ORIGINAL ARTICLE

Cross-education Effects of Wrist Flexor Strengthening on Grip Strength: Comparison of Eccentric and Concentric Training

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ABSTRACT

Introduction: Time away from training and competition from sport injuries may lead to detrimental effects on muscle strength and endurance. The cross-education effect plays an important role in preserving strength during recovery and rehabilitation; however, the effects have been found to be inconclusive. In addition, the distinct impacts of eccentric and concentric strengthening exercises need to be explored. The objective of this study was to compare the cross-education effects of eccentric and concentric wrist flexor strengthening exercises on hand grip strength among recreational athletes. **Methods:** A total of 39 recreational athletes aged between 18-25 years old were randomly assigned into two groups of wrist flexor strengthening exercise: eccentric (ECC) and concentric (CON) training groups. The training period for the study was 4 weeks with 3 sessions of strengthening exercises per week. Handgrip strength was measured bilaterally, before and after the intervention using the JAMAR handgrip dynamometer. **Results:** Significant increases in hand grip strength were observed for the ECC and CON groups in both the trained and untrained hands following 4 weeks of training. However, the handgrip strength between the two groups in the untrained hand was not significantly different (p=0.64). The strength gain in the untrained hand was 9.8% and 10.8%, for ECC and CON groups, respectively. **Conclusion:** The cross-education effect was significant in improving strength in the untrained hand. There was no difference in strength gains between concentric and eccentric strength training.
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INTRODUCTION

Downtime due to sport injuries is common at all levels of sports. The time away from training and competition can lead to detrimental effects on muscle strength and endurance (1). One of the approaches that has been used to minimise these effects is the cross-education effect (2). The cross-education effect is described as strength training of a limb on one side, leading to an increase of strength in the contralateral limb. This strength increase is specific as it only occurs in the homologous and contralateral muscle groups (3). The cross-education effect plays an important role during recovery or rehabilitation from sport injuries (4).

The prevalence of wrist and hand injuries, such as fractures and overuse injuries, has been found to be substantial in several sports such as racket sports, handball, volleyball, and gymnastics (5). Management of these injuries may require immobilisation, rest, or modification of training which might lead to a loss of muscle strength and endurance (6). Consequently, this may prolong the time required for athletes to return to levels prior to their injury. If cross-education effects can prevent loss in muscle strength of the injured side, it can then play a significant role in reducing the time required for them to return to sports.

While previous studies have examined cross-education strength training effects, the outcomes have exhibited substantial heterogeneity (4,7,8). These variations can be attributed to the diversity in study contexts, encompassing distinct training regimens and target muscle groups within the upper or lower limbs (2,4,7,8,9). Consequently, the absence of well-defined protocols and consistent findings emphasises the necessity for further investigation into cross-education effects.

This study specifically explores the cross-education effects of wrist flexor strengthening on grip strength, representing a notable gap in the existing literature. The results of this research hold the potential to make valuable contributions to the formulation of evidence-based protocols for hand and wrist rehabilitation. These protocols may prove advantageous during periods of recuperation from injuries, offering a means to preserve strength in the injured limb. Such preservation of strength may lead to reduced downtime in sports activities and expedited recovery.

Additionally, hand grip strength assumes a fundamental role in sports performance (10), injury prevention, recovery, and rehabilitation. In various sports disciplines, hand grip strength serves as a performance indicator, reflecting the power and force generated by finger and hand muscles (11). Notably, a decrease in hand grip strength has been correlated with a higher risk of wrist and hand injuries (10). Leveraging the cross-education effect to conserve hand grip strength could potentially translate into enhanced grip strength during the rehabilitation phase, potentially averting recurring injuries and augmenting performance. An exploration of cross-education effects in the context of eccentric and concentric strength training is also warranted, given the observed disparities in outcomes from prior studies (2,4,12). This investigation stands to provide valuable insights into the relative effectiveness of eccentric and concentric strengthening for specific muscle groups, facilitating tailored training programs to cater to individual requirements, thereby optimizing outcomes for rehabilitation, athletic training, and general fitness.

The objectives of this study are aimed at comparing and determining cross-education effects resulting from eccentric and concentric wrist strengthening regimens on hand grip strength. The findings are expected to significantly contribute to the development of rehabilitation protocols for hand and wrist conditions and foster further research in this domain.

MATERIALS AND METHODS

This study employed a single-controlled trial design with pre-test and post-test measurements. In this study, recreational athletes aged 18 to 25 years old who played a variety of sports were included. The recreational athletes in this study were defined as people participating in leisure sports 1 to 2 times a week. To ensure the reliability of the results, participants who have been diagnosed with musculoskeletal problems in the upper limbs in the last 6 months, and who were on medication at the time of data collection were excluded. The sample size was calculated using the GPower 3.1 software (13), where power was set at 80%, with the effect size at 0.25, and level of significance at $p<0.05$, An additional 20% of participants were included for attrition rate, which resulted in a total sample size of 38. Participants were randomly assigned to either the eccentric (ECC) or concentric (CON) wrist flexor training group using the lottery method.

Wrist flexor training was selected in this study due to the role it plays in hand grip strength. Hand grip strength is generated by the activation of flexor digitorum superficialis, flexor digitorum profundus, and flexor pollicis longus (14). The flexor digitorum profundus and flexor pollicis longus produce the action of wrist flexion, as well as the gripping action (15). Additionally, hand grip strength contributes to wrist flexor strength (16). Therefore, increasing wrist flexor strength is a recommended method to increase grip strength in sports (17).

Ethical Clearance

The study was approved by the Universiti Tunku Abdul Rahman Scientific and Ethical Review Committee, reference number U/SERC/144/2018.

Procedure

Participants were instructed not to engage in exercise or physical activity within twenty-four hours prior to reporting for the testing session. Participants who met the eligibility criteria had given consent and were also informed on the experimental procedure of the study. The Revised Edinburgh Handedness Inventory was used to determine the laterality of the participants (18). Participants' personal profiles including their body weight and height were also recorded.

All participants performed standard forearm warm-ups, which included hand pumps and wrist circumduction for 3 sets of 15 repetitions, followed by 3 sets of wrist-stretching (wrist flexors and extensors) for 15 seconds each. Maximal grip strength was then assessed with the JAMAR® Hydraulic Hand Dynamometer (Model J00105, Lafayette Instrument Company, United States of America) for both the right and left hand. During the test, the participants were seated on armrest-free chairs with their shoulders in neutral position, elbows bent at a 90-degree angle, forearms and wrists in neutral position, and fingers flexed for maximum contraction. To ensure a stable base of support, the participants were required to keep their feet planted firmly on the ground. Before the actual test began, the participants practiced several times with the dynamometer. During the test, the participants had undergone 3 trials, and the average maximal voluntary grip strength was calculated. The instructions to participants were standardised and the testing procedure for maximal hand grip strength was consistent for both pre and post-test. An external tester evaluated the grip strength tests while they were blinded to which group the participants belonged to. Separate recording sheets were used for the pre and post readings to minimise bias.

After the pre-test, training load was determined by having the participants lift one repetition maximum (1RM) on the dominant hand using Adams' 1RM predictive equation.

(19). Initially, participants familiarised themselves with the wrist curl exercise using a 1-kg dumbbell to ensure proper technique. They then performed the exercise with a weight they could not lift more than 20 times in one set. If they were able to lift the weight more than 20 times, they rested for 5 minutes before the weight was increased by 2.5 kg and the test was repeated. The number of repetitions until fatigue and the weight used were recorded and applied in the following formula: 1RM = RepWt/(1-0.02RTF) (20).

*1RM = 1 Repetition Maximum; RepWt = repetition weight (kg), load less than 1RM to perform repetitions; RTF = repetitions to fatigue.

To prevent fatigue from the 1RM testing, the actual training sessions were conducted on the following day. Training consisted of three sessions per week, lasting for four weeks. During training, participants were seated in wooden chairs with armrests, positioning their forearms on the armrest, shoulders at 0 degrees flexion, elbows at 90 degrees flexion, and wrists fully flexed.

In the ECC group, with their forearm supinated, the participants extended their wrists for a count of 5s. The tester placed the dumbbell in the participants' hand at full wrist flexion, removed the dumbbell when their wrists reached extension, and then placed the dumbbell back in the hand at full wrist flexion. Participants performed 3 sets of 6 repetitions. A rest period of 1 minute was given between each set.

Meanwhile, in the CON group, participants performed wrist flexion curls with the forearm supinated with 20 repetitions. The tester placed the dumbbell in the participants' hands at full wrist extension, removed the dumbbell when their wrists reached flexion, and then placed the dumbbell back in the hand at full wrist extension. Participants performed 3 sets of 6 repetitions. A rest period of 1 minute was given between each set. An increment of 2 repetitions per set was added each week for both groups. All strength training was performed on the dominant hand.

Data and Statistical Analyses

Data was analysed using SPSS version 23 (SPSS Inc., Chicago, IL, USA). Demographic data including age, height, body weight, and body mass index were reported with descriptive statistics, as means (M) and standard deviations (SD). The strength gain percentage was computed as follows: ((non-dominant hand strength difference between post-test and pre-test)/ pre-test strength) x 100. An independent sample T-test was employed to determine the baseline demographic differences and pre-test measurements for all variables between the groups. Mixed between–within subjects analysis of the variance (MANOVA) was used to compare the group means and determine significant differences between the groups. The level of significance was set at $p<0.05$. Normality in distribution was assessed for all variables.

RESULTS

A total of 39 participants were recruited for this study (ECC, n=19 and CON, n=20). Table I illustrates the means (M) and standard deviation (SD) of the participants' anthropometrics measures. There were no significant differences between the groups.

The means (M) and standard deviation (SD) of hand grip strength in the untrained hand are shown in Table II. Significant increases in the untrained hand grip strength after 4 weeks of training were observed in ECC ($p=0.02$) and CON ($p<0.01$) groups. However, there was no significant difference observed between the 2 groups in post-training hand grip strength ($p=0.64$) and in strength gain percentage ($p=0.79$).

Table II shows the means (M) and standard deviation (SD) of hand grip strength in the trained hand. Significant increases in the trained hand grip strength after 4 weeks of training were observed in both ECC and CON groups ($p<0.05$). However, there was no significant difference observed between the two groups in post-training hand grip strength ($p=0.98$) and in strength gain percentage ($p=0.98$).

Table I: Anthropometrics Measures of the Participants

	ECC (n = 19) M (SD)	CON (n = 20) M (SD)
Age (years)	20.21 (0.25)	20.05 (0.28)
Height (cm)	166.90 (2.10)	168.90 (2.21)
Weight (kg)	61.23 (3.0)	65.51 (3.30)
BMI (kg/m^2)	21.92 (0.96)	22.80 (0.81)

Note. *Significant at p<0.05
ECC: eccentric; CON: concentric; n: number of subjects; M(SD): mean (standard deviation); cm: centimetre; kg: kilogram; BMI: body mass index; kg/m^2: kilogram per square metres

Table II: Hand Grip Strength in Dominant (Trained) and Non-Dominant (Untrained) Hand

Hand Grip Strength (kg)	ECC (n = 19) M (SD)		CON (n = 20) M (SD)		p-value (between groups)	
	D	ND	D	ND	D	ND
Pre	34.70 (9.43)	31.88 (9.39)	34.50 (8.07)	32.20 (8.96)	0.94	0.91
Post	38.12 (9.89)	34.21 (8.57)	38.20 (9.70)	35.67 (10.64)	0.98	0.64
Strength Gain in %	10.95 (13.16)	9.81 (14.87)	10.83 (12.21)	10.86 (9.79)	0.98	0.79
p-value (within groups)	0.001*	0.02*	0.001*	< 0.001**		

Note. *Significant at p < 0.05, **Significant at p < 0.01
ECC: eccentric; CON: concentric, kg: kilogram, M(SD): mean (standard deviation), D: Dominant, ND: Non-dominant

DISCUSSION

The aim of this study was to compare the cross-education effects of eccentric and concentric wrist flexor strengthening exercises on hand grip strength among recreational athletes. Significant increases in the trained and untrained maximal hand grip strength were observed in both the CON and ECC groups. However, there were no significant differences in maximal hand grip strength and strength gain percentage between the CON and ECC groups in the trained and untrained hands.

Remarkably, higher increases in the untrained hand grip strength were observed in both the ECC (9.81%) and CON (10.86%) groups compared to previous meta-analyses (7.6-7.8%) (3). The difference in results may be attributed to the training protocol applied. Previous studies on upper limb training regimes including isometric exercises and 50% of the 1RM raise questions about their sufficiency to produce increases in strength that are comparable to those seen in this study (3).

Unlike previous studies that found a greater strength gain percentage in eccentric compared to concentric training (21), this study did not observe significant differences between the ECC and CON groups in post-training untrained hand grip strength and strength gain percentage. This discrepancy might be related to the variables in the strength training protocol as well as other methodological variations such as sample size and participants recruited. Strength training was performed using a dumbbell, and the hand grip strength was measured using the hand grip dynamometer in this study, while Kidgell etal (12) used the isokinetic dynamometer for the training and measurement.

Then, in the eccentric training group, lower strength gain in the trained hand (10.95%) was observed compared to previous studies (12), which may explain the lower strength gain in the untrained hand (i.e. decreased cross-education effects) because strength transfer is related to the strength gained in the trained limb (3).

The lack of difference between the eccentric and concentric groups could be due to factors such as a less intense strength training stimulus, a shorter intervention duration, and a lower strength training volumes (repetition x sets). A previous study suggested that cross-education eccentric exercise programmes should span for more than 4 to 5 weeks, about 3 to 5 days of training per week to allow for muscle-specific biochemical, mitochondrial, and neurological adaptations to reach a steady state (7). Additionally, we recruited recreational athletes whose sporting activities might be similar to the assigned training which might lead to reduced cross-education transfer. It has been suggested that the task should be unfamiliar to both hands for the cross-education effect to occur (21) and more complex tasks yield greater strength gain through the cross-education effect (23). The complexity of the task might be the determining factor in explaining the differences found in this study compared to previous research. These findings indicate that unilateral strength training of one limb has bilateral effects, that manifest as increased corticomotor excitability of the motor pathway ipsilateral to the training limb (23).

Several limitations should be acknowledged in this study. Firstly, the strengthening exercises were solely focused onthe wrist flexor, whilst the isometric strength of the finger flexors was used as the assessment.. Isometric strength assessment with a hand grip dynamometer was used in this study as it is more practical in clinical and education settings. Assessment of isometric strength with the hand grip dynamometer has been shown to correlate to wrist concentric and eccentric strength (16). Additionally, wrist flexor strengthening exercises while gripping has been widely prescribed to increase hand grip strength (17). Hence, future studies should consider isokinetic strength assessment of the hand and wrist movements as well as strength training of other muscles of the wrist.

CONCLUSION

In conclusion, this study demonstrated significant increases in the trained and untrained maximal hand grip strength for both the concentric and eccentric strength training groups, thereby signifying the potential of cross-education effects. However, strength gains between ECC and CON groups were not significant suggesting that the cross-education effect equally occurs with both eccentric and concentric trainingfor both trained and untrained hands. This study can contribute to the knowledge base of the cross-education effects that can be considered during the rehabilitation of sports injuries.

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