

POSTURAL EFFECTS ON FOREARM EXTENSOR MUSCLE LOADING

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Abstract

The contribution of posture and grip force to muscle loading has been recognized but not adequately quantified. In six healthy individuals, five handgrip efforts (5%, 50%, 70% and 100% MVC, and 50 N) were performed in each of 9 different postures. Forearm flexor and extensor muscle activity was measured using electromyography (EMG). Extensor activity was substantial, especially with forearm pronation and wrist extension, where it exceeded flexor activity regardless of effort level ($p=0.00016$). The common digital extensor was activated to a higher level during flexion than extension, regardless of forearm posture ($p=0.005$). When simply maintaining a gripping posture in pronation, extensor activity ranged from 5.1% MVC (flexed wrist) to 10.8% MVC (extension), while flexor activity was 2.1% to 1.6% MVC for the same postures. Specific forearm and wrist postures increase the static load on the extensor muscles, which may lead to increased risk of fatigue or injury.

Keywords: EMG; grip; posture

EFFETS DE LA POSTURE SUR L'ACTIVATION DES MUSCLES EXTENSEURS DE L'AVANT-BRAS

La contribution de la posture et de la force de préhension sur l'activation musculaire a été mentionnée mais insuffisamment quantifiée. Cinq niveaux de préhension (5%, 50%, 70% et 100% contraction maximale volontaire (CMV) et 50 N) ont été effectués par six volontaires en santé, sous neuf postures différentes. L'activation musculaire des fléchisseurs et des extenseurs fut mesurée par électromyographie (EMG). L'activation des extenseurs était substantielle, particulièrement en pronation et en extension du poignet, où elle surpassait l'activation des fléchisseurs pour tous les niveaux d'effort ($p=0,00016$). Le muscle extenseur commun des doigts était davantage activé lors de la flexion, peu importe la posture ($p=0,005$). Lors du simple maintien d'une position de préhension en pronation, l'activation des extenseurs variait de 5,1% CMV (flexion) à 10,8% CMV (extension) et l'activation des fléchisseurs variait de 2,1% à 1,6% pour les mêmes postures. Certaines postures de l'avant-bras et du poignet augmentent l'activation des muscles extenseurs, ce qui pourrait entraîner une augmentation du risque de fatigue ou de blessure.

Mots clés : EMG, préhension, posture

INTRODUCTION

The mechanisms of work-related injuries in muscle have often been attributed to assumed relationships between external force and muscle activation (2). The action of gripping requires exertion of the finger flexor muscles, yet the forearm extensor muscles receive more worker complaints (4). Ergonomic hand tools have decreased the forces workers must exert and improved worker posture, however, the exact nature of forearm muscle loading has not been fully investigated. This is especially true for the effects of forearm rotation on muscle activation patterns. Electromyography (EMG) has been used to examine control of the forearm, including the effects of posture on muscle activity and force production (1). For example, co-contraction is necessary to counteract gravity and maintain wrist posture during different forearm and hand orientations (6). Further examination of these relationships would contribute to a better understanding of the physiological basis for the loading and potential injury of the extensor aspect of the forearm. The goal of this research was to determine the effects of several postural combinations of the wrist and forearm on forearm muscle loading.

METHODS

The preliminary results of this study include the data of six healthy individuals who were all pain free in the forearm at the time of testing, and reported no history of hand, wrist or forearm dysfunction. Data is that of 4 males and 2 females (mean age: 23.5 years; range: 21-25 years). Surface EMG was recorded from the following forearm muscles: flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), flexor digitorum superficialis (FDS), extensor carpi radialis (ECR) and extensor carpi ulnaris (ECU), extensor digitorum communis (EDC). The right forearm was placed on a horizontal platform, adjusted for height to standardize posture. The hand and wrist were not supported. Each posture was maintained prior to each contraction to attain a baseline activation level for that posture. Baseline activity levels were examined to determine muscle activity required to maintain each posture while holding the dynamometer (450 g). Each trial was videotaped and simultaneously monitored on a television screen to ensure proper posture was achieved and maintained throughout the effort. A pointer taped to the back of the right hand was aligned with a line on the forearm drawn parallel to the radius.

Maximum grip force (maximum voluntary contraction, MVC) was determined for each individual with the wrist and forearm in neutral. All EMG levels were normalized to maximum EMG amplitude from the maximum grip force trial and a series of contractions to elicit maximal activation. Four relative efforts (5%, 50%, 70% and 100% MVC) and an absolute load of 50 N were performed using a grip dynamometer (MIE Medical Research Ltd., Leeds, U.K.) in each postural combination. Three wrist postures (45° flexion, neutral, 45° extension) were used in combination with three forearm postures (full pronation, neutral, full supination), resulting in 9 combined postures. Each effort consisted of a ramped contraction (2 sec. up, 3-sec. plateau, and 2 sec. down). Postural combinations and efforts were randomized, and a 30% MVC was recorded before the first block of trials and after each following block of trials to monitor fatigue. Each block consisted of 15 trials. Each fatigue trial (i.e. 30% MVC) was performed in a neutral wrist and forearm posture, and the mean power frequency (MPF) of each muscle was examined after each fatigue trial. If considerable differences appeared in the frequency content of any muscle then an extra five-minute rest period was induced. Raw EMG was collected at a sampling rate of 1000 Hz for all block efforts and 1024 Hz for fatigue trials. Signal bias was removed from each channel and each signal was full-wave rectified and low-pass filtered (3 Hz, single pass) prior to analysis. Repeated measures ANOVAs were performed to determine levels of significance. No gender effects were analyzed.

RESULTS

Baseline muscle activity (holding dynamometer in position) revealed greater activation in the extensor muscles than the flexors muscles with forearm pronation, regardless of wrist posture ($p=0.001$). When pronated, extensors ranged from about 5.9% MVC when the wrist was flexed to 10.8% MVC when extended; flexor activity ranged from 2.1% to 1.6% MVC, respectively (Fig. 1). Extensor muscle activity increased from wrist flexion to extension while pronated, yet decreased from flexion to extension in both neutral and supinated forearm postures (Fig. 1). Also of note in Figure 1 is the apparent increase in digital extensor (EDC) activity with a flexed wrist as the forearm is rotated from neutral to supination.

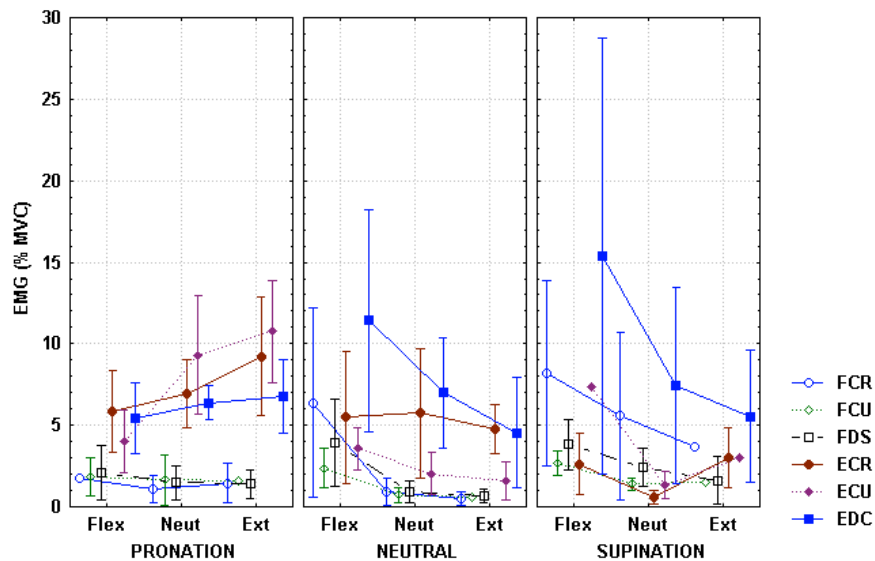


Figure 1: Mean baseline muscle activity (% MVC) to maintain each posture while holding the grip dynamometer.

Flexor and extensor activity generally follow the same pattern. Pooled across effort levels, the activity levels of both the flexors and extensors appear to decrease as the wrist is moved from flexion to extension (Fig. 2). Regardless of posture, the extensors are always activated at a higher relative level than the flexors.

The mean maximum grip force during calibration contractions (neutral wrist and forearm) was 354.3 N (± 127.4 N) and ranged from 230 - 570 N. Table 1 shows maximal grip force values within each posture tested. Maximal grip force does not appear to vary with forearm rotation with the wrist in a neutral posture. Significantly less grip force was produced when the wrist was flexed than when either neutral ($p=0.004$), or extended ($p=0.0008$).

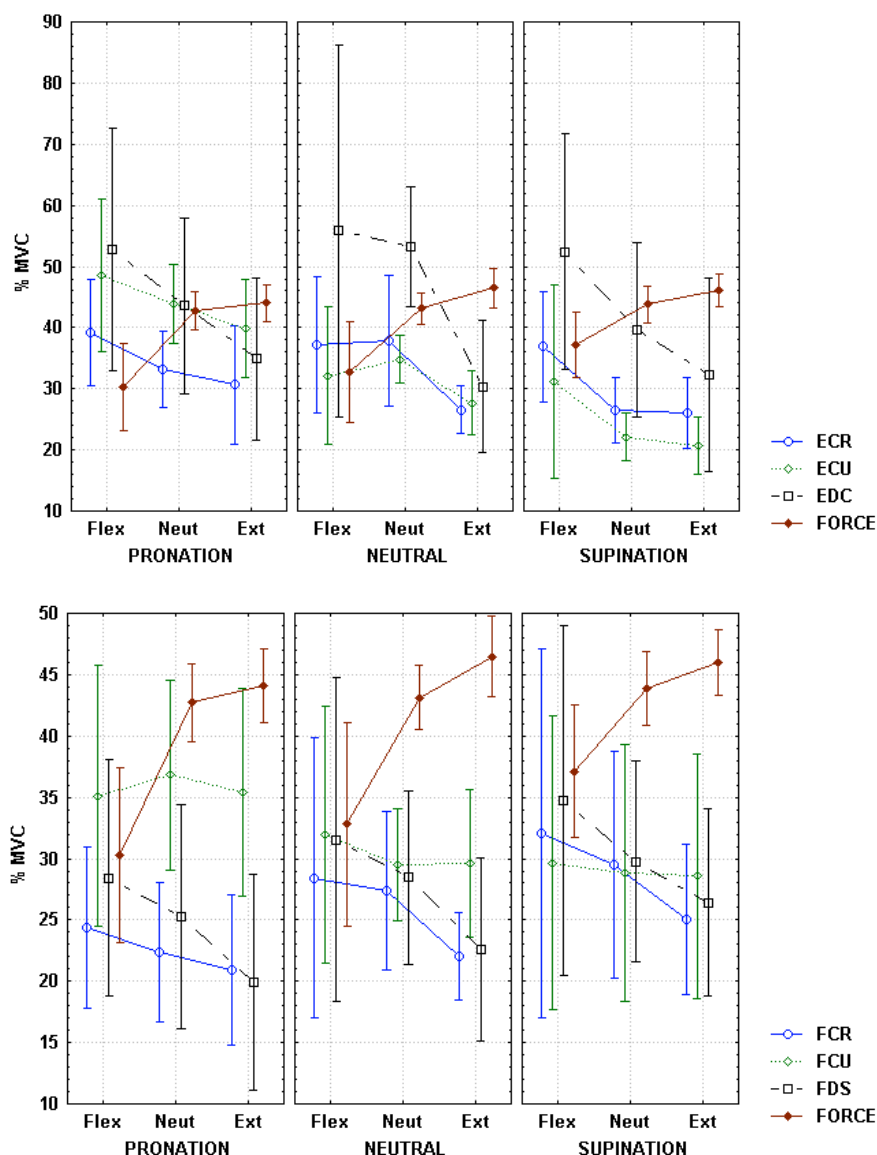


Figure 2: Mean relative extensor (top) and flexor EMG (bottom), and grip force in each wrist and forearm posture, pooled across effort level.

		Flexion	Neutral	Extension
Pronation	(N)	186.7 (70.7)	302.5 (121.9)	322.2 (109.3)
	(% MVC)	52.7 (19.9)	85.4 (34.4)	90.9 (30.9)
Neutral	(N)	210.7 (81.3)	316.8 (121.0)	360.2 (135.3)
	(% MVC)	59.5 (22.9)	89.4 (34.1)	101.6 (38.2)
Supination	(N)	243.0 (106.4)	318.5 (110.6)	355.2 (130.4)
	(% MVC)	68.6 (30.0)	89.9 (31.2)	100.2 (36.8)

Table 1: Mean values for maximal grip force in each posture in both absolute (N) and relative (% MVC) measures, with standard deviation in parentheses.

DISCUSSION

The baseline (or postural “maintenance”) activity resulted in relatively higher extensor activity in pronation. This was not unexpected, as the extensors must maintain the wrist posture against gravity. Along the same lines, wrist flexion while pronated resulted in lower extensor activation than with neutral or extended wrist, presumably due to the greater passive tension present (3). The increased digital extensor activity during wrist flexion in both neutral and supinated forearm postures may be due to reflex activity as EDC is passively stretched. The increase in EDC activity in a supinated posture (flexed wrist, Fig. 1, right panel), might suggest an increased contribution to wrist stabilization to compensate for the apparent drop in ECR activation.

The higher extensor activation can be explained by their reduced biomechanical potential compared to the flexor muscles. The wrist and finger flexor muscles have both greater moment arms and cross-sectional areas than the wrist and finger extensor muscles (5), resulting in the need for greater activation to balance moments at the wrist.

Relative extensor activation levels (i.e. % MVC) may be slightly elevated, as normalized amplitudes exceeded 100% MVC in some trials, indicating that a true maximal activation was not achieved during the calibration process. This would affect only reported EMG amplitudes. Also of note, in the trial involving maximum grip in a neutral wrist and forearm posture, individuals produced only 89.4% of initial grip force attained in the same posture. Fatigue was not evident in the study as a concurrent decrease in MPF and increase in amplitude was not found.

The smaller relative grip force levels achieved in wrist flexion are similar to those found previously (1). The decrease can be explained by the force-length relationship of the flexor muscles and, as found here, a concurrent increase in finger extension activation.

The relationship between grip force, posture and forearm muscle loading is more complex than previously thought. It does appear that the extensors work at a relatively higher level than the flexors to stabilize the wrist. Extended periods of pronation during the workday could limit extensor rest, and help explain the incidence of extensor forearm pain.

ACKNOWLEDGEMENT

This study was supported by an NSERC operating grant awarded to P. Keir.

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