行政院國家科學委員會專題研究計畫 成果報告

在不同姿勢與慣用手/非慣用手的狀況下對於手部施力值之Borg感知評分之校正之探討
研究成果報告(精簡版)

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計 畫 編 號 ：NSC 98-2221-E-216-013-
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計 畫 主 持 人 ：李開偉

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中 華 民 國 99 年 09 月 10 日

行政院國家科學委員會補助專題研究計畫 ■**成 果 報 告**
□**期中進度報告**

在不同姿勢與慣用手/非慣用手的狀況下對於手部施力值之 Borg 感知評分之校正之探討

計畫類別：■個別型計畫　□整合型計畫
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中　華　民　國　99　年　9　月　1　日

行政院國家科學委員會專題研究計畫成果報告

在不同姿勢與慣用手/非慣用手的狀況下對於手部施力值之 Borg 感知評分之校正之探討

Calibrating Borg 's Scale of Ratings Perceived Hand Exertion Under Different Postures & Dominant/Non-Dominant Hands

計 畫 編 號：NSC 98－2221－E －216－013－
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中文摘要

Borg 的 RPE 尺度已經很廣泛的被應用在不同的作業與體力活動上。除了 RPE 尺度以外，Borg 也建構了 CR-10 尺度在類似的用途上。本研究的目的在於決定當使用 CR-10 尺度在分析手部施力時，CR-10 的分數是否需求校正；以及若答案是肯定的那應該如何校正。此外，兩性之間在使用 CR-10 的差異也被分析與討論。本計畫包括兩個實驗，第一個檢驗慣用手與非慣用手在兩種手臂姿勢下施力的狀況；實驗得到的施力值與 CR-10 的分數以迴歸分析來探討。第二個實驗將檢驗兩隻手在五種姿勢下的捏握力值，捏握採用姆指與食指側緣來進行。實驗的結果也將以迴歸分析來探討。本研究的結果有助於使用 CR-10 來記錄力握與捏握的數據的解釋。

關鍵詞：認知負荷水準、CR-10、握力

Abstract

Borg's rating of perceived exertion (RPE) scale has been widely used in studying various tasks and physical activities. In addition to the RPE scale, Borg's category rating 10 (CR-10) scale has also been constructed for a similar purpose. The objectives of this project were to determine whether calibration of the CR-10 is required for hand exertion and how to calibrate the rating if a calibration is needed. In addition, the difference in reporting the CR-10 scores between the two genders was also discussed. Two experiments were performed. The first one will tested the power grip forces for both the dominant and non-dominate hands under two arm postures. Regression analyses were performed for the grip force and the CR-10 scores. The second experiment was performed to test the pinch grip forces for the two hands under five postures. The pinch was conducted using the thumb and the lateral of the index finger. Regression analyses were performed for the grip force and the CR-10 scores. The results of this study were helpful in interpreting the perceived exertion when using the CR-10 scale in both power and pinch grip.

Keywords: rating of perceived exertion, CR-10, grip force

Introduction

The study of perceived effort has long been dominated by Borg's concept of perceived exertion (Borg, 1982; 1990). Borg's ratings of perceived exertion (RPE) scale have been

widely used in analyzing manual tasks and in many physical works (Borg and Sjöberg, 1981) as a supplementary measure in addition to physiological measures. Examples of using the RPE scale may be found in the literature (Drury, et al., 1985**;** Wang, et al., 2000; Nussbaum and Lang, 2005). The literature has shown that the RPE scale to function very well. The linearity between ratings, workload, and heart rate, and the high correlation across subjects with heart rate and some other physiological variables make it easy to use.

In addition to the RPE scale, Borg (1992) has constructed another subjective scale, called Category Rating 10 (CR10) scale. Borg (1998) claimed that the advantage of the CR10 scale over the RPE scale is that the former lacks of an inter-subjective unit for direct determinations of intensity levels while the latter provides direct level estimates for determinations of ratio relationships between perceptual responses.

Even though the Borg's RPE and CR10 scales have been claimed function well, investigations and discussions on the design, function, and requirement of calibration are still continued. Hutchinson and Tenenbaum (2006) conducted a research to examine the uniqueness of three dimensions of perceived effort, i.e., sensory-discriminative, motivational-affective, and cognitive-evaluative, and to discern how these dimensions are perceived during engagement in two physically demanding tasks. Deeb (1999) investigated the effects of muscular fatigue on human's perception of weights. Twenty males and 20 females participated in his experiment. Ten weights ranged from 50 to 500 g were tested. The subjects were asked to exert and maintain a maximum push-down force with the right arm until fatigued. Immediately after fatigue, the subjects had to lift two weights in both the left and right arms simultaneously and compare the weight in the right arm (variable weight) to the one in the left arm (constant weight) and rate it on the RPE scale. The results showed that when muscles were not fatigued, the RPE values coincided well with the tested weight, such as 500 g represented number 10, and 50 g represented number 1 on the RPE scale.

Buchholz et al. (2008) examined the agreement of subjective ratings of upper extremity exposures with corresponding direct measurements obtained simultaneously from workers. Psychophysical ratings of exposure, based on the Borg CR-10 scale, were obtained for the period of time in which direct measurements were acquired. The authors' found that ratings of manual effort were significantly correlated with directly measured grip force (%MVC). Ratings of pace were significantly correlated with directly measured wrist motion and this relationship was strengthened with the addition of relative grip force as a covariate.

Spielholz (2006) conducted a study to evaluate the efficacy of calibrating subjective worker ratings of hand exertions so as to reduce error in estimates of applied force. In his study, the subjects applied pinch and power grip forces of different levels using both ''grip-to-scale'' and ''guided-grip'' procedures. The data were used separately to define relationships between scale ratings and actual force application. Gripping tasks were performed and corresponding subjective hand force ratings were calibrated using the grip-to-scale calibration data. The results showed that the mean estimation error for a 44.5 N power grip task was significantly reduced from 142.8 to 62.3 N.

The objectives of this project were to test the hypotheses that the perceived exertions of hand grip of dominant hand and non-dominant hand are different and perceived hand exertions dependent on the postures.

Methods

This study was conducted in the laboratory.

Subjects

Twenty male college students were recruited as human subjects. All the subjects were free from musculoskeletal injuries. Their age, stature, and body weight were 22.1 (±2.5) yrs, 172.3 (±5.3) cm, and 69.8 (±12.5) kg, respectively. All the subjects received payment and had signed informed consent for their participation in the study. All the subjects, except one, were right-handlers. They were requested to refrain from physical activities at least one hour before joined the experiment.

Apparatus

A TAKEI® 5001 hand dynamometer was used to measure the grip force of the hand. The dynamometer was calibrated by the supplier before the experiment. A commercially available handgrip to build up hand/arm muscles was also adopted. A Borg CR-10 scale (Borg, 1982) was used for subjective rating.

Hand/posture conditions

The hand exertions were measured under two hand conditions and two posture conditions. The measurements were conducted using either dominant hand or non-dominant hand. The hand postures included 90° and 180° at the elbow.

Grip force measurement

Before the study, the subjects were verbally instructed the nature and use of the CR-10 scales. The grip-to-scale calibrating procedure proposed by Spielholz (2006) was adopted. In this procedure, each subject was required to exert hand forces corresponding to different CR-10 scale levels. Four levels on the CR-10 scale were tested: 2 (weak), 5 (strong), 7 (very strong) and 10 (extremely strong). Each subject was requested to grip the dynamometer to one of these levels. The grip span of the dynamometer was 5 cm. The power grip sustained for four seconds and the peak value of the grip force was recorded.

Estimation of CR-10 rating

The handgrip was adopted as a basis to examine the CR-10 rating for the subjects under different experimental conditions. The subjects were requested to apply a 10 kgf force. The grip span was approximately 4 cm. He, then, reported a CR-10 rating of the hand exertion.

Experiment design & data analysis

The grip force measurement experiment was conducted using a three-factor completely randomized design. Both the descriptive statistical analysis and analysis of variance (ANOVA) were performed.

In addition, linear regression equations without intercept were built:

$$\text{CR-10 rating} = \beta \times \text{grip force} + \varepsilon_i \qquad (1)$$

where β is the regression coefficient and ε_i is a random error.

In the handgrip test, the CR-10 ratings after applying a 10 kgf power grip force were also collected under a three-factor completely randomized design with one trial in each treatment. A total of 80 measures were collected.

These CR-10 ratings were compared with the estimated rating calculated using Eq. (1). The statistical analyses were performed using the SPSS® 12.0 computer software.

Results

The ANOVA results showed the main effects of the CR-10 level, hand used, and posture on power grip force were all significant (p<0.0001). The Duncan's multiple range test results showed that the mean grip force at the level 10 of the CR-10 (41.9 kgf) was significantly (p<0.05) higher than those at levels 7 (32.6 kgf), 5 (24.4 kgf), and 2 (10.5 kgf). The grip force at level 7 was significantly (p<0.05) higher than those at levels 5 and 2. The grip force at level 5 was significantly higher than that at the level 2. Duncan's multiple range test results comparing the two postures showed that the grip force at the 180° posture (28.3 kgf) was significantly (p<0.05) higher than that at the 90° posture (26.5 kgf). Dominant hand (28.0 kgf) showed a significantly (p<0.05) higher grip force than that of the non-dominant hand (26.7 kgf).

The interaction effects of the CR-10 level and the hand used were significant (p<0.0001). The interaction effects of the CR-10 level and the posture were also significant (p<0.0001). The overall Pearson's correlation coefficient between the CR-10 rating and the grip force was 0.92 (p<0.0001).

A total of 80 linear regression models were established for each hand-posture condition for each subject. All the regression models were statistically significant at p<0.0001 with coefficients of determination (R^2) of 0.96 or higher. All the hypotheses testing whether the regression coefficient was zero were rejected (p<0.0001). Table 1 shows the means and standard deviations of the estimated regression coefficients.

Table 1. Means and standard deviations of estimated regression coefficients.

Posture	non-dominant hand	dominant hand
90°	0.24 (±0.03)	0.23 (±0.03)
180°	0.23 (±0.03)	0.21 (±0.02)

In the handgrip test, the ANOVA results showed that the effects of both the hand and posture on the reported subjective rating were not statistically significant. For the estimated rating, however, the effects of both the hand and posture were significant. Non-dominant hand (2.36) showed significant (p<0.05) higher values than those of dominant hand (2.22). The estimated subjective ratings at 90° posture (2.37) were significantly (p<0.01) higher than those at the 180° posture (2.20). The effects of hand and posture on the estimation error were not statistically significant.

4. Discussions

The 2, 5, 7, and 10 on the CR-10 scale were assumed to represent 20%, 50%, 70%, and 100% of perceived maximum voluntary contraction (MVC), respectively. The results of the study indicated a strong linear correlation between the CR-10 rating and grip force. This was consistent with the findings in the literature (Borg, 1990). The interaction effects between exertion level and hand used in Fig. 3 showed that at low CR-10 ratings such as 2 and 5, the grip forces between dominant and non-dominant hands were negligible. At level 10, however, the grip forces of dominant hand were higher than those of the non-dominant hand. When divided the grip forces at levels of 2, 5, and 7 by

the force at level 10, the grip forces were converted into %MVC. The %MVC at levels of 2, 5, and 7 for dominant hand were 24.7%, 56.2%, and 75.6%, respectively. The %MVC values at the three levels for non-dominant hand were 25.6%, 60.5%, and 80.0%, respectively. All the %MVC values were higher than their corresponding CR-10 levels times 10. This implies that the subjects applied a force exertion higher than they perceived. Comparing the %MVC between the two hands at the 2, 5, and levels, non-dominant hands showed higher values than those of the dominant hand at all three levels.

The interaction effects between the exertion level and posture in Fig. 4 showed similar trends as in Fig. 3. The grip forces between the two postures at low exertion levels such as 2 and 5 were negligible. At level 10, the grip forces at 180° posture were higher than those at the 90°. The %MVC at levels of 2, 5, and 7 for the 90° posture were 26.1%, 59.2%, and 79.0%, respectively. The %MVC values at the three levels for the 180° posture were 24.3%, 57.4%, and 76.6%, respectively. All the %MVC values were higher than their corresponding CR-10 levels times 10. The %MVC values for the 90° posture were higher than those of the 180° posture for all the 2, 5, and 7 levels.

The regression coefficients in Table 1 indicate that the increases of the CR-10 rating due to an increase of grip force depend on the hand used and posture. With each unit (kgf) increase in grip force, the CR-10 ratings at the 90° posture increased 0.24 and 0.23 for non-dominant and dominant hands, respectively. At the 180° posture, the increases were 0.23 and 0.21 for non-dominant and dominant hands, respectively. A pair-wised *t*-test results comparing the regression coefficients showed that the difference between dominant and non-dominant hands was statistically significant ($p<0.001$). In Table 1, lower increases in the CR-10 rating associated with an increase in grip force were also observed for the 180° posture than those of the 90° posture. A pair-wised *t*-test results comparing the regression coefficients also showed that the difference between the two postures was statistically significant ($p<0.001$).

The R^2 represents the percentage of variation of the dependent variable which could be explained by the independent variable. An R^2 of 0.96 or higher indicates that almost all the variation of the subjective rating may be explained by the grip force. It was shown in Table 2 that the estimated CR-10 ratings were significantly ($p<0.01$) lower than those of the actual values under all the hand/posture conditions. For non-dominant hand, the estimation errors for the 90° and 180° postures were 1.50 (38.1%) and 1.54 (40.2%), respectively. For dominant hand, the estimation errors for the two postures were 1.18 (33.7%) and 1.08 (33.7%), respectively. The subjects reported subjective scores higher than those estimations based on their own perception and grip force data even though the corresponding regression models had very high R^2 values.

The results of the current study indicated that the CR-10 rating scale has high correlation with the power grip force. This was consistent with those in the literature (Buchholz et al., 2008). However, perceived exertions of power grip might be affected by both the hand used and hand/arm posture. In addition, the subjects had a tendency to report the subjective ratings of power grip exertion higher than the actual %MVC values.

5. Conclusion

An experiment was conducted to test the grip force of male subjects at four perceived exertion levels on the CR-10 scale under four hand and posture conditions. Generally speaking, the subjects tended to apply a higher power grip force (%MVC) than they perceived at levels 2, 5, and 7 on the CR-10 scale. It was found that the grip forces between dominant and non-dominant hands at low CR-10 levels were negligible. The grip forces were significantly different between the two hands at level 10. Similar results were found for the hand/arm posture conditions. The grip forces between the two postures at low CR-10 levels were negligible. At level 10, the grip forces at 180° posture were significantly higher than those at the 90°. The overall correlation coefficient between the CR-10 rating and the grip force was significant. Eighty regression models have been established between the CR-10 rating and the grip force. The subjects reported higher subjective ratings than the estimations which were based on their own perception and grip force data, even though the regression models had very high R^2 values.

The data from the female tests will be reported shortly.

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附件二

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

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說明：

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本研究以慣用手與非慣用手在兩種不同姿勢下之手部施力來探討受測者使用Borg CR-10量表之行為，研究成果已撰寫文稿投稿國際學術期刊與國際學術研討會。Borg CR-10量表為一種分析肌力與體力負荷的工具，本研究的結果顯示受測者施力時，其施力水準往往高於對應的CR-10等級，因此CR-10由0到10的線性遞增設計理論上不符合受測者施力的習慣。另外，使用這個工具在量化慣用手與非慣用手間的差異不顯著。本研究顯示類似的實驗方法可以用來開發與修正此類量表的設計。

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CORRELATION BETWEEN GUIDED GRIP FORCE AND PERCEIVED EXETION FOR MALES

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I. INTRODUCTION

The study of perceived effort has long been dominated by Borg's concept of perceived exertion [1]. Borg's ratings of perceived exertion (RPE) scale (ranged from 6 to 20) have been widely used in analyzing various manual tasks as well as in many physical works [1] as a supplementary measure in addition to physiological measures. In addition to the RPE scale, Borg [2] has constructed another subjective scale, called CR-10 scale. Borg [2] claimed that the advantage of the CR-10 scale over the RPE scale is that the former lacks of an inter-subjective unit for direct determinations of intensity levels while the latter provides direct level estimates for determinations of ratio relationships between perceptual responses. Both the RPE and the CR-10 scales may be used to measure muscular exertion and physical workload for whole body or specific body segment.

Even though the Borg's RPE and CR-10 scales have been claimed function well, investigations and discussions on the design, function, and requirement of calibration are still continued. Buchholz *et al.* [3] examined the agreement of subjective ratings of upper extremity exposures with corresponding direct measurements obtained simultaneously from workers. Psychophysical ratings of exposure, based on the Borg CR-10 scale, were obtained for the period of time in which direct measurements were acquired using electro-goniometers, electro-inclinometers and electromyography. Subjects from workers at two automobile manufacturing plants were selected. Significant relationships between subjective ratings of wrist position and measured wrist posture or motion and between ratings of shoulder position and measured shoulder posture were not found.

In the study of Spielholz [4], twenty subjects applied power grip forces corresponding to their perceptions of different Borg CR-10 scale levels using both "grip-to-scale" and "guided-grip" procedures. These data were used separately to define relationships between scale ratings and actual force application. Two gripping tasks were performed and corresponding subjective hand force ratings were calibrated using the grip-to-scale calibration data. The results showed that the mean estimation error for a 44.5 N power grip task was significantly reduced from 142.8 to 62.3 N. The guided-grip calibration method also significantly reduced rating error for the power grip task. Spielholz's [4] study indicated that calibration of hand force ratings using the grip-to-scale procedure may improve the accuracy of hand exertion measurements using the Borg CR-10 scale.

Handgrip is a fundamental element in performing many tasks. The Borg's CR-10 has been discussed in the literature [1,2,3]. The objective of this study were to examine the relationship between the grip force of the dominant hand and the Borg's CR-10 ratings and to report the deviation of predicted grip force from measured force based on a linear regression model developed in the study.

II. METHODS

Twenty males were recruited as human subjects in the study. All the subjects were free from musculoskeletal injuries. Their age, gender, stature, and body weight were 22.1 (±2.5) yrs, 172.3 (±5.3) cm, and 69.8 (±12.5) kg, respectively. All the

subjects received payment and had signed informed consent forms for their participation in the study. All the subjects, except one, were right-handlers.

In the experiment, each subject was required to grip a dynamometer under one of the four Borg CR-10 scale levels: 2, 5, 7, and 10. The scores of 2, 5, 7, and 10 on the CR-10 scale were assumed to represent 20%, 50%, 70% and 100% of perceived maximum voluntary contraction (MVC), respectively. The grip forces of the dominant hand of the subjects were measured. The upper arm of the subject was straight down and the lower arm was horizontal, or at 90° with the upper arm. The span of the dynamometer was 5 cm. Each subject will take a break for five minutes or more after he finished one measurement at the 5, 7, or 10 levels so as to avoid the effects of fatigue on the measurement.

Descriptive statistical analysis was performed. In addition, a linear regression model was built to describe the relationship between the grip force and the Borg's CR-10 scale. The statistical analyses were performed using the SPSS® 12.0 computer software.

III. RESULTS AND DISCUSSION

The means (±standard deviations) of the grip force corresponding to the scores of 2, 5, 7, and 10 on the CR-10 scale were 10.0 (±2.8), 23.5 (±4.2), 32.8 (±3.5), and 43.3 (±5.3) N, respectively. The Pearson's correlation coefficient between the CR-10 rating and the grip force was 0.95 (p<0.0001). A linear regression model was established to describe the relationship between the CR-10 score and grip force:

$$\text{Grip force} = 2.29 + 4.18 \times \text{CR-10 score} \quad (1)$$

This model is statistically significant at p<0.0001 with an R^2, or coefficient of determination, of 0.90 and a root mean square error of 4.11. The intercept (2.29) and the slope (4.18) of the regression model were statistically significant at p<0.032 and p<0.0001, respectively. The scatter plots and regression line of (1) are shown in Figure 1. To assess the deviations of the measured grip force and the predicted values using (1), a mean absolute deviation (MAD) was defined using the following equation:

$$\text{MAD} = \frac{1}{n}\sum_{i=1}^{n} |\text{measured value} - \text{predicted value}|$$

where n is the sample size. The MAD was 3.02 N.

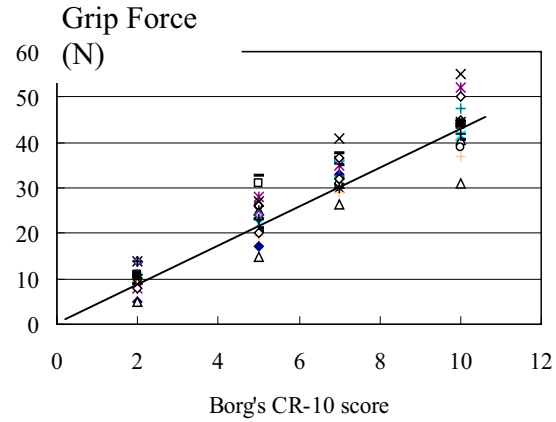

Figure 1: Scatter plots and regression line

In the regression model, the CR-10 score was highly correlated with the grip force. The linear regression model in (1) may be used to describe and predict the grip force of the dominant hand for the male subjects. The results of this study were consistent with the findings in the literature [4].

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無研發成果推廣資料

98 年度專題研究計畫研究成果彙整表

計畫主持人：李開偉	計畫編號：98-2221-E-216-013-
計畫名稱：在不同姿勢與慣用手/非慣用手的狀況下對於手部施力值之 Borg 感知評分之校正之探討	

成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	2	2	100%	人次	
		博士生	1	1	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	0	2	100%	篇	兩篇已投稿中
		研究報告/技術報告	0	0	100%		
		研討會論文	2	2	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	無

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

□實驗失敗

□因故實驗中斷

□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：■已發表 □未發表之文稿 □撰寫中 □無

專利：□已獲得 □申請中 ■無

技轉：□已技轉 □洽談中 ■無

其他：(以 100 字為限)

已發表一篇研討會論文於 the 34th Annual Meeting of America Society of Biomechanics 另外已投稿兩篇國際期刊論文及一篇國際學術研討會論文

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）(以 500 字為限)

本研究以慣用手與非慣用手在兩種不同姿勢下之手部施力來探討受測者使用 Borg CR-10 量表之行為，研究成果已撰寫文稿投稿國際學術期刊與國際學術研討會。Borg CR-10 量表為一種分析肌力與體力負荷的工具，本研究的結果顯示受測者施力時，其施力水準往往高於對應的 CR-10 等級，因此 CR-10 由 0 到 10 的線性遞增設計理論上不符合受測者施力的習慣。另外，使用這個工具在量化慣用手與非慣用手間的差異不顯著。本研究顯示類似的實驗方法可以用來開發與修正此類量表的設計。