# EFFECT OF GRIP FORCE ON WRIST RANGE OF MOTION

Allison DiMartino, Kathryn Doné, Timothy Judkins,
M. Susan Hallbeck, Gregory Bashford
University of Nebraska-Lincoln
Lincoln, NE

This study investigated the effect of a constant grip exertion on wrist range-of-motion (ROM). Seven different levels of grip force were investigated, including two levels of zero exertion, 25%, 50%, 75%, 90%, and 100% MVC. Both hands were tested for each of three forearm positions (pronation, halfway between pronation and supination (neutral), and supination). Twenty student subjects (10 males and 10 females) were tested. Subjects held a particular grip force level constant while simultaneously moving their wrist. The maximum angles of flexion and extension were recorded to measure range-of-motion (ROM). ANOVA analysis was performed for the dependent variables of flexion angle, extension angle, and total ROM. Independent variables were gender, hand, forearm position, and exertion level. Exertion level was a significant factor for extension, flexion, and ROM. Forearm posture was a significant factor for extension and ROM. Tukey-Kramer analysis revealed similar groupings of exertion levels and forearm positions for flexion, extension, and ROM. The data show a significant decrement in wrist ROM as grip force exertion level increased.

## INTRODUCTION

Many daily activities require the use of the hands and arms to manipulate an object. Execution of these activities often requires the hand to exert a force while simultaneously moving the wrist or arm. Tasks that require this type manual handling and adjustment are abundant in both industrial and domestic environments. While these tasks are commonplace, the study of the effect of the tasks on the motion or posture has not been common. It is important to understand what forces and range-of-motion (ROM) are within human capabilities so that tasks can be designed with physiological limitations in mind in order to eliminate risk factors for cumulative trauma disorders (CTDs). CTDs of the wrist are a common and costly problem in industry, and they are becoming more prevalent. The Bureau of Labor Statistics has estimated that cumulative trauma disorders (CTDs) represented 39% (1987), 52% (1989), 54% (1991), 57% (1993), 64% (1996) and 67% (2000) of all occupational illnesses and injuries as listed on their website (http://www.bls.gov). High force exertions and repetition, coupled with awkward wrist and hand postures are believed to lead to CTDs. The levels of these factors and interactions among them are currently unknown. This study helps to determine the relationship between force exertion and awkward postures for the upper limb.

In the past, studies have investigated the relationship between grip force and wrist position. Ryu et al studied the wrist/hand system to find the ROM required by the wrist to perform daily activities (Ryu et al, 1991). Similarly, Pryce determined the wrist angle to allow maximum grip strength was near neutral (Pryce, 1980). Other studies have focused on determining how deviated wrist postures affect maximum grip exertion (Fong and Ng, 2001; Hazelton et al, 1975; O'Driscoll et al, 1992). These investigators took maximum grip measurements while subjects held their wrists in static deviated postures and found that maximum grip strength decreased as the wrist postures deviated more from neutral. Another study focused on how individual finger forces change as the wrist is moved during a grip exertion. Li found that individual finger forces decrease as the wrist is deviated from normal postures (Li, 2002). Overall, many other researchers have determined that as wrist position deviates from neutral, the amount of pinch or grasp force exerted is reduced (Anderson, 1965; Kraft and Detels, 1972; Putz-Anderson, 1988; Skovly, 1967; Terrell and Purswell, 1976).

The interaction between grip force and wrist ROM has previously been studied by investigating one aspect of this relationship –constraining posture and motion while assessing strength. In this study, we have investigated another aspect of the grip strength/wrist ROM relationship. To the author's knowledge, there is no published research paper that investigates how a constant grip force affects dynamic wrist ROM. We are interested in quantifying awkward and uncomfortable wrist postures for tasks involving a constant grip force exertion and a simultaneous rotation of the wrist. We hypothesize that as grip force increases, dynamic wrist ROM will decrease. We believe that forearm position may have an effect on ROM as well.

## METHODS

### Subjects

Subjects for this study were University of Nebraska-Lincoln students. Ten male subjects and 10 female subjects were tested. Subjects were at least 19 years of age (age of majority in Nebraska), and reported no prior history of injury in the hand, wrist or shoulder. Female subjects confirmed that they were not pregnant (as this temporarily affects ROM).

### Apparatus

A digital hand dynamometer (Jamar Model 5030 PT) was coordinated with an electrogoniometer (Biometrics, LTD) system, a laptop computer, and LabVIEW Express (V7) software. A display for subject feedback and a program for data collection were designed with LabVIEW. The subject feedback was a dial with a pie-shaped green area that subjects were instructed to stay within. The green area was automatically adjusted for each trial by the computer to represent the appropriate force level +/- 5% MVC for that particular trial. Subjects were warned if they went outside of the green pie area for more than 1 second, the trial ended. A desk chair with adjustable arm rests and Velcro straps were used keep the subject's upper arm and forearm in a standardized posture of 90º included elbow angle and adducted upper arm during testing.

### Procedure

The Research Compliance Office's Institutional Review Boards of the University of Nebraska-Lincoln approved the study and all subjects were fully informed about the experimental procedures before giving their consent.

Each subject's right and left hands and forearms were measured to obtain 4 anthropometric dimensions, including hand length, hand breadth, wrist circumference, and forearm length. Dominant hand was also recorded as reported by the subject. The subject practiced building up and holding their grip steady on the dynamometer while moving their wrist through the active ROM, as required by the feedback system in the computer program. The computer program randomly selected the first forearm position (full pronation, full supination, or halfway between pronation and supination) for each subject. The electrogoniometer was affixed to the subject's hand and forearm with double-sided tape and the cords were secured to the forearm with a reusable bandage. Subjects were seated with the upper arm adducted, elbow at a 90º included angle in the desk chair, and Velcro straps were used to secure the subject to standardize posture.

The subject was instructed to exert their strongest grip force, or maximal voluntary contraction (MVC), on the dynamometer that he or she could without causing discomfort, beginning with the right hand. Upon completion of the first MVC trial on the right hand, the left hand MVC was recorded. The subject rested for 2 minutes between MVC trials to prevent fatigue. A total 3 MVC measurements were obtained for each hand, in each forearm position and the values were averaged to define the mean MVC for that hand and forearm position. Mean MVC was used to calculate the grip force exertion levels for each individual subject for each hand and forearm position. Additionally, two levels of zero exertion were of interest. They were 0% while holding the dynamometer and 0% while placing the hand flat without touching the dynamometer. In total, seven different levels of exertion were tested (0 flat, 0, 25, 50, 75, 90, and 100%). A total of three different forearm positions were tested for all 7 exertion levels: 1) neutral position with the forearm halfway between pronation and supination, 2) full supination, and 3) full pronation. Separate MVC and corresponding exertion levels were calculated for each forearm position for both hands for each subject.

The computer randomly selected an exertion level for a blocked forearm position. The subject looked at the laptop screen for feedback during the experiment, which was programmed to show the subject the correct force to exert. The display was a dial with color-coding and auditory feedback, programmed using LabVIEW. Using the audio-visual feedback system, subjects were asked to exert the amount of force necessary to keep a pointer in the target area on the display for their right hand. The subject was told to hold the force constant and to simultaneously move his or her wrist through its ROM (flexion/extension) until he or she began to experience discomfort and/or could no longer sustain the required constant force. Each subject began at neutral and went to his or her maximum extension and flexion point. If the subject went for more than 1 second outside of the target force (could not sustain the constant force), the trial was terminated and that point was recorded as the end of the ROM for that percentage of MVC. ROM was determined by summing angle of wrist flexion and extension. Upon completion of a ROM trial with the right hand, the left hand was tested for the same level of exertion, in the same forearm posture.

The subject rested for 2 minutes after each exertion level except for the two levels of zero exertion. During the rest period, a new exertion level was set on the display. After resting, the hand was again tested using another randomly assigned percent of maximum grip strength. This cycle of exertion and rest was repeated until the subject had completed all 7 levels of exertion for both hands and the specified forearm position. Next, the computer randomly selected another forearm position and all 7 exertion levels were completed for both hands. The experiment continued until all 7 exertion levels were tested for both hands and all 3 forearm positions.

### Experimental Design

An ANOVA on the mean for the dependent variables of maximum flexion, maximum extension, and total ROM was calculated using the independent variables of exertion (7 levels: 0% flat hand, 0% with dynamometer, 25%, 50%, 75%, 90% and 100% MVC), forearm position (3 levels: fully supinated, halfway between pronation and supination (neutral), and fully pronated), hand (2 levels: right and left), gender (2 levels: male and female), and their interactions. This is a 7 (force percentage) x 3 (forearm position) x 2 (hand) x 2 (gender) x 10 (subjects within gender) factorial with blocking on subjects. The ANOVA was performed with blocking on subjects with SAS version 8.2. In addition, Tukey-Kramer tests were done for post hoc analysis on any significant main effects.

## RESULTS

### ANOVA

*Flexion*. The only significant factor found was exertion level (percentage of MVC) ($p < 0.0001$). All other factors and their interactions were not statistically significant.

*Extension*. Significant effects were exertion level ($p < 0.0001$), forearm position ($p = 0.02$), exertion level x gender (p = 0.0349), gender x hand (p = 0.0006), and gender x forearm position (p = 0.0258).

*Range of Motion*. Significant effects for ROM were found for exertion level (p < 0.0001), for forearm position (p = 0.0453), and for gender x hand (p = 0.0033).

**Post Hoc Analysis**

The results of the post hoc test for forearm position is shown in Table 1.

| | Flexion | | Extension | | Range of Motion | |
|---|---|---|---|---|---|---|
| | Mean | Group | Mean | Group | Mean | Group |
| Neutral | 32.25 | A | 58.67 | A | 90.91 | A |
| Pronation | 31.54 | A | 54.71 | B A | 86.25 | B A |
| Supination | 30.51 | A | 52.14 | B | 82.65 | B |

Table 1. Post-hoc (Tukey) tests for the effect of forearm position for each of the three dependent variables (in degrees).

The post hoc test for exertion level is depicted in Table 2.

| | Flexion | | Extension | | Range of Motion | |
|---|---|---|---|---|---|---|
| | Mean | Group | Mean | Group | Mean | Group |
| 0% flat | 73.23 | A | 62.58 | B | 135.81 | A |
| 0% | 61.73 | B | 67.02 | A | 128.75 | A |
| 25% | 47.08 | C | 62.74 | B | 109.82 | B |
| 50% | 31.13 | D | 58.08 | C | 89.21 | C |
| 75% | 15.00 | E | 49.39 | D | 64.39 | D |
| 90% | 1.45 | F | 45.01 | E | 43.55 | E |
| 100% | 6.66 | F | 41.38 | E | 34.72 | E |

Table 2. Post-hoc (Tukey) tests for the effect of exertion level for each of the three dependent variables (in degrees).

**Regression Analysis**

Regression analysis was performed for the dependent variable range of motion (ROM, in degrees) using the independent variable exertion level. A regression analyses were performed for each of the three forearm positions. The prediction equations and coefficients of determination are as follows:

Neutral: ROM = 138 - 0.99(exertion level) $R^2$=0.66

Pronation: ROM = 136 - 1.05(exertion level) $R^2$=0.67

Supination: ROM = 122 - 0.82(exertion level) $R^2$=0.62.

Figure 1, at the end of the paper, depicts the average ROM for each exertion level, for each of the three forearm positions.

## DISCUSSION

The analysis of flexion angle revealed significant effects only for exertion level, while extension and ROM had both exertion level and forearm position as significant main effects. The post-hoc results for forearm position demonstrated that supination reduced the flexion (not significantly), extension and ROM measurements more severely than did neutral forearm postures. It was expected that neutral would be the best position for all three dependent variables, as was shown. However, the magnitudes of the differences in ROM for the different forearm positions were not as large as expected for any of the dependent variables.

The data support our hypotheses and indicate that as grip force increases, wrist flexion, extension and ROM magnitudes significantly decrease. This relationship applies to all three forearm positions. The analysis of flexion with respect to exertion level showed that a flat hand posture (not gripping the dynamometer) had a significantly greater magnitude flexion angle than holding the dynamometer with no exertion. This was expected based on the physiological interaction of grip and flexion. This pattern differed for extension, where the greater magnitude extension angle was while holding the dynamometer and the flat hand posture was not different from a 25% exertion level extension angle. This was also expected due to the changes in hand and finger postures with respect to the axis of the forearm that occur when the flat hand closes to grip a handle. When the flexion and extension data were combined (ROM), these differences in the two 0% exertion levels were averaged and both 0% exertions (flat handed and with the dynamometer) did not differ. The decrease in flexion, extension and ROM was consistent as the exertion levels increased. Each exertion level significantly decreased the magnitude until 90% and 100% MVC exertion levels, which were grouped together. This result indicated that further examination of the data for exertion level by regression would be beneficial.

The linear regression analysis indicated that there is a reasonably strong relationship between grip force exertion level and percent reduction in ROM because all $R^2$ values were equal to or greater than 0.62. This linear relationship can be explained by the physiology of the wrist. Exerting a grip force causes tension in the tendons in the wrist and shortens them. The tendons act as cables over a pulley, with the wrist acting as the pulley. The greater the hand grip force exertion, the more the tension and less slack in the tendons. Therefore, the wrist is not able to move as far when there is a grip exertion. This effect is magnified as the exertion level increases. The data show that grip forces as little as 25% of MVC can cause a substantial reduction in wrist ROM.

The results of this study should be used to design tasks that require a constant hand grip force and simultaneous wrist movement. Clearly, tasks that require high force should require only a small movement in order to reduce the risk of CTDs and should be performed in neutral where possible.


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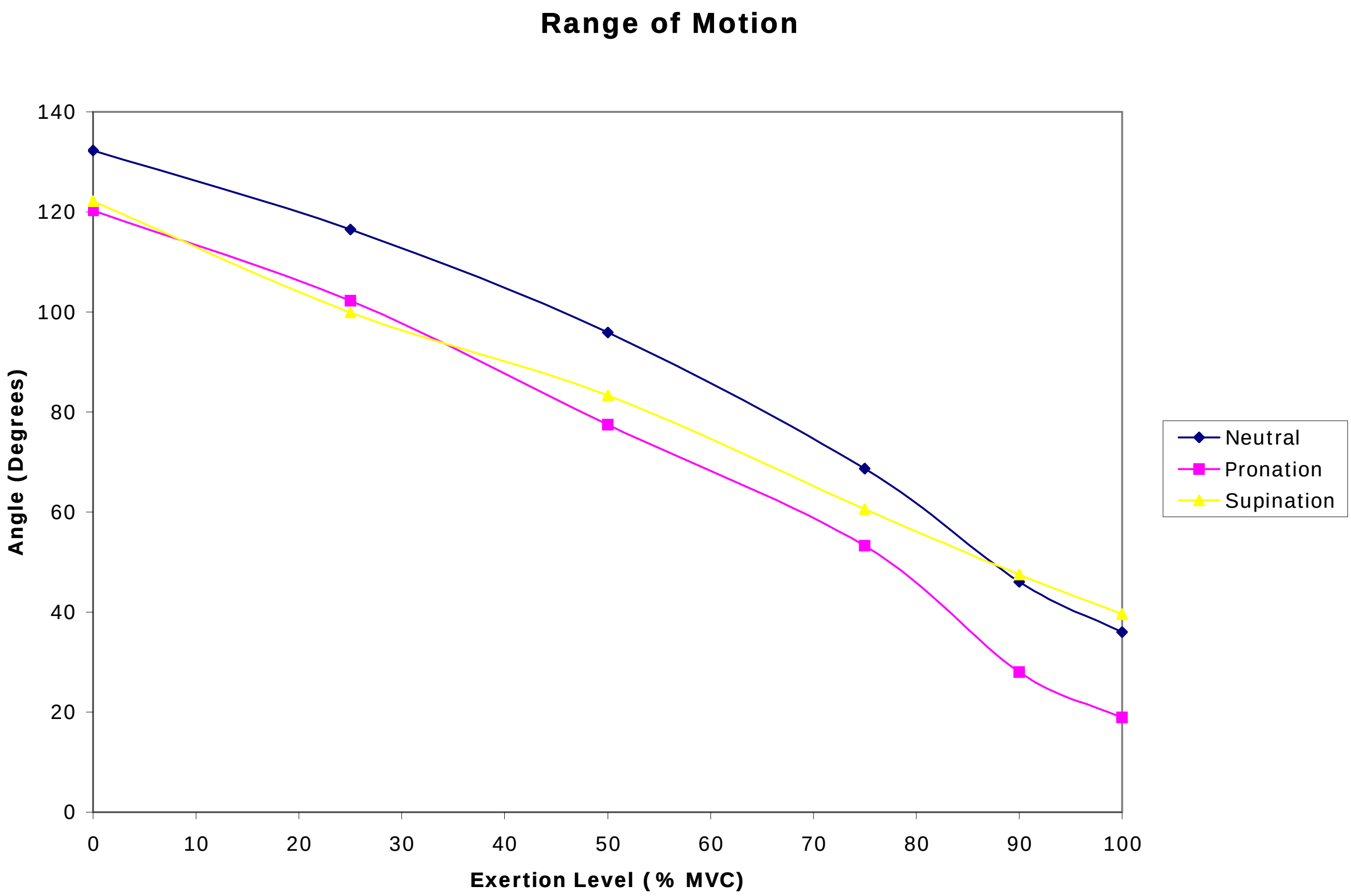


Figure 1: Average Range of Motion for Exertion Levels by Forearm Position