# Effects of Work Gloves on Gripping and One-Handed Carrying Strength

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**Abstract**
Gloves are widely used at work to protect hands from potential hazards and injuries. Three common types of work gloves were chosen to study the effect of wearing gloves on gripping and one-handed carrying strength. Six male and six female adults were recruited as subjects. The gripping and one-handed carrying strength of both dominant and non-dominant hands were tested. Glove conditions included bare hand and wearing three types of gloves. For hand grip force measurements, grip spans included 4.5, 5.5, 6.5, and 7.5 cm. For one-handed hand carrying strength, the postural conditions included straight and semi-squat. The result indicated that all the gender, handedness, grip span, and glove conditions affected the hand grip strength significantly ($p<0.05$). The effects of posture and gender on the hand carrying strength were significant ($p<0.01$). Wearing work gloves reduced gripping strength. Among the three types work gloves, Glove C was the worst choice for grip strength, however, it was the best choice for one-handed carrying strength. The information of this study is useful for workers to select suitable gloves when they perform gripping and carrying tasks.
Index Terms: carrying strength, gripping strength, work gloves

## 1. Introduction

In the manufacturing industry of Taiwan, the proportion of occupational disasters caused by stabbing, cutting and scrapping increased from 13.9% in 2020 to 16.6% in 2021[1]. Stabs, cuts and bruises have become the second largest occupational disaster in Taiwan. Similar situations have occurred in other countries, such as Singapore and the United States [2-3]. The 2017-2020 survey data on occupational injuries from the U.S. Bureau of Labor Statistics showed that cuts and lacerations led about 50,525 occupational injuries per year, 65.8% of them were related to hands [3]. Hand injuries not only lead to absence, but also inability to return to work [4]. At the same time, workers with hand injury must pay medical expenses and higher healthcare cost, which had caused great economic losses to both workers and society [5]. Therefore, hand protection is essential for workers.

Work gloves are used to protect hands from potential hazards and injuries during work, for example cuts and stabs, vibrations, pressure, and low temperature [6-9]. However, work gloves also adversely affect the capabilities of hands on performing manual operations. When wearing work gloves, the hands do not contact the object been handled directly, which caused a reduction of manual dexterity and tactile sensitivity [10-11]. Dexterity of hand decreased with the thickness of the work gloves increased [12]. Wearing work gloves also made a change of the hand force exertion. It could reduce the gripping strength. Similar to hand dexterity, gripping strength also reduced when the thickness of the work gloves increases [13]. The reduction of the gripping strength caused by wearing work gloves depends on the fitness and the number of layers [14-15].

The literature on the effects of work gloves on hand strength mainly focused on gripping strength. Both at work and in our daily activities, carrying an object using one hand wearing glove is common. However, the investigations of the influence of work gloves for hand carrying strength were not common. Such information will be beneficial for glove design and selection at workplaces. Our hypothesis was that the effect of gloves was significant on one-handed carrying strength. The objective of this study was to test this hypothesis. In addition, the effect of posture on one-handed carrying strength. The correlations between the hand strength hand the anthropometric data were also discussed.

## 2. Methods

### Subjects

Twelve healthy adults (6 male and 6 female) were recruited as subjects in the experiment. Their age, body weight, stature, knuckle height, knee height, hand width and length, are shown in Table. 1. All the subjects were asked to read and sign the experimental consent form. They all have not experienced musculoskeletal injuries in the past year.

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Table. 1 The Basic physical parameters of the subjects

| Item | | | Female | | Male | |
|---|---|---|---|---|---|---|
| | | | mean | std | Mean | std |
| Age (years) | | | 27.5 | 6.3 | 34.8 | 8.6 |
| Weight (kg) | | | 57.9 | 6.8 | 79.8 | 20.0 |
| Height (cm) | body | | 158.7 | 5.4 | 171.0 | 11.0 |
| | Knuckle | | 71.0 | 4.2 | 71.6 | 8.2 |
| | Knee | | 42.9 | 2.6 | 48.4 | 3.1 |
| Circumference of Arm (cm) | Upper | D | 27.6 | 3.1 | 31.2 | 3.9 |
| | | ND | 26.9 | 3.8 | 30.6 | 3.7 |
| | Lower | D | 23.9 | 2.0 | 28.1 | 1.9 |
| | | ND | 22.8 | 1.9 | 27.3 | 1.7 |
| Length of hand (cm) | | D | 16.9 | 0.8 | 19.0 | 1.4 |
| | | ND | 16.9 | 0.8 | 19.0 | 1.3 |
| Width of hand (cm) | | D | 7.6 | 0.3 | 9.0 | 0.7 |
| | | ND | 7.3 | 0.3 | 8.8 | 0.8 |
| Note: D-Dominant hand, ND-Non-Dominant hand. | | | | | | |

## Glove Conditions

Four glove conditions including bare hand and wearing one of the three work gloves (see Fig. 1), were tested in the experiment. Because of the low cost, glove A, made of cotton thread, is the most commonly used gloves at work in Taiwan. Glove B (SS-100, 3M, Korea) is made of nylon, and the palm side was covered with nitrile rubber foam (NBR). It has been used in logistics and construction sites. Glove C (CP-500, 3M, Korea) is made of nylon, glass fiber and spandex, and the palm side is also covered with NBR. It is a kind of professional safety glove for cut resistance, and generally used in handling of sharp objects. The thickness of the palm side of each work glove was measured 10 times with vernier caliper (No. 530-108, Mitutoyo, Japan), and the mean (±std) value were 2.2 (±0.02) mm, 1.0 (±0.03) mm, and 1.5 (±0.03) mm, respectively.


*Fig. 1 Work gloves: (a) Glove A, (b) Glove B, and (c) Glove C.*

The coefficient of friction (COF) between the surface of the palm side of each work glove and the steel plate was test 10 times with the Horizontal Pull Slip Meter (HPS) (C.S.C. Force Measurement, Inc., Agawam, USA), and the mean (±std) value were 0.30 (±0.02), 0.89 (±0.03), and 0.91 (±0.02), respectively.

The stiffness of each type of work glove was tested using a simple method (see Fig. 2). Point F1 and F2 are the root and tip of the middle finger of the glove, respectively. The ratio of L2 to L1 (L2/L1) was used to indicate the stiffness of the glove. The stiffness of Glove A, Glove B, and Glove C, 0.48 (±0.002), 0.57 (±0.005), and 0.95 (±0.004), respectively.

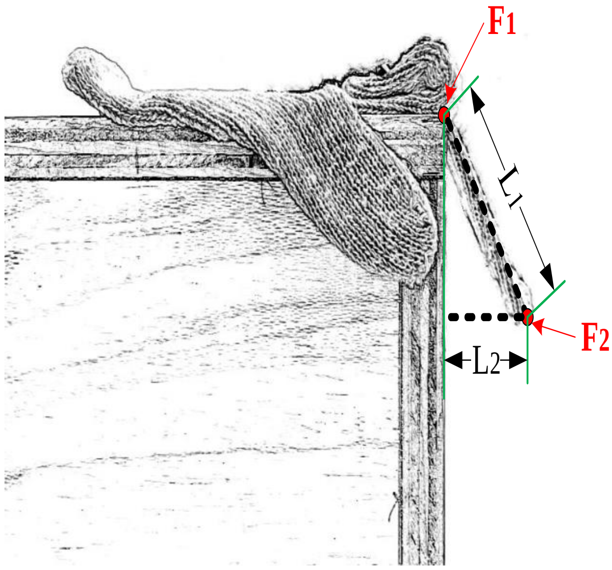
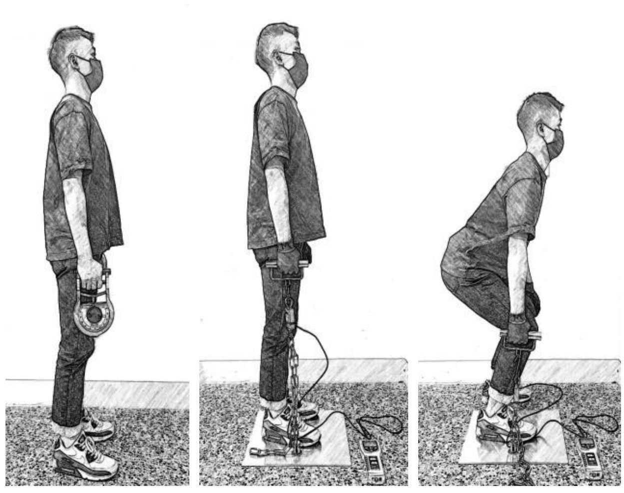



*Fig. 2 The test of the stiffness of each work glove*

## Gripping and Carrying Strength Tests

The strength measurements included gripping strength and one-handed carrying strength test.

A dynamometer (T.K.K. 5001, GRIP-A, TAKEI, Japan) was used to measure the gripping strength. When testing, the subjects stood with their arms hang naturally on the sides, and gripped the dynamometer at their maximum voluntary contraction (MVC) for approximately 5 s (see Fig. 3(a)). Each subject needed to complete the grip strength test under 32 different experimental conditions (4 glove conditions × 4 grip span conditions × 2 handedness conditions). The grip span conditions included 4.5, 5.5, 6.5, and 7.5 cm. The handedness conditions included dominant and non-dominant hands. The subjects took a rest at least 5 min between any two trails for the same hand. The experimental condition was randomly arranged. An apparatus, which included a force gauge (FG-5100, Lutron, Taiwan), a steel plate, a handle (Φ = 3.2 cm), and an iron chain, was used to measure the carrying strength (see Fig. 3(b) and (c)). The iron chain was used to connect the handle, the force gauge, and the steel plate, and adjust the handle to the experimental height. When testing, the subjects stood straight or squatted with their arms hang naturally at the sides of their body, one hand hold the handle and pull up at their maximum voluntary contraction (MVC) for 4-6 s. Each subject completed the carrying strength test under 16 different experimental conditions (4 glove conditions × 2 posture conditions × 2 handedness conditions). The posture conditions included straight and semi-squat. For straight posture (see Fig. 3(b)), the handle height was adjusted to the knuckle height of the subject. For semi-squat posture (see Fig. 3(c)), the handle height was the knee height of the subject. The handedness conditions included dominant hand and non-dominant hand. The subjects must have a rest at least 10 min between two trails for the same hand. The experimental conditions were random.



(a) (b) (c)

*Fig. 3 Strength tests*

Note: (a) gripping strength test, (b) one-handed carrying strength test under straight posture, (c) one-handed carrying strength test under semi-squat posture.

## 3. Data Analysis

A total of 384 grip strength data and 192 carrying strength data were collected. Descriptive statistics and analysis of variance (ANOVA) were conducted. In order to compare the difference between each level of each factor, Duncan's multiple range tests were adopted as the post-hoc test. In addition, the correlations between the anthropometric data and gripping strength and carrying strength were analyzed. The data was analyzed using the SAS 9.0® (SAS Institute Inc., Cary, NC, USA). The significance level was 0.05.

## 4. Results

### Gripping Strength

Figs. 4 and 5 show the gripping strength of female and male under different experimental conditions, respectively. The ANOVA results showed that the gripping strength was significantly affected by glove conditions ($p < 0.05$), gender ($p < 0.0001$), grip span ($p < 0.05$), and handedness ($p < 0.001$). The gripping strength of male (33.6 ± 9.7 kgf) was significantly higher than that of female (20.3 ± 5.3 kgf). The gripping strength of dominant hand (28.4 ± 10.6 kgf) was significantly higher than that of non-dominant hand (25.4 ± 9.7 kgf). Duncan's multiple range test results showed that the gripping strength of bare hand condition (29.1 ± 11.4 kgf) was significantly higher than those of ware glove A condition (26.4 ± 9.6 kgf), glove B condition (26.7 ± 9.9 kgf), and glove C condition (25.5 ± 9.8 kgf). However, the difference between any two of the the latter three was not significant ($p > 0.05$).

The ANOVA results showed that the interaction effects between gender and hand grip span on the gripping strength were significant ($p < 0.0001$) (see Fig. 6). For male subjects, the gripping strength of 7.5 cm grip span condition (38.9 ± 12.9 kgf) significantly higher than those of 4.5 cm condition (31.7 ± 10.2 kgf), 5.5 cm condition (31.9 ± 5.9 kgf) , and 6.5 cm condition (31.7 ± 6.2 kgf). The difference between any two of the latter three was not significant ($p > 0.05$). However, for female subjects, the gripping strength of 5.5 cm grip span condition (21.9 ± 5.4 kgf) was significantly higher than that of 7.5 cm condition (18.7 ± 4.9 kgf). Both of the gripping strength of 6.5 cm condition (20.8 ± 5.1 kgf) and 4.5cm condition (19.8 ± 5.5 kgf) were not significantly different with that of 5.5 cm and 7.5 cm conditions.

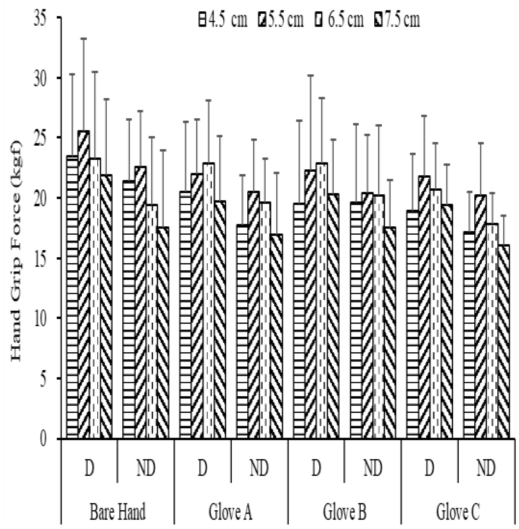



*Fig. 4 Gripping strengths of female under different experimental conditions*

*Note: D: Dominant hand, ND: Non-Dominant hand.*

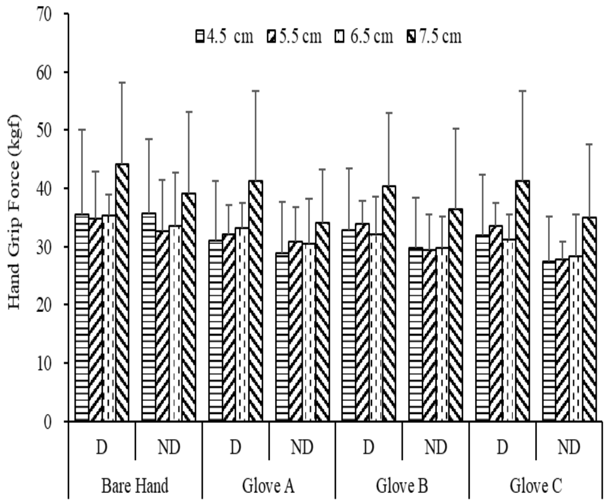



*Fig. 5 Gripping strength of male under different experimental conditions*

*Note: D: Dominant hand, ND: Non-Dominant hand.*

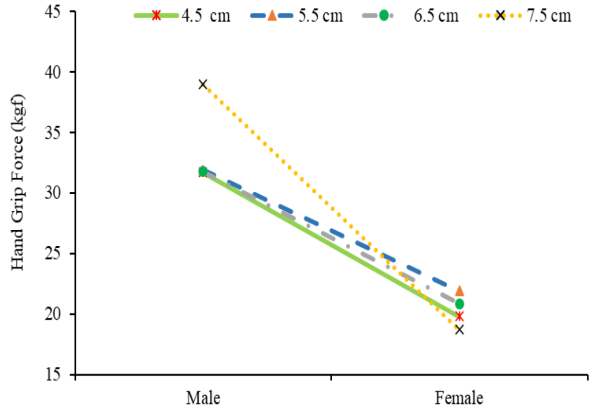



*Fig. 6 Interaction effect between gender and hand grip span on gripping strength*

The gripping strength was significantly ($p < 0.001$) correlated with age, body height, body weight, the length of hand, the width of hand, etc., the coefficients of the correlation were shown in Table 2.

Table. 2 The correlations between gripping strength and the anthropometric data

| | age | body | | hand | | Circumference of arm | | Grip span |
|---|---|---|---|---|---|---|---|---|
| | | weight | height | length | width | upper | lower | |
| grip strength | 0.43 | 0.62 | 0.57 | 0.66 | 0.73 | 0.46 | 0.58 | male 0.25* |

Note: *p<0.001, else p < 0.0001

## One-Handed Carrying Strength

Fig. 7 shows the one-handed carrying strength under different experimental conditions. The ANOVA results showed that the carrying strength was significantly affected by gender ($p < 0.0001$), posture ($p < 0.01$). However, the effects of glove condition and handedness on carrying strength was not significant ($p > 0.05$). The carrying strength of male (51.1 ± 5.1 kgf) was significantly higher than that of female (28.5 ± 7.7 kgf). The carrying strength under straight posture (42.0 ± 15.5 kgf) was significantly higher than that under semi-squat posture (37.5 ± 17.1 kgf).

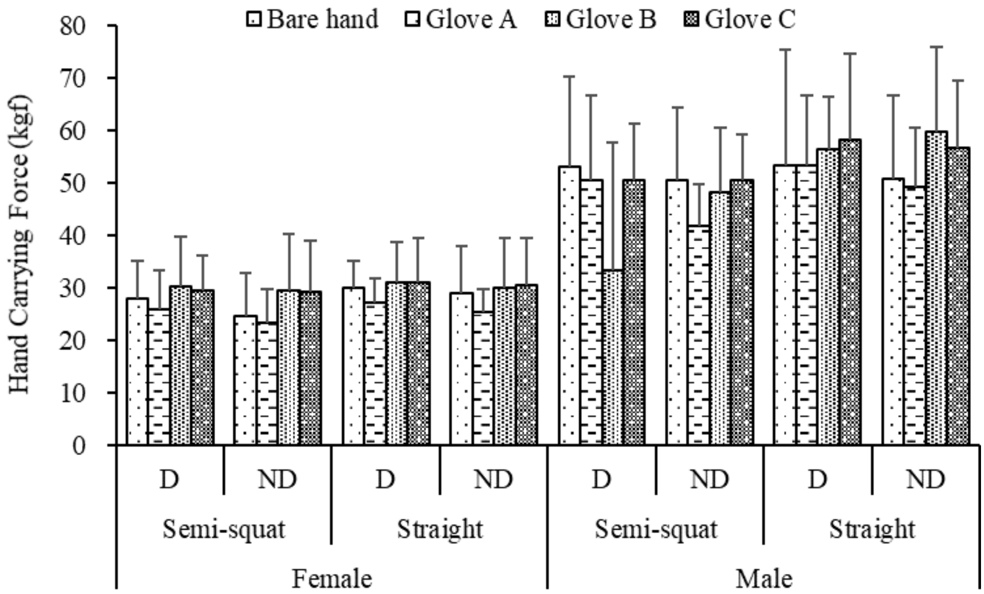



*Fig. 7 Carrying strength under different experimental conditions*

*Note: D: Dominant hand, ND: Non-Dominant hand.*

Table 3 showed the coefficients of the correlation between the carrying strength and age, body height, body weight, the length of hand, the width of hand, etc.

| Table. 3 The correlations between the hand carrying strength and the anthropometric data | | | | | | | |
|---|---|---|---|---|---|---|---|
| | age | body | | hand | | Circumference of arm | |
| | | weight | height | length | width | upper | lower |
| carrying strength | 0.27* | 0.66 | 0.66 | 0.69 | 0.72 | 0.67 | 0.73 |
| Note: * $p < 0.001$, else $p < 0.0001$ | | | | | | | |

## 5. Discussion

Gender and handedness have been considered as the factors affecting gripping strength [16-17]. The results of gender and handedness in this study were consistent with this. For male subjects, the highest gripping strength (38.9 ± 12.9 kgf) was observed at the 7.5 cm grip span, on the contrary, female subjects have the lowest gripping strength (18.7 ± 4.9 kgf) at this grip span. The highest gripping strength (21.9 ± 5.4 kgf) for female subjects occurred at the 5.5 cm grip span condition. These discrepancies were due to the difference in hand size between men and women. Gripping strength had a significant correlation with hand size (see Table. 2). Hand sizes of males are normally larger than that of females. Males, therefore, have advantages than females in applying gripping force. Hence, optimum grip span allows maximum grip strength. It was about 7.5 cm and 5.5 cm for males and females, respectively.

Compared with the bare hand conditions, all the three types of work gloves had significant lower grip strengths. Previous research had shown that as the thickness increased, the reduction in grip strength increased [15]. However, glove C, which was not the thickest glove among the three work gloves in out experiment, showed the largest drop in gripping strength. The proportion of reduction of gripping strength for glove C for males and females were 11.9% and 13.2%, respectively. The reason for the inconsistency between our study and the literature [15] could be due to the difference of glove thickness. In previous research [15], glove thickness was adjusted by adding different layers of the same glove, while the glove thickness was determined by the glove material in our study. Gloves made by different materials had different stiffness. The correlation between glove's longitudinal stiffness and grip strength was strong (0.77-0.94) [18]. The stiffness of Glove C was the largest (0.95), therefore, it leaded the largest drop in gripping strength. When the thickness of gloves was close to each other, the effect of glove stiffness on gripping strength became more obvious and the effects of gloves on hand grip strength were dependent on the stiffness of gloves.

Although the handedness had no significant ($p > 0.05$) effects on on handed carrying strength, dominant hand had a higher carrying strength than that of non-dominant hand. The effects of posture on carrying strength were significant ($p < 0.01$). The carrying strength under semi-squat posture was lower than that under straight posture. The difference between the two postures of male subjects was more obvious. The carrying strength of males under straight posture was higher than that under semi-squat posture by 15%. When measuring the carrying strength under semi-squat posture, many male subjects reported that their leg muscles were fatigued, which affected their ability to apply carrying force.

The effects of glove conditions on carrying strength were insignificant ($p > 0.05$). However, the carrying strength for male on glove C condition (54.0 ± 12.2 kgf) was higher than that of barehand condition (52.0 ± 16.4 kgf), both the carrying strength for females on glove C (30.3 ± 8.8 kgf) and glove B conditions (30.1 ± 8.1 kgf) were higher than that of barehand condition. These were different from the grip strength. This may be due to the COF of the gloves. Gloves B and C had higher COF (0.89 and 0.91), which increased the friction between the hand and handle and made a positive effect when applying carrying strength. Unlike gloves B and C, wearing glove A reduced carrying strength. Many subjects reported that hand slip when applying carrying force. Hence, increasing the COF between the hand and the object in contact was an effective way to increase the carrying strength. Compare with gripping strength, the carrying strength had a stronger correlation (0.67-0.73) with the circumference of the arm (see Table. 3). This indicates that muscles strength of the arm contributes to the applying of carrying strength.

There are limitations of this research. Only three type of work gloves were tested. Further research should add more other work gloves commonly used in industry to explore the relationship among stiffness of glove, COF of glove and the hand strength in detail.

## 6. Conclusion

Three common work gloves were selected to study the effects of wearing glove on gripping and carrying strength. We found that wearing gloves reduced the gripping strength. Glove C was the most undesirable choice for gripping strength among the three gloves tested. Glove A was better and glove B was the best one for grip strength. For gripping strength, selecting work gloves with less stiffness should be more desirable when the thickness of gloves is approximately the same. Unlike gripping strength, Glove C was the most desirable choice when applying carrying force. Gloves with high COF values had advantages on applying carrying force.

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