Shoulder Muscle Activity Increases With Wrist Splint Use During a Simulated Upper-Extremity Work Task

Amy G. Mell,
Mark A. Friedman,
Richard E. Hughes,
James E. Carpenter

OBJECTIVE. The purpose of this study was to test the hypothesis that wearing a wrist splint while performing a common light manufacturing task (moving an object from a bin) increases shoulder muscle activity.

METHODS. Electromyography (EMG) signals were evaluated from the anterior, middle, and posterior deltoid, trapezius, supraspinatus, and infraspinatus of 14 volunteers while they moved an object from a bin. Two test conditions were measured: with and without a wrist splint. The height of the bin was also varied.

RESULTS. Wearing a wrist splint increased maximum EMG for all six muscles and average levels for the deltoid (anterior, middle, posterior) and trapezius. As bin height increased, maximum muscle activity increased in the deltoid (anterior, middle, and posterior) and trapezius, and the average increased in the deltoid (middle and posterior) and trapezius.

CONCLUSIONS. Workplace factors can modify the activation of a patient's shoulder muscles when he or she is wearing a wrist splint. An ergonomic job analysis should be conducted for patients who are returning to work wearing wrist splints.

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Wrist orthoses are commonly used as a portion of the treatment for conditions such as carpal tunnel syndrome, epicondylitis, and other hand or wrist injuries. Soft or semirigid orthoses may frequently be worn in the workplace. Despite the generally positive outcome for these conditions, wrist immobilization may not be entirely benign. Clinically, we have observed new or exacerbated shoulder complaints with patients being treated in wrist splints, which raises the obvious question of how wrist immobilization affects shoulder function and how it could contribute to shoulder injury. Very little research, however, has been devoted to this subject.

Perez-Balke and Buchholz (1994) have theorized that wearing a wrist splint for the treatment of a hand or wrist disorder may increase the risk of injuring the shoulder. Elevated arm postures have been epidemiologically demonstrated to be a risk factor for shoulder disorders (Punnett, Fine, Keyserling, Herrin, & Chaffin, 2000). It has been shown that wearing a wrist splint increases humeral elevation when performing the Jebsen Hand Function Test (Jebsen, Taylor, Trieschmann, & Trotter, 1969) and selected activities of daily living (Adams, Grosland, Murphy, & McCullough, 2003; King, Thomas, & Rice, 2003). We have demonstrated that wearing a wrist splint results in an increase in active shoulder elevation while picking an object from a bin (Mell, Childress, & Hughes, 2005).

Several studies have examined the effect of wearing a wrist orthosis on muscle activity in the wrist and elbow (Bulthaup, Cipriania, & Thomas, 1999; Jansen, Olson, & Hasson, 1997; Johansson, Bjoring, & Hagg, 2004), but few have investigated the effect on shoulder muscle activity (Burtner et al., 2003). Bulthaup et al. (1999) found a statistically significant increase in motor unit recruitment for four proximal muscles of the shoulder (pectoralis major, trapezius, biceps brachii, and the medial head of the triceps) when wearing a wrist orthosis. The middle deltoid did demonstrate increased activity; however, this difference was not significant. In

Amy G. Mell is Research Assistant, Orthopaedic Research Laboratories and MedSport, Department of Orthopaedic Surgery, University of Michigan, Ann Arbor, Michigan.

Mark A. Friedman, MD, is House Officer, Orthopaedic Research Laboratories and MedSport, Department of Orthopaedic Surgery, University of Michigan, Ann Arbor, Michigan.

Richard E. Hughes, PhD, is Associate Professor, Orthopaedic Research Laboratories and MedSport, Department of Orthopaedic Surgery, University of Michigan, 24 Frank Lloyd Wright Drive, Ann Arbor, Michigan 48106; rehughes@umich.edu

James E. Carpenter, MD, is Associate Professor, Orthopaedic Research Laboratories and MedSport, Department of Orthopaedic Surgery, University of Michigan, Ann Arbor, Michigan.

addition, Burtner et al. (2003) reported increased use of the proximal shoulder muscles in patients with rheumatoid arthritis during pinch and dexterity tests with and without splints. Their study showed that wearing a wrist splint during pinch and dexterity tests increases activation of the shoulder muscles compared to the wrist and elbow and could lead to fatigue and increased stress on the shoulder. Carlson and Trombly (1983) found that some of the subjects who performed the Jebsen Hand Function Test while wearing a wrist splint reported shoulder fatigue.

Many occupational therapists and physical therapists conduct job site ergonomic analyses for injured workers. These therapists need scientifically based guidelines for recommending job modifications and light duty tasks. If wearing a wrist splint increases a worker's risk for shoulder disorders when he or she performs specific occupational tasks, then the therapist may recommend a job modification.

The purpose of our study was to determine the effect of wearing a wrist splint on shoulder muscle activity during an occupational task. We tested the hypothesis that wearing a wrist splint increases shoulder muscle activities while picking an object from a bin in front of the body. This task was selected because it is widespread in occupational settings, especially for people working in manufacturing jobs. A secondary objective was to determine whether the height of the bin also increases shoulder muscle activities. The height of the bin was varied because of the different sizes available in the industrial setting and because this is a workplace factor that can easily be modified by an occupational therapist.

Methods

Participants

After Institutional Review Board approval was obtained for this study, 14 healthy adult volunteers (8 men, 6 females) between the ages of 19 and 34 years (age *[SD]* = 27.6 [4.7] years) with no prior history of shoulder or back injury participated in this study. All participants were right-handed.

Testing Protocol

After each participant read and signed a consent form, a wire intramuscular electrode was placed in his or her supraspinatus using a superior approach (Kelly, Kadrmas, & Speer, 1996) and sterile technique. Bipolar silver-silver chloride surface electrodes (Blue Sensor®, Ambu Inc., Linthicum, Maryland) were then applied to the participant's anterior, middle, and posterior deltoid, upper trapezius, and infraspinatus according to a well-defined protocol and previously defined locations (Basmajian & Blumenstein, 1983; Cram, Kasman, & Holtz, 1998; Geiringer, 1994; Sporrong, Palmerud, Kadefors, & Herberts, 1998). The electrodes for the anterior deltoid were placed 4 cm anterior to the lateral end of the clavicle and angled toward the deltoid insertion (Cram et al., 1998). The electrodes for the middle deltoid were applied 5 cm distal from the lateral aspect of the acromion on a line from the middle of the lateral aspect of the acromion to the deltoid tuberosity (Basmajian & Blumenstein, 1980; Cram et al., 1998). The posterior deltoid electrodes were positioned 2 cm below the distal end of the scapular spine on a line from the location point to the deltoid tuberosity (Cram et al., 1998). The upper trapezius electrodes were placed halfway between the C7 spinous process and the tip of the acromion on the crest of the shoulder in line with the muscle fibers (Geiringer, 1994). The electrodes for the infraspinatus were put 3 cm inferior to the spine of the scapula, one third of the distance from the medial angle of the scapula to the middle of the spine of the scapula (Sporrong et al., 1998). All electrode pairs were placed 2 cm apart. After application, electrode resistance and potential difference were measured. When resistance or potential difference was excessively high, the electrode pair was removed and replaced. All signals were verified by functional muscle testing (Cram et al., 1998; Kelly et al., 1996) and checked on an oscilloscope to confirm the integrity of the system and appropriate placement of electrodes. The dorsum of the left hand was used as a ground. Wires were routed and secured to eliminate movement artifact.

Electromyography (EMG) activity was recorded at 1000 Hz with a Noraxon Myosystem™ 2000 EMG system (Noraxon, Inc., Scottsdale, Arizona) and collected on a personal computer using MotionMonitor™ software (Innovative Sports Training, Inc., Chicago, Illinois). Manual muscle testing was performed with the participant seated. For each muscle, 4-sec maximal voluntary contractions (MVCs) were performed against manual resistance. The middle 2 sec of each effort were used for normalization. Participants were tested in shoulder abduction at both 90° and 135° of abduction, flexion at 45°, extension in neutral position, external rotation with arm at side and elbow at 90°, and "full-can" scaption. Two shrugs were performed—one unilateral with manual resistance and the second bilateral with the participant holding the chair edge and providing his or her own resistance.

Participants were seated in front of a table, providing a 28-inch-height work surface. A stack of standard industrial style bins was placed directly in front of the right shoulder with a similar bin on the left (see Figure 1). Participants moved five medium-sized nuts from the stack of bins on the right to the single bin on the left.

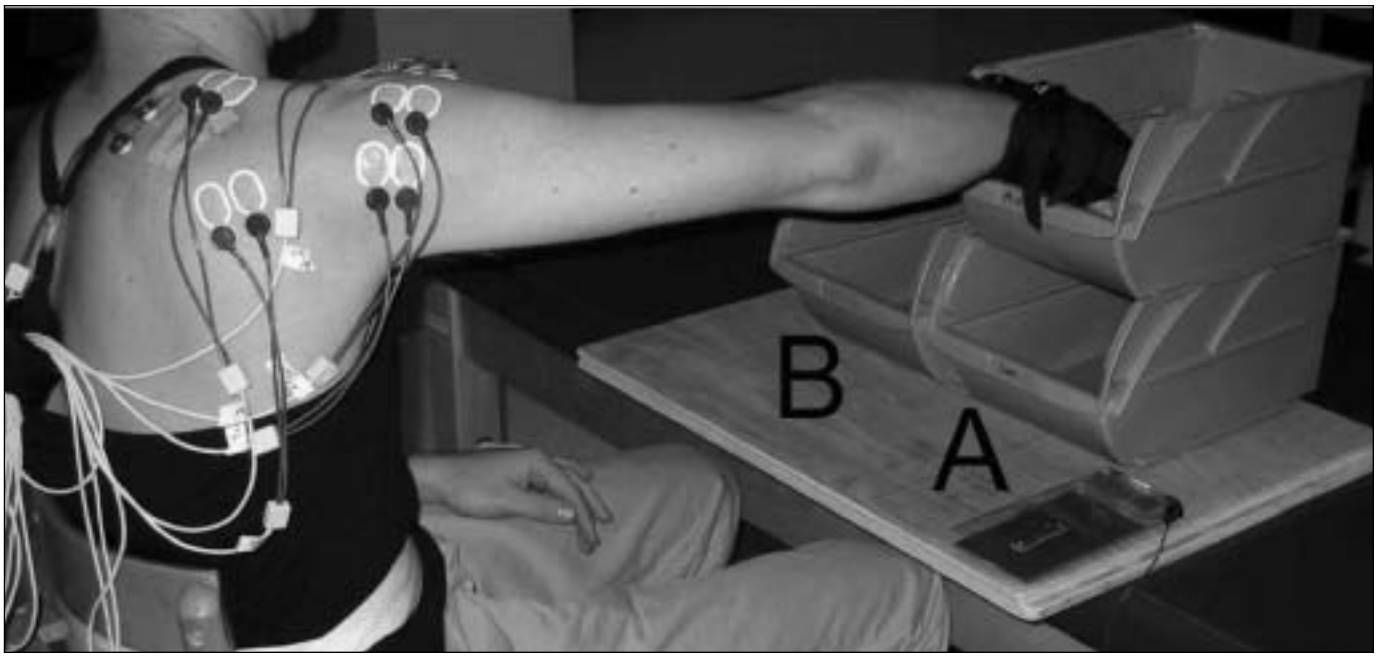

Figure 1. The setup for the middle height is shown. The participant moved five medium-sized nuts from the bins on the right (A) to the bin on the left (B). The top bin was removed for the low height and a third bin was added to the above setup for the high height.

The stack of bins on the right contained one (low height), two (middle height), or three (high height) bins. Two splint conditions were also tested—wearing a Signature Ultra Fit Cool Wrist Splint® (Corflex, Manchester, NH), and not wearing a splint. The participant was tested reaching into the bin while wearing the splint and without the splint at each of the bin heights; thus, there were six experimental test conditions. The testing order for all conditions was randomized for each participant. A 1-sec rest was permitted between multiple repetitions at each height. A longer rest period was permitted between test conditions.

Data Processing

A baseline EMG, taken with the muscle at rest, was first subtracted from each EMG signal for each muscle. The signal was then rectified and a 3 Hz high pass Butterworth filter was applied. Finally, the data was normalized by the MVC. Except for the normalization, the previously mentioned protocol was applied to the MVC trials. The maximum and average EMG for each muscle at every trial was calculated. Percent change of EMG was calculated as the difference in EMG with a splint minus without a splint divided by the EMG without a splint. This value was calculated at each bin height for each muscle and then averaged across all heights for each participant.

Statistics

The effects of wearing a wrist splint and bin height were evaluated using a repeated-measures analysis of variance model. Dependent measures were maximum and average normalized EMG values for each muscle. Pairwise post hoc comparisons were not computed; rather, statistical trend analysis was performed on the height factor using orthogonal polynomials. Both linear and quadratic trends were statistically evaluated. The sample size was determined based on a statistical power analysis. The power analysis, which used data from three pilot subjects to estimate variance and effect size, sought to provide 80% power to detect a 5% change in normalized EMG when using a two-sided test and controlling the Type I error at 0.05.

Results

Wearing a wrist splint increased the maximum EMG for six of the shoulder muscles (see Figure 2): anterior deltoid ($p < 0.001$), middle deltoid ($p < 0.001$), posterior deltoid ($p < 0.001$), upper trapezius ($p < 0.001$), infraspinatus ($p = 0.029$), and supraspinatus ($p = 0.017$). The wrist splint also increased the average EMG for four muscles (see Figure 3): anterior deltoid ($p = 0.018$), middle deltoid ($p < 0.001$), posterior deltoid ($p < 0.001$), and upper trapezius ($p < 0.001$). However, the average EMG of the infraspinatus ($p = 0.052$) and supraspinatus ($p = 0.092$) did not achieve statistical significance.

As bin height increased, maximum EMG for four shoulder muscles also increased: anterior deltoid ($p = 0.005$), middle deltoid ($p < 0.001$), posterior deltoid ($p = 0.007$), and trapezius ($p < 0.002$). Elevated bin height also increased average EMG for three muscles: middle deltoid ($p < 0.001$), posterior deltoid ($p < 0.013$), and trapezius

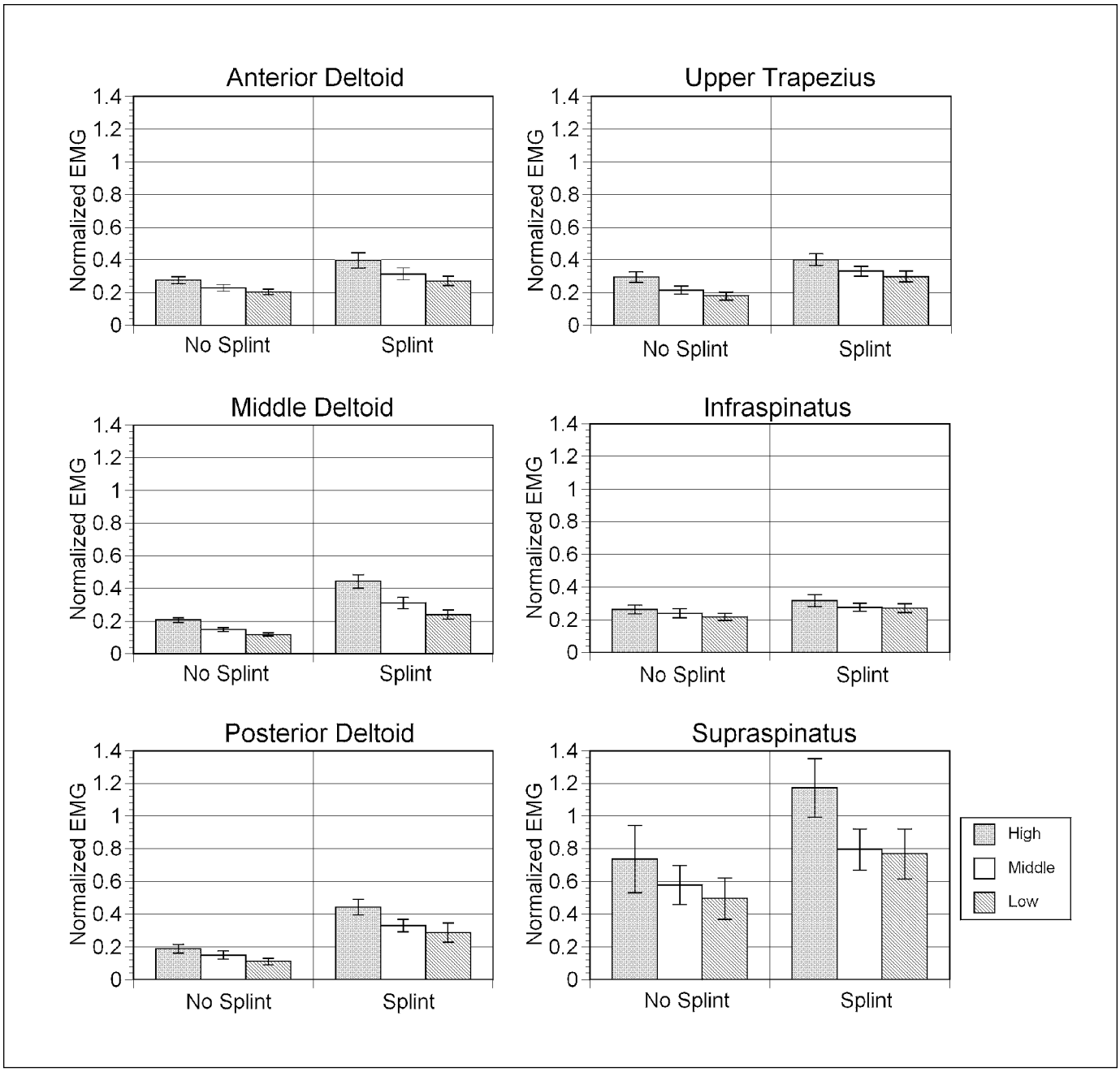

Figure 2. Maximum normalized EMG for anterior, middle, and posterior deltoid, upper trapezius, infraspinatus, and supraspinatus with and without a wrist splint.

(p = 0.014). All other average EMG measures did not achieve statistical significance. Trend analysis using orthogonal polynomials indicated the existence of linear increasing trends with increasing bin height for maximum normalized EMG of five shoulder muscles: anterior deltoid ($p < 0.001$), middle deltoid ($p < 0.001$), posterior deltoid ($p = 0.002$), trapezius ($p < 0.001$), and supraspinatus ($p = 0.041$) muscles. Increasing linear trends with bin height were found for average normalized EMG of four shoulder muscles: anterior deltoid ($p = 0.028$), middle deltoid ($p < 0.001$), posterior deltoid ($p = 0.004$), and trapezius ($p = 0.004$) muscles. No quadratic trends were found.

Conclusions

Our results demonstrate a clear increase in muscle activity during the use of a simple wrist orthosis. The results are consistent with the previous study from Bulthaup et al. (1999), which reported that wearing a wrist orthosis puts more stress on the shoulder musculature than not wearing a splint. They found an increase in muscle activity in the pectoralis major, trapezius, biceps brachii, and the medial head of the triceps. Unlike Bulthaup et al., who found only a trend, we found a significant increase in the middle deltoid activity. Our study also complements the findings of

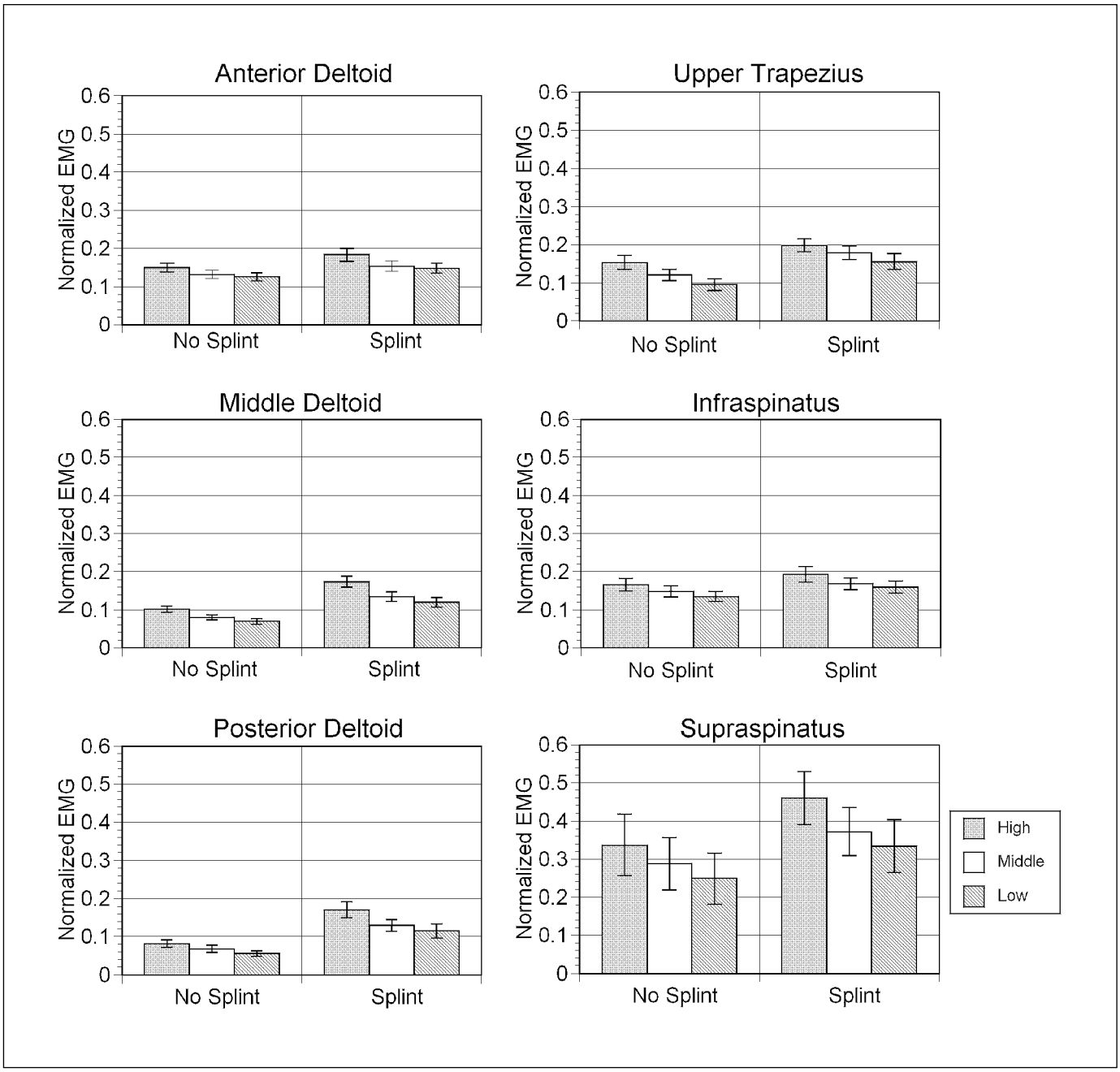

Figure 3. Average normalized EMG for anterior, middle, and posterior deltoid, upper trapezius, infraspinatus, and supraspinatus with and without a wrist splint.

altered shoulder kinematics with wrist immobilization (Adams et al., 2003; Beckenbaugh & Linscheid, 1977; King et al., 2003; Millender & Nalebuff, 1973).

Increased muscle activity has not been definitively shown to cause rotator cuff tendon tears or impingement syndrome. Therefore, our results do not prove that wearing a wrist splint causes rotator cuff tendon pathology. However, there is evidence that increased mechanical loading of the shoulder may cause neck pain (Bernard, 1997). Therefore, our results indicate that wearing a wrist splint increases factors that are likely to cause pain.

It is important to remember that EMG is not a direct measurement of force and may not be linear. However, peak activity increased in all muscles measured, and the average activity was significantly increased in the three heads of the deltoid and the upper portion of the trapezius. The biological significance of peak versus average muscle activity is unclear. Therefore, both measures were included. Another limitation is that the study was performed in a laboratory rather than a workplace setting. In addition, only one workspace configuration was studied. Wearing a wrist splint during other occupational tasks may increase or decrease

the effect on the shoulder. An additional limitation was the use of a study design that could not definitively link wrist splint use to impingement syndrome; such a study would require a prospective epidemiological investigation. Finally, EMG and shoulder kinematic data were not recorded at the same time and thus cannot be correlated.

The findings of this study do clearly link use of a wrist orthosis to increased shoulder muscle activity. Our results suggest that detailed job analyses should be performed for patients who are returned to work with a wrist orthosis. Many job analysis tools are available, ranging from computerized biomechanical models (Das & Sengupta, 1995) to simple checklists (Keyserling, Brouwer, & Silverstein, 1992). Unfortunately, much of the ergonomics and job modification literature has compartmentalized job analysis into hand or wrist tools and low-back tools. Analysis of hand-related tasks and postures generally do not incorporate their effect on the shoulder. Use of existing ergonomic analysis tools may fail to detect the possibility of wrist orthoses affecting the shoulder.

Work surface height is a critical parameter in ergonomic job analyses. Too high a work surface is known to affect shoulder posture and shoulder muscle EMG. Ergonomic guidelines (Grandjean 1988; Rodgers & Eggleton, 1983) address the shoulder by recommending avoidance of elevated arm work. This recommendation is based on endurance and EMG studies of the shoulder (Chaffin, 1973; Wiker, Chaffin, & Langolf, 1989). Manipulating work surface height is an important way to prevent elevated arm work (Grandjean, 1988). Our results indicate that wearing a wrist orthosis has a biomechanical effect similar to elevating the work surface. Therefore, the job analyst should be cognizant of the fact that a work station suitably adjusted for an uninjured worker may be potentially unsuitable for the worker wearing a wrist orthosis.

The practical implication of our results is that a job analysis using traditional ergonomic tools should be augmented by an evaluation of the need to flex the wrist when the job is being performed by an employee wearing a wrist orthosis. Placement of the employee in a more suitable job may be an option, especially if a return-to-work program is in place. If the employee must return to a job that requires flexing the wrist during reaches into bins, the job analyst should consider the possibility of altering the height of the work surface.

In summary, it is important to understand job demands when a patient returns to work with a wrist orthosis. Job demands should be comprehensively evaluated for risks to all body parts. Although a wrist orthosis may help hand or wrist symptoms, it may create problems more proximally. The results of this study indicate the potential for neck or shoulder discomfort secondary to wearing a wrist splint if the job requires object transfer in front of the body. ▲

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