Grip Force and CR-10 Ratings for Youth Females

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Abstract. In this study, an experiment was conducted to measure the grip force for teenaged females at four pre-determined exertion levels on the CR-10 scale. The exertion levels of 2, 5, 7, and 10 corresponded to the 20%, 50%, 70%, and 100% of the maximum voluntary contraction (MVC). The subjects were required to grip a dynamometer using both dominant and non-dominant hand. The posture of the elbow was either straight down or at 90 degree flexion. Eight one females participated in the study. The analysis of variance (ANOVA) results indicated that the exertion level, elbow posture, handedness were all significant factors affecting the grip force. The Duncan's multiple range test results indicated that the grip force at exertion level 10 (208.95 N) was significantly (p<0.05) higher than those of the levels 7 (164.66 N), 5 (128.08 N), and 2 (56.65 N). The grip force at exertion level 7 was significantly (p<0.05) higher than those of the levels 5 and 2. The grip force at exertion level 5 was significantly (p<0.05) higher than that of level 2. The Duncan's multiple range test results indicated that the grip force at 180 degree elbow posture (142.26 N) was significantly (p<0.05) higher than that of the 90 degree posture (136.91 N). The interaction effects of the exertion level and hand used were also significant (p=0.0035). The overall Pearson's correlation coefficient between the CR-10 ratings and the grip forces was 0.84 (p<0.0001).

Keywords: hand exertion, power grip, subjective rating, CR-10.

1 Introduction

Applying grip force is very common not only on workplaces but also in our daily activities. Grip force is required when operating hand tools, carrying containers, or even standing and holding the rail on a bus or a subway train for balance purpose. Forceful hand exertion has been recognized as one of the major risk factors for hand/wrist musculoskeletal disorders [1-5]. Measurement of hand force has been conducted not only to assess the risk of upper extremity work-related musculoskeletal disorders but also for proper hand-object interface design [5-6]. Power grip is one of the hand functions that involves forceful hand exertions frequently and has been one of the most frequently assessed hand activities. The hand force or muscular strength when performing hand grip function may be measured using dynamometers or force gauges [7-10]. Grip force assessments and factors affecting the grip force have been discussed in the literature. But most of the studies in the literature are about adult data [11-13]. Assessments of grip force on youth females are not common.

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The purpose of the study is to determine the relationship of perceived exertion level and actual force applied for youth females and to discuss the relationship between grip force applied and subjective ratings of hand force exertion.

2 Methods

A laboratory study was conducted. This study was performed using the similar protocol as those in the literature [14].

2.1 Subjects

Eighty one females from a middle school in Changhwa, Taiwan were recruited as human subjects. All the subjects were healthy and were free from musculoskeletal injuries. Their age, stature, and body weight were 13.23 (±0.43) yrs, 153.4 (±12.6) cm, and 48.6 (±10.6) kg, respectively. Both the subjects and their parents signed informed consent for their participations in the study. All the subjects were right handlers. They were requested to refrain from physical activities at least one hour before participated in the experiment.

2.2 Apparatus

The grip force was measured using a TAKEI® 5001 hand dynamometer. This dynamometer was calibrated by the supplier before the experiment. A Borg CR-10 scale [15-17] was used for subjective rating.

2.3 Hand/posture Conditions

The hand exertions were measured under two handedness conditions and two elbow posture conditions. The elbow postures included 90° and 180° at the elbow. For

(a) (b)

Fig. 1. 90 (a) and 180 (b) degree elbow postures

the 180° posture, the arm was straight down by the side. For the 90° posture, the upper arm was straight down by the side. The lower arm was flexed 90° and was horizontal (see Fig. 1). The wrist posture was natural for all testing conditions. There was no pronation or supination of the arm during the test. Both dominant hand and non-dominant hand were tested. This comprised four hand used and elbow posture conditions.

2.4 Grip Force Measurement

The nature and use of the CR-10 scales were communicated to all the subjects verbally before the experiment. The grip-to-scale procedure in Spielholz [18] was adopted. In this procedure, each subject was required to apply hand forces corresponding to different CR-10 scale levels. Levels of 2 (weak), 5 (strong), 7 (very strong) and 10 (extremely strong) were tested. Each subject was requested to grip the dynamometer to one of these levels with a grip span of 5 cm. The subject gripped for four seconds and the peak value on the dynamometer was recorded. A break of five or more minutes was arranged after the subject completed each trial so as to avoid the effects of fatigue on following trials.

2.5 Experiment Design and Data Analysis

The grip force measurements were conducted using a three-factor completely randomized design. The factors were the level of exertion, hand used, and elbow posture. A total of 1,296 (4 CR-10 levels × 2 hands × 2 elbow postures × 81 subjects) measures were collected. Both the descriptive statistical analysis and analysis of variance (ANOVA) were performed. Duncan's multiple range test was conducted if a factor was found statistically significant at α =0.05 level. The statistical analyses were performed using the SAS® 9.3 computer software.

3 Results

The means and standard deviations grip forces (N) under experimental conditions are shown in Table 1. The range of mean grip force for dominant hand was between 53.72 N to 223.53 N. The range of mean grip force for non-dominant hand was between 57.53 N to 209.90 N. The Pearson's correlation coefficient between the CR-10 and grip force was 0.84 (p<0.0001).

Table 1. Grip force (N) under experiemntal conditions

		CR-10			
	posture	2	5	7	10
Dominant hand	90°	53.72(23.61)	130.97(34.55)	163.21(39.18)	210.82(42.79)
	180°	56.56(26.51)	126.55(38.65)	171.32(39.33)	223.52(44.61)
Non-dominant hand	90°	57.53(23.80)	125.95(30.49)	157.53(35.53)	195.58(37.26)
	180°	58.80(26.63)	128.85(35.84)	160.60(35.18)	205.90(41.27)

*Numbers in parenthesis are standard deviations

The ANOVA table for the grip force under CR level, handedness, and elbow posture conditions are shown in Table 2. All the three main factors, including the CR level (p<0.0001), handedness (p=0.0107), and elbow posture (p=0.0063) were statistically significant. The CR×hand interaction effect was also significant at p=0.0035.

Table 2. ANOVA table for grip force

Source	DF	SS	MS	F	Pr > F
CR	3	4034216.6	1344738.8	1087.0	<.0001
Posture	1	9276.0	9276.0	7.5	0.0063
CR*posture	3	7824.5	2608.2	2.1	0.0974
Hand	1	8079.8	8079.8	6.5	0.0107
CR*hand	3	168856	5628.5	4.6	0.0035
posture*hand	1	94.9	94.9	0.1	0.7818
CR*posture*hand	3	1174.1	391.4	0.3	0.8136

Fig. 2 shows the grip force under the four CR-10 levels. The grip force on the level 10 may be regarded as the grip strength of the subject.

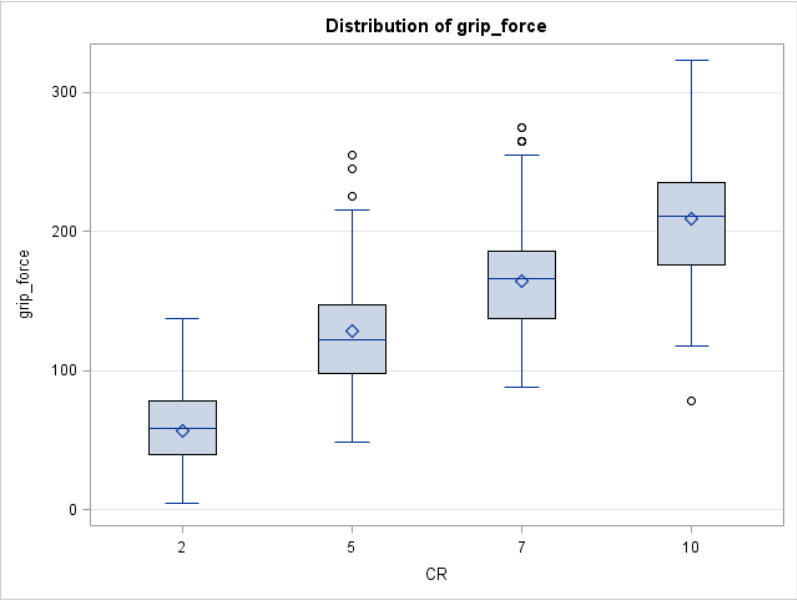

Fig. 2. Grip force (N) on the four CR-10 scale

4 Discussion

It was clear that the grip force was positively correlated with the exertion level which was administered using the CR-10 levels. This was consistent with the findings in the literature [14], [19-24].

The grip force may be converted to the %MVC if divided by the grip force at level 10 to see the deviations that they deviated from the CR-10 scales. The %MVC of the grip force at levels 2, 5, and 7 for dominant hand at 90 degree posture were 25.5%, 62.1%, and 77.4%, respectively. For dominant hand at 180 degree, the %MVC at levels 2, 5, and 7 were 25.3%, 56.6%, and 76.6%, respectively. For non-dominant hand, the %MVC at 90 degree posture for the three levels were 29.4%, 64.4%, and 80.5%, respectively. At 180 degree, the %MVC for the three levels were 28.6%, 45.6%, and 78.0%, respectively. It was apparent that the subjects applied higher grip force than they were supposed to except when applying a force at level 5 in the non-dominant hand/180 degree condition. This was consistent with the findings in the literature [14]. In other words, the subjects tended to apply a force higher than they were supposed to at 2, 5, and 7 of the Borg CR-10 scale.

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