No Splint	Splint	No Splint	Splint	No Splint	Splint
			0% of maximum force			
FCR	2.5 ± 1.2	2.2 ± 1.8	2.3 ± 1.6	2.0 ± 1.1	2.2 ± 1.5	2.1 ± 1.5
FCU	2.6 ± 2.7	2.9 ± 4.5	3.8 ± 4.9	2.4 ± 2.5	3.2 ± 3.5	2.4 ± 4.1
FDS	1.6 ± 0.6	1.3 ± 1.0	1.3 ± 0.8	0.9 ± 0.4	1.2 ± 0.5	1.0 ± 0.8
ECR	3.3 ± 3.0	2.7 ± 2.2	3.8 ± 4.6	2.9 ± 2.8	3.0 ± 1.9	2.6 ± 2.7
ECU	2.1 ± 1.8	3.0 ± 3.0	2.5 ± 1.6	1.9 ± 1.8	4.1 ± 1.8	1.2 ± 7.3
EDC	2.1 ± 3.5	2.6 ± 2.4	2.8 ± 3.7	2.6 ± 4.7	3.2 ± 2.6	1.9 ± 4.5
			12.5% of maximum force			
FCR	4.0 ± 2.5	3.1 ± 1.9	2.8 ± 1.6	2.7 ± 1.4	2.7 ± 1.7	5.2 ± 7.3
FCU	3.9 ± 2.7	3.9 ± 3.7	4.2 ± 4.8	5.0 ± 5.3	4.5 ± 4.6	4.0 ± 4.5
FDS	5.3 ± 2.4	4.5 ± 2.5	3.1 ± 1.0	3.7 ± 1.7	3.3 ± 1.3	3.2 ± 1.1
ECR	8.3 ± 4.5	7.6 ± 6.3	5.8 ± 3.4	5.9 ± 4.2	5.5 ± 3.9	5.1 ± 3.8
ECU	9.0 ± 5.4	8.9 ± 5.2	7.0 ± 3.8	7.4 ± 4.3	7.5 ± 3.8	5.4 ± 3.9
EDC	7.9 ± 12.2	9.7 ± 12.0	5.7 ± 7.0	7.0 ± 7.8	5.0 ± 7.4	4.3 ± 7.0
			25% of maximum force			
FCR	7.0 ± 3.0	5.6 ± 2.8	5.1 ± 2.8	5.9 ± 3.5	4.0 ± 2.4	5.9 ± 2.7
FCU	9.0 ± 5.5	8.3 ± 5.6	10.5 ± 11.2	9.6 ± 7.6	6.2 ± 4.2	6.2 ± 4.6
FDS	13.5 ± 6.2	10.6 ± 6.4	7.0 ± 3.6	9.8 ± 4.2	7.0 ± 3.3	9.2 ± 3.5
ECR	15.4 ± 7.1	13.7 ± 6.3	10.0 ± 5.2	9.7 ± 4.0	8.6 ± 5.8	9.4 ± 5.8
ECU	16.8 ± 8.5	15.9 ± 7.3	13.9 ± 6.7	15.0 ± 4.9	12.0 ± 4.4	10.8 ± 6.0
EDC	14.8 ± 16.6	16.3 ± 14.7	9.8 ± 9.6	12.7 ± 15.0	8.1 ± 10.4	8.7 ± 11.2
			50% of maximum force			
FCR	14.7 ± 8.7	17.5 ± 11.8	12.8 ± 6.7	15.5 ± 8.0	11.4 ± 7.9	12.4 ± 6.9
FCU	22.2 ± 11.3	23.3 ± 12.7	17.4 ± 8.0	23.4 ± 15.3	15.7 ± 7.0	17.4 ± 8.8
FDS	23.9 ± 9.6	33.8 ± 14.9	21.7 ± 7.0	28.4 ± 10.5	16.6 ± 8.7	23.0 ± 8.3
ECR	35.1 ± 16.5	34.9 ± 17.4	22.4 ± 9.5	24.8 ± 10.6	17.7 ± 10.0	18.6 ± 7.3
ECU	29.7 ± 13.6	32.8 ± 13.9	24.9 ± 10.7	32.5 ± 9.6	21.8 ± 6.9	20.0 ± 9.1
EDC	20.2 ± 24.9	34.2 ± 27.6	18.9 ± 17.1	32.3 ± 26.5	17.6 ± 18.3	17.7 ± 17.4
			100% of maximum force			
FCR	18.9 ± 13.2	19.9 ± 33.3	23.4 ± 14.7	27.6 ± 13.7	26.7 ± 17.9	28.7 ± 17.2
FCU	22.4 ± 11.2	37.0 ± 15 8	37.1 ± 13.6	42.5 ± 19.4	42.5 ± 20.0	39.9 ± 13.4
FDS	31.2 ± 11.8	37.9 ± 15.8	38.4 ± 12.2	46.1 ± 14.8	40.6 ± 13.7	39.4 ± 17.6
ECR	38.9 ± 15.2	46.8 ± 17.2	43.2 ± 16.4	46.8 ± 17.3	41.9 ± 15.4	49.8 ± 20.5
ECU	32.6 ± 11.3	41.6 ± 16.6	45.0 ± 17.8	52.4 ± 15.7	45.7 ± 14.8	48.4 ± 16.3
EDC	19.8 ± 23.1	41.5 ± 31.4	38.0 ± 26.6	37.4 ± 28.3	30.2 ± 24.2	30.1 ± 27.6

expected. Using a splint during periods of heavy manual labor should not be advised as is evidenced by the increased muscle activity observed in the splinted wrist at maximal effort. Increased muscle activity on both sides of the wrist (i.e., co-contraction of flexors and extensors) would result in higher compressive forces in the wrist, in addition to the obvious lack of muscular rest, likely negating the intended purpose of the brace.

The current findings are similar to those of several other studies, with some subtle differences. For example, Johansson et al. (2004) found that a stiff volar orthosis increased flexor activity at 40% maximum voluntary contraction, but neither a soft commercial splint nor their stiff volar splint affected extensor activity. Bulthaup et al. (1999) found increased nonnormalized extensor carpi radialis brevis (ECRB) muscle activity when using a long splint versus a short splint during simulated pouring from a can (with forearm pronation). However, they found no difference between a short splint and a free wrist while FCR activity increased with addition of either splint. It should be noted that the functional task in that study would likely not be directly comparable to our maximal effort. Jansen et al. (1997) reported that only a semicircular volar splint reduced ECRB activity in a series of functional and gripping tasks. In grip tasks, the semicircular splint reduced ECRB activity by 6%, but all splints tested were found to significantly reduce grip strength. Thus the design of the splint and type of tasks tested play an important role in study outcomes.

While the general purpose of splinting is similar for all joints, there may be body part or joint specific differences. For example, a lumbar orthosis was found to significantly lower abdominal and lower back muscle activity (Kawaguchi et al., 2002). The spine-stiffening effect of a lumbosacral orthosis has been estimated to reduce trunk muscle activity by up to 14% of maximum activation, with a small reduction in spine compression (Cholewicki, 2004). Function appears to be an important factor as knee brace use during walking was found to increase quadriceps EMG but not that of hamstrings (Diaz et al., 1997). The lack of reduced EMG during splinted gripping in the current study is likely indicative of the functional role of the splint and provides some support to the slight increase in carpal tunnel pressures with active wrist splint use (Rempel et al., 1994), and also likely result in elevated wrist joint forces.

While the wrist splints created for this study were not representative of commercially available products, these data indicate that the effectiveness of splinting may be governed by activities of the hand. Thus, wrist splinting for active workplace duties may increase wrist joint support (and likely comfort) but likely does not reduce muscle activity. These implications should be understood by therapists and, specifically, users who may see the wrist brace as a panacea for wrist disorders. Similarly, the use of industrial wrist bracing with power hand tools (to reduce wrist torque) may act to reduce muscle activity and operator effort (Johnson, 1988), but perhaps require further evaluation from a total muscle loading perspective (flexor/extensor and proximal/distal). In addition, our data indicate that workers may benefit from some sort of bracing or support between active tasks at work.

There are a few limitations associated with the current study. First, only simple isometric gripping tasks were used. Results may differ with dynamic unsupported tasks. Secondly, caution should be used when generalizing the effects from our simple Plexiglas splints to commercial products as they were a fixed length and fit individuals slightly differently depending on their anthropometrics, and a prime design criterion was to not interfere with grip force generation. The constant 50-mm grip width used may have resulted in nonoptimal grip sizes for some participants but it was deemed more representative of the workplace, where hand tools have fixed handle dimensions. Finally, it is unlikely that any cross-talk occurred in the collected EMG signals given our previous work that indicated minimal cross-talk between forearm muscles with proper electrode placement (Mogk & Keir, 2003b).

In conclusion, this study revealed that wrist splinting under low-to-moderate grip force conditions can assist to support the wrist joint but should be avoided when exerting maximal forces. It appears that using a splint to perform work-related tasks or activities of daily living during periods of heavy manual labor should not be advised. The results from this study would suggest that braces should only be prescribed for use when the injured area is not active and not for assistance during activities, such as occupational tasks. Further research is required to gain insight into the magnitude of muscle activity in the hand, wrist, and forearm, as well as adaptations in other muscles and joints, when performing more complex tasks when splinted.

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References

Bulthaup, S., Cipriani, D., & Thomas, J. (1999). An electromyography study of wrist extension orthoses and upper-extremity function. *The American Journal of Occupational Therapy, 53*, 434–440.

Cort, J.A., Stephens, A., & Potvin, J.R. (2006). A biomechanical and psychophysical examination of fastener initiation in automotive assembly. *International Journal of Industrial Ergonomics, 36,* 837–845.

Cholewicki, J. (2004). The effects of lumbosacral orthoses on spine stability: What changes in EMG can be expected? *Journal of Orthopaedic Research, 22,* 1150–1155.

Diaz, G.Y., Averett, D.H., & Soderberg, G.L. (1997). Electromyographic analysis of selected lower extremity musculature in normal subjects during ambulation with and without a protonics knee brace. *The Journal of Orthopaedic and Sports Physical Therapy, 26*, 292–298.

Jansen, C.W., Olson, S., & Hasson, S.M. (1997). The effect of use of wrist orthosis during functional activities on surface electromyography of the wrist extensors in normal subjects. *Journal of Hand Therapy, 10,* 283–289.

Johansson, L., Gunnar, B., & Hagg, G. (2004). The effect of wrist orthoses on forearm muscle activity. *Applied Ergonomics, 35,* 129–136.

Johnson, S.L. (1988). Evaluation of powered screwdriver design characteristics. *Human Factors, 30*, 61–69.

Kawaguchi, Y., Gejo, R., Kanamori, M., & Kimura, T. (2002). Quantitative analysis of the effect of lumbar orthosis on trunk muscle strength and muscle activity in normal subjects. *Journal of Orthopaedic Science, 7,* 483–489.

Mogk, J.P.M., & Keir, P.J. (2003a). The effects of posture on forearm muscle loading during gripping. *Ergonomics, 46*(9), 956–975.

Mogk, J.P.M., & Keir, P.J. (2003b). Crosstalk in surface electromyography of the proximal forearm during gripping tasks. *Journal of Electromyography and Kinesiology, 13*, 63–71.

Rempel, D., Manojlovic, R., Levinsohn, D.G., Bloom, T., & Gordon, L. (1994). The effect of wearing a flexible wrist splint on carpal tunnel pressure during repetitive hand activity. *The Journal of Hand Surgery, 19A,* 106–110.

Snijders, C., Volkers, A., Mechelse, K., & Vleeming, A. (1987). Provocation of epicondylalgia lateralis (tennis elbow) by power grip or pinching. *Medicine and Science in Sports and Exercise, 19*, 518–523.

Stern, E. (1996). Grip strength and finger dexterity across five styles of commercial wrist orthoses. *The American Journal of Occupational Therapy, 50*, 32–38.

Van Elk, N., Faes, M., Degens, H., Kooloos, J.G.M., de Lint, J.A., & Hopman, M.T.E. (2004). The application of an external wrist extension force reduces electromyographic activity of wrist extensor muscles during gripping. *The Journal of Orthopaedic and Sports Physical Therapy, 34*, 228–234.