Grip Span and Arm Position Effects on Grip Strength

RAVINDRA S. GOONETILLEKE (Email: ravindra@usthk.ust.hk),
BAKRI O. HAMAD (Email: nafisa@usthk.ust.hk),
and
RICHARD H. Y. SO (Email: rhyso@usthk.ust.hk),
Department of Industrial Engineering and Engineering Management
Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

Abstract
Many studies describing relationships between grip span and grip strength exist. However, the relationship appears to depend on the sampled population. The study reported here is an attempt to quantify the effects of grip span on maximum strength that can be exerted with a group of Hong Kong subjects and also to elicit the relationship between preferred grip span and the grip span with maximum force exertion. The study was conducted with 16 male subjects and 16 female subjects. The results show that the maximum strength is obtained with a grip span of 4.7 cm even though the preferred span is not necessarily that producing the maximum force. No significant differences were found for different arm positions when using the preferred grip span.

Index words: Preferred grip span, forearm positions, elbow posture, grip strength.

1. Introduction

People are generally limited by their strength when exerting force. Strength is a muscle's capacity to exert maximal effort or resist maximal opposing force. It is often measured in terms of the force lifted or force exerted against a fixed weight. In addition, the duration of force exertion, type of grip, type of exertion (isometric, iso-kinetic, or isotonic), and posture will determine the comfort or discomfort associated with a task. For example, the grasping power of the hand is greatest when the hand is in the neutral position or slightly bent upwards (extended) and is reduced when the wrist is bent downwards or from side to side (Putz-Andersson, 1988). Comfortable postures are defined to be those that have a low biomechanical load (Mathilde et al, 1997). Experiments have shown that subjective ratings of muscle exertion measured on a 10-point Borg rating scale (Borg 1982, 1990) increase linearly with holding time (Takisc, 1986; Manenica, 1986; Dul et al 1990; Meijst et al., 1995).

The variation of grip strength with grip span has been reported by many researchers (Kamon and Goldfus, 1978; Champney, 1979; Eastman Kodak, 1986). Greenberg and Chaffin (1976) have found that the maximum grip strength is achieved when the grip span is in the range of 7.5-8.0 cm.. The maximum grip force that can be exerted is strongly dependent on the population (industrial workers, students, or ethnic group) tested and the grip span itself (preferred versus a fixed span). A comparison is shown in Table 1.

The objectives of this study were to evaluate the grip strength of Hong Kong Chinese with varying grip span and a "free" posture, determine preferred grip span and then determine the maximal force exertion in different arm positions when using the preferred grip span.

2. Methodology

Subjects
A total of 32 Hong Kong Chinese were tested. Sixteen were female and the other 16 male.

Procedure

Anthropometric data were measured using a caliper or a cloth tape. The data measured were hand length, hand width, the circumference of the lower arm with the arm in a resting position. Other data such as age, height, and weight were also recorded.

Experimentation involved two phases. The first involved determining the preferred grip span and the second involved the investigation of maximum force exertion for different arm positions with the preferred grip span. For the first phase, each of the subjects was asked to exert maximum strength in a "free" posture on a Jamar dynamometer when the grip span was set to 3.5, 4.7, and 5.9 cm. At the end of each force exertion, the subjects were asked to rate the grip span on a 1 to 5 scale where 1 is the "least preferred" and 5 is the "most preferred". In addition, each subject was also asked for their preferred value of grip span. The preferred span was used in all subsequent testing.

In the second phase, when the subjects were using their preferred grip span, they were asked to exert their maximum force in four different positions when standing: arm directly *upwards*, arm *horizontal* (at shoulder level) with an elbow angle of 180 degrees, upper arm straight down but with a 90 degree *elbow* flexion, and arm directly *downwards* along body (elbow flexion of 0 degrees). The maximum force value in each of these positions and their subjective ratings (1 is the "least preferred" and 5 is the "most preferred") were recorded. Subjective rating for each arm position was also recorded.

The experimental design was counter-balanced to reduce any ordering effects.

Table 1. Maximum grip forces (Adapted from Eastman Kodak, 1986). Note that the preferred span refers to an individual setting considered to be "comfortable" for each subject.

Grip Span	**Population (N)**	**Force in Newtons ± one SD**	**Source**
Preferred span	Industrial males (463)	449 ± 105	Kamon and Goldfus, 1978
Preferred span	Industrial females (139)	268 ± 64	Kamon and Goldfus, 1978
Preferred span	Industrial males (74)	535 ± 97	Champney, Eastman Kodak, 1979[1]
Preferred span	Industrial females (18)	310 ± 59	Champney, Eastman Kodak, 1979[1]
Grip span = 5 cm	Students, male (18)	535 ± 110	SUNYAB-IE, 1982/1983
Grip span = 5 cm	Students, female (8)	230 ± 52	SUNYAB-IE, 1982/1983

3. Results and Analysis

The descriptive statistics of the subjects are shown in Table 2.

The mean force exerted for each grip span in a "free" posture is shown in Figure 1. A general observation is that all subjects used a 90 degree bent elbow position even though they were told that they could use any position to exert force. It appears that a grip span of 4.7 cm allows maximum force exertion. The mean subjective rating corresponding to each position is shown in Figure 2.

A two factor (gender * grip span) ANOVA was performed for the two dependent variables of grip force and subjective rating. Table 3 shows the results of this analysis. There is no significant interaction. The three grip spans are significantly different. A post-hoc Student Newman Keuls test showed that the 4.7 and 5.9 cm positions were not different from each other but different from the 3.5 cm position for both dependent variables. The gender difference for force is rather obvious with the males been able to exert a larger force compared to the females.

[1] Adapted from Eastman Kodak (1986)

Table 2. Descriptive Statistics for Female Subjects. Values in parenthesis are for the males

Subject	Minimum	Maximum	Mean	Standard Deviation
Age (years)	21 (19)	50 (45)	27.4 (28.5)	7.4 (7.3)
Weight (Kg)	43 (51)	61.8 (72.5)	51.6 (61.7)	5.6 (6.9)
Height (cm)	152 (163)	172 (180)	160.1 (170.4)	5.6 (4.0)
Hand Diameter (cm)	20 (22.4)	24 (28)	21.7 (24.9)	1.1 (1.7)
Hand Length(cm)	15.8 (17)	17.7 (18.7)	16.8 (17.8)	0.6 (5.2)
Hand Width (cm)	6.9 (7.3)	7.7 (8.5)	7.3 (7.9)	0.3 (0.3)

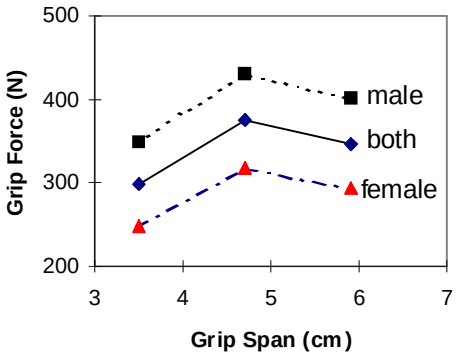

Figure 1. Mean force exerted with different grip spans

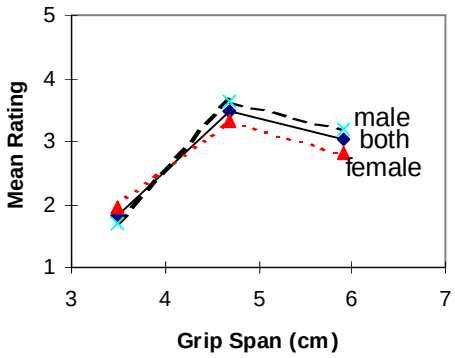

Figure 2. Mean subjective rating with different grip spans

Table 3. ANOVA results for grip span and gender.
(Note that * indicates a significant effect at the $p < 0.05$ level)

	Source	D.F.	MS	F (p value)
Force	Grip Span	2	485.1	15.38(0.0001)*
	Gender	1	2866.7	90.87(0.0001)*
	Grip Span * Gender	2	4.6	0.14(0.8653)
Subjective Rating	Grip Span	2	23.6	28.77(0.0001)*
	Gender	1	0.375	0.46(0.5005)
	Grip Span * Gender	2	0.84	1.03(0.3613)

Of the 16 males tested

- One (1) preferred the 3.5 cm position even though the maximum force exerted between the three grip spans did not correspond to this grip span.
- Ten (10) preferred the 4.7 cm position. Of these ten, only eight subjects had a preferred position that matched the grip span with maximum force and
- Five (5) preferred the 5.9 cm position. Two out of the five had the preferred position matching the maximum force grip span.

For the females tested

- Eleven (11) preferred the 4.7 cm position. Of these eleven subjects, nine had a preferred position that matched the grip span for maximum force.
- Five (5) preferred the 5.9 cm position. Two out of the five had the preferred position matching that of the grip span which gave them maximum force.

These findings are summarized in Table 4.

Table 4. Matching maximum force with preferred grip span for each gender.
Values in parenthesis indicate the percent values in each category.

			Number of subjects exerting max. force at each grip position			Matched maximum force with preferred grip span
Gender	No. of subjects	Preferred grip span	3.5 cm	4.7 cm	5.9 cm	% of total in each gender (N=16)
Male	1	3.5	0(0%)	1(100%)	0	0/16 = 0%
	10	4.7	0	8(80%)	2(20%)	8/16 = 50%
	5	5.9	0	3(60%)	2(40%)	2/16 = 12.5%
Female	0	3.5	0(0%)	0	0	0/16 = 0%
	11	4.7	0	9(82%)	2(18%)	9/16 = 56%
	5	5.9	0	3(60%)	2(40%)	2/16 = 12.5%

Figure 3 shows the maximum force exerted by the subjects in the four different arm configurations when using the preferred grip span. Figure 4 indicates the mean rating values for the corresponding positions on the 1 (least preferred) to 5 (most preferred) scale.

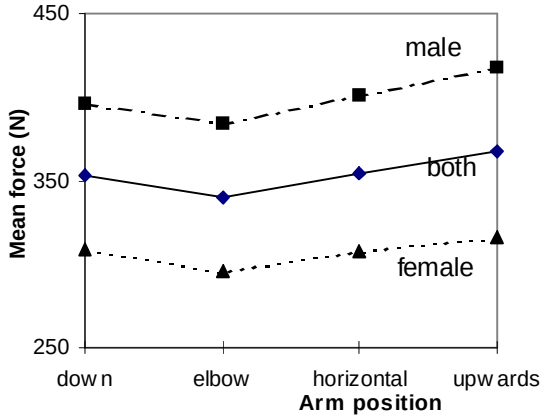

Figure 3: Mean force with for four different arm positions

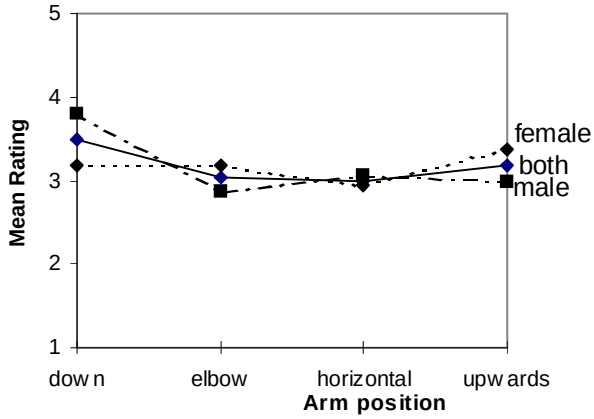

Figure 4. Mean subjective rating for four different arm positions

A similar ANOVA was performed for the second phase of the experimentation. The results of the two factor (gender * arm position) ANOVA for the two dependent variables of grip force and subjective rating are shown in Table 5. Statistically significant effects are seen only for Gender when using the force as the dependent variable, which is not a surprising result (Figure 3).

Table 5. ANOVA for arm position and gender
(Note that * indicates a significant effect at the $p < 0.05$ level)

	Source	**D.F.**	**MS**	**F (p value)**
Force	Arm Position	3	43.3	1.11(0.35)
	Gender	1	2850.1	73.37(0.0001)*
	Arm Position * Gender	3	3.56	0.09(0.96)
Subjective Rating	Arm Position	3	1.67	2.08 (0.11)
	Gender	1	0.008	0.01 (0.92)
	Arm Position * Gender	3	1.72	2.13 (0.10)

Even though no significant differences exist between the four arm positions, the maximum forces exerted in each arm position and the corresponding subjective ratings are shown in Figures 5 and 6 (for male) and Figure 7 and 8 (for female).

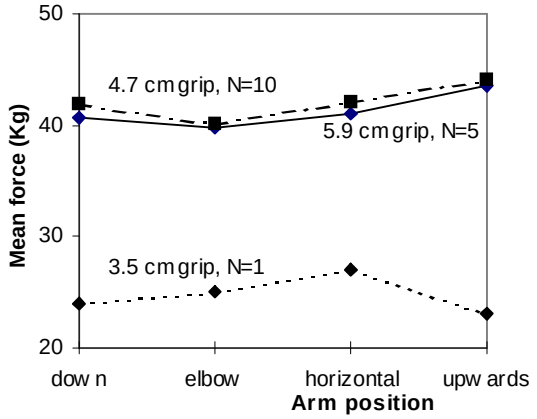

Figure 5: Mean force for different arm position with preferred grip span (males)

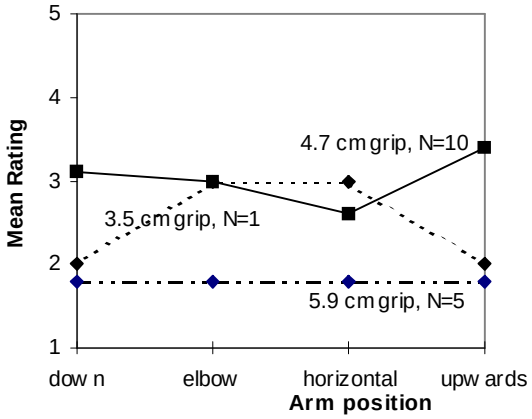

Figure 6: Mean subjective rating for different arm position with preferred grip span (males)

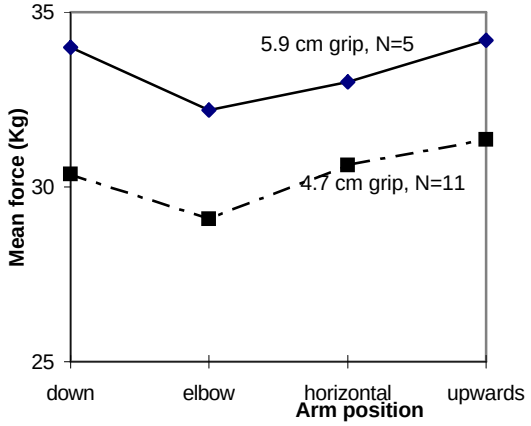

Figure 7: Mean force for different arm position with preferred grip span (females)

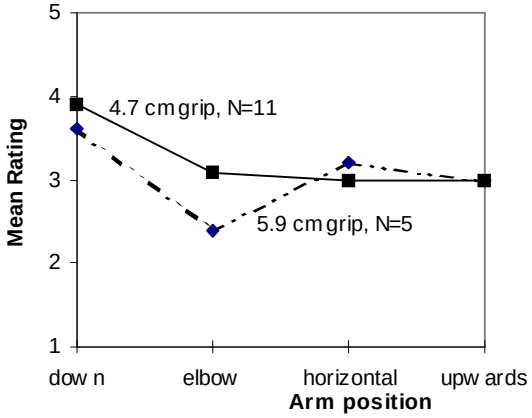

Figure 8: Mean subjective rating for different arm position with preferred grip span (females)

4. Discussion

The results indicate that the maximum grip strength is obtained when the grip span is 4.7 cm. (Figure 1). Indeed, the subjective rating is also highest at this grip span. A two factor ANOVA indicated a significant ($p < 0.05$) difference for gender and grip span. A post-hoc Student Newman Keuls test showed no difference between the 4.7 and 5.9 cm positions but different from the 3.5 cm position for both dependent variables.

The preferred grip span is not necessarily always the span at which maximum force is exerted. For the male subjects, 62.5% had matching preferred span and the highest force exertion, while the matching percentage of females was 68.5%. However, 75% (for both male and female) of the subjects exerted maximum force at a grip span of 4.7 cm even though 62.5% of the males and 68.75% of the females preferred this span.

A similar ANOVA was performed for the second phase of the experimentation. The results of the two factor (gender * arm position) ANOVA showed statistically significant ($p < 0.05$) effects only for gender with grip force as the dependent variable, which is not a surprising result (Figure 3).

5. Conclusions

It appears that the grip span of 4.7 cm is appropriate for the Hong Kong population based on preference and maximal force exerted.

6. References

Borg, G. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports Exercise*, *14*: 377-381.

Borg, G. (1990). Psychophysical scaling with applications in physical work and perception of exertion. *Scandinavian Journal of Work, Environment and Health*, *16* (supplement). pp. 55-58.

Dul, J., Douwes, M., and Smitt, P. (1990). A work-rest model for static postures. In: *Proceedings 11th Congress of the International Ergonomics Association*. London: Taylor and Francis. pp. 93-95.

Eastman Kodak Company, (1986), *Ergonomic Design for People at Work*. Van Nostrand Reinhold Company, New York.

Greenberg L. and Chaffin, D. B. (1976*). Workers and their tools; A guide to the ergonomic design of hand tools and small presses*. Midland, MI: Pendell Publishing.

Kamon and Goldfus (1978). In-plant evaluation of the muscle strength of workers. *American Industrial Hygiene Association Journal*, *39,* 801-807.

Manenica, I. (1986). A technique for postural load assessment. In: N. Corlett, J. Wilson, and I. Manenica (Eds.), *The Ergonomics of working postures: models, methods, and cases: Proceedings of the first International Occupational Ergonomics Symposium, Zadar, Yugoslavia.* London: Taylor and Francis, pp. 270-227.

Mathilde C. M., Marjolein D., and Jan D. (1997). Recommended maximum holding times for prevention of discomfort of static standing posture. *International Journal of Industrial Ergonomics*, *19,* pp. 9-18

Meijst, W., Dul, J. and Haslegrave, C., (1995). *Maximum holding times of static standing postures*. TNO Institute of Preventive Health Care, Leiden.

Putz-Anderson, V. (1988). *Cumulative Trauma Disorders: A manual for musculoskeletal diseases of the upper limbs*. Taylor and Francis, London, pp. 55-59

Takisc, V., (1986). Comparison of some indices of postural load assessment. . In: N. Corlett, J. Wilson, and I. Manenica (Eds.), *The Ergonomics of working postures: models, methods, and cases: Proceedings of the first International Occupational Ergonomics Symposium, Zadar, Yugoslavia*. Taylor and Francis, London, pp. 278-282.