

The comparison of cross –education effect in young and elderly females from unilateral training of the elbow flexors

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Abstract

Background: Many studies have reported the increase in strength of the untrained contralateral limb after unilateral training. The aim of this study was to compare the cross education effect in the young and elderly persons.

Methods: In this quasi-experimental and pre-post study, 12 young people aged 28.25 ± 3.11 years and 12 elderly persons (aged 73.08 ± 5.3 years) participated. The subjects had no history of strength training and upper limb movement impairments. Maximal isometric flexion strength in the dominant limb and the contralateral side before and after training were measured by tensiometer. Subjects performed elbow flexion exercises in the dominant side, using 3 sets of 10 repetition of the 60-70% maximal force for two weeks. Independent and paired t test were used to analyze between and within groups differences.

Results: The results showed that short-term isometric resistive exercise led to a significant increase of strength in trained and untrained limbs in both groups ($p < 0.05$). There was not a significant difference between the two groups in the rate of strength increase, both in the upper limb that was exercised and also in the opposite side ($p > 0.05$).

Conclusion: The increased muscle strength observed during training indicates positive effect of training in old adult. The increased muscle strength in untrained limb suggests the capacity of neuromuscular adaptation among old adults, suitable to be used in cases of limb immobility or unilateral impairment.

Keywords: Elderly, Maximal isometric muscle strength, Cross training, Cross education, Elbow flexors.

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Introduction

Many studies have shown that the strength decreases after age 60 (1,2). With increasing age, the muscle becomes weak due to several reasons; decrease in the muscle fiber size, decrease in number of type II fiber, and reduction in the number of motor units and also a reduction in the ability to activate motor units (3). Studies have shown that aerobic, resistive and flexibility exercises have many beneficial ef-

fects on the muscle strength and flexibility, quality of life and physical functioning in young and older adults (4-6).

Several studies have shown that in the long term strength exercises would lead to an increase in muscle cross-sectional area, but only 10-15% of the increased power is as a result of changes in muscle structure and the greater part of the increase is the result of neurological and motor nervous system adaptation after exercise (7-10). In

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Frontera et al (11) study, the effects of neuromuscular adaptation during resistive exercises in older and younger groups were compared. In this study, muscle size, muscle fiber size and strength within 2 weeks and 12 weeks of resistive exercises were examined and observed that after two weeks, muscular force was increased while the muscle and the fiber size was not changed (11). Thus, early strength changes are primarily neural in basis while later the strength increases are due to changes in the muscle itself (10, 11).

Cross education lead to strengthening and endurance improvement of the untrained contralateral limb after a period of unilateral practice. Studies have shown that exercise in one limb can increase strength in the contra lateral limb (12-15). Cross education of strength has been attributed to neural mechanisms (16-19).

A recent meta-analysis showed that strength might improve the untrained limb by ~8% after contralateral strength training (13). Despite the relatively small effect of contralateral strength training, it could be beneficial in some situations. That is, training the healthy limb may be beneficial in conditions in which the affected limb is unable to exercise (e.g. limb immobilization after injury or surgery) or unilateral impairment (stroke) (20, 17).

Conducting a study that can show the neural adaptation during resistive exercises in older adults seems necessary. To investigate the neural adaptation effect, a short period of two weeks training seems adequate (11, 16). On the other hand it was necessary to draw a comparison between younger and older age groups and investigate the effect of age on amount of neural adaptation. Accordingly, the change in muscle strength in the first two weeks is directly related to neural agents (11, 16). Therefore, any strength changes observed during these two weeks can indicate elders' nervous system ability and capacity of adaptation to face with resistive exercises. On the other hand, the effect of exercises on the other limb strength represents the

changes in the nervous system more accurately. In line with that recent studies have shown that adaptation mechanism for the contra lateral limb strength exercises is on cortical levels and the spinal levels exert less effect on it (17). Thus, the current study was designed to compare strength changes in the contralateral and untrained elbow flexion, after a 2-week unilateral strength training program in elderly and young persons.

Methods

This quasi-experimental and pre and post-test study was carried out in the biomechanical laboratory of University of Social Welfare & Rehabilitation Sciences between 2012 and 2013. A convenience sample of 24 female subjects with no history of strength training and upper limb movement impairments participated in this study. The participants were young people aged 24-32 years and older group aged 64-79 years. All subjects were right hand dominant. The right shoulder was examined. Before participating in the study, all subjects signed an informed consent form approved by Committee of Ethics in University of Social Welfare & Rehabilitation Sciences.

Prior to testing protocol, each participant undertook a familiarization session. After a brief explanation of the testing procedures, participants were asked to execute three submaximal trials to be familiarized with the tests procedures. The subjects were seated in a chair. Maximal isometric flexion strength in the dominant limb and the contralateral side in the 90 degree of elbow flexion were measured by a tensiometer. Subjects were verbally encouraged to maintain maximal effort and then maximal isometric flexion strength data collected for 5 seconds. The mean of three repetitions of maximal isometric contraction was measured in Newton meter (Nm) as peak force.

After determining maximal elbow flexion, subjects performed isometric progressive resistive exercises of elbow flexion in the dominant side, using 3 sets of 10 repetition of the 60-70% maximal force for two

Table 1. Results of paired t test comparing pre and post maximal isometric strength of trained and untrained arm for each group

| group | side | strength | | | | Strength increase (%) | p |
|----------------|-----------|----------|------|-------|------|-----------------------|----------|
| | | Pre | | post | | | |
| | | mean | SD | mean | SD | | |
| Young (n=12) | Trained | 10.06 | 3.38 | 13.19 | 3.33 | 31% | P<0.0001 |
| | untrained | 9.13 | 3.20 | 11.33 | 3.01 | 24% | P<0.0001 |
| elderly (n=12) | Trained | 4.48 | 1.33 | 6.85 | 1.79 | 52% | P<0.0001 |
| | untrained | 3.62 | 1.18 | 5.04 | 1.65 | 39% | P<0.0001 |

Table 2. Results of paired t test comparing post maximal isometric strength of trained and untrained arm for each group

| group | post maximal isometric strength after exercise | | | | p |
|---------|--|------|-----------|------|----------|
| | Trained | | untrained | | |
| | mean | SD | mean | SD | |
| Young | 13.19 | 3.33 | 11.33 | 3.01 | P<0.0001 |
| elderly | 6.85 | 1.79 | 5.04 | 1.65 | P<0.0001 |

weeks. Each repetition lasted 6 seconds and was separated by a rest interval of 10 seconds. The training was carried out three times weekly. After two weeks, maximum isometric strength of the elbow flexion of both limbs was taken from all cases of both groups. Independent and paired t-tests were used to analyze between and within groups differences.

Results

Twelve females in the elderly group (aged 73.08 ± 5.3 years, Body mass index (BMI) = 25.25 ± 1.96) and 12 females in the young group (aged 28.25 ± 3.11 years, BMI = 23.96 ± 2.39) completed the study.

Measurement scores before and after two weeks training are presented in Table 1.

The result of paired t- test (Table 2) showed that the maximum isometric elbow flexion strength in both young and elderly group significantly increased after exercise

and this increase has taken place in both right upper extremity that has given the exercise and the left upper extremity that had not been given any exercise.

The results of the study showed that in young group during two weeks of resistive exercises, the strength increase of the dominant upper extremity was to the extent of 31% and 24% in opposite side whereas in elderly group, strength increase of the dominant upper extremity was to the extent of 52% and 39% in opposite side .

The result of independent t- test also showed that despite the lower strength in the elderly group, they can also increase their strength during exercise like young people. The result also showed that the two groups had no significant difference in the rate of strength increase, both in exercised upper extremity and the opposite side (Tables 3, 4).

Table 3. Results of Independent t test comparing pre and post maximal isometric strength of trained and untrained arm between two group

| side | exercise | Young group | | elderly group | | Mean difference | T test | p |
|-----------|----------|-------------|------|---------------|------|-----------------|--------|---------|
| | | mean | SD | mean | SD | | | |
| Trained | pre | 10.06 | 3.38 | 4.48 | 1.33 | 5.58 | 5.32 | P<0.001 |
| | post | 13.20 | 3.33 | 6.85 | 1.80 | 6.34 | 5.81 | P<0.001 |
| untrained | pre | 9.13 | 3.20 | 3.62 | 1.18 | 5.51 | 5.60 | P<0.001 |
| | post | 11.33 | 3.01 | 5.04 | 1.65 | 6.28 | 6.35 | P<0.001 |

Table . The results of the independent t-test to compare the rate of strength increase after training between two groups

| Rate of strength increase | Young group | | elderly group | | Mean difference | T test | p |
|---------------------------|-------------|------|---------------|------|-----------------|--------|-------|
| | mean | SD | mean | SD | | | |
| Trained side | 3.13 | 1.01 | 2.37 | 0.93 | 0.77 | 1.93 | 0.067 |
| Untrained side | 2.20 | 1.19 | 1.43 | 1.02 | 0.78 | 1.71 | 0.102 |

Discussion

The results of this study showed that after two weeks of resistive exercises, increases of trained upper extremity strength was 31% and of the untrained side were 24% in young group, while in elderly group they were 52% and 39% respectively. Our result also showed that despite the lower strength in the elderly, they can increase their strength during exercise like young people. Two groups had no significant difference in the rate of strength increase ($p>0.05$) that represents high capacity and elderly ability to increase strength and improve their performance. Many studies have shown that short-term training cannot lead to structural changes in the muscular system (11, 16). In Frontera et al (11) study, muscle size, strength and muscle fiber size within 2 weeks and 12 weeks of resistive exercises in 7 young and 7 elderly people were studied and observed that after two weeks, muscle force was increased in both groups while muscle and fiber size was unchanged. Early adaptation of strength exercises was reported to be related to the nervous system and there was no change in cellular level. In a study by Bembien et al (16) carried out in 2004, muscle strength, electrical activity level and muscle cross-sectional area of both limbs were examined before and after doing dynamic resistive exercises on right upper limb during two weeks. Their results showed that strength improvement was the result of neural adaptation and no change in muscle size was occurred (16). The present research also showed that strength increase in both limbs in two groups was represented as early adaptation of nervous system.

The results of this study also showed in both young and elderly groups, in addition to increasing muscle strength in upper extremity that gave exercise, opposite side muscles were also significantly increased after exercise ($p<0.05$). This indicates the impact of exercise on the muscles of untrained side due to cross training effect. Several studies have been conducted to investigate this phenomenon. Adamson et al (12) in 2008 found that strengthening exer-

cises in a limb would improve contralateral limb strength. The results of this study showed that after 8 weeks of resistive training, the maximum isometric strength of exercised side limb muscles increased 37% and 34% in opposite side (12). Dragert et al (17) in 2011 studied the impact of dorsiflexion resistive exercises of a foot on agonists and antagonists' muscles of opposite side in a 5-week period and observed that the maximum isometric strength dorsi flexor muscles in exercise side and opposite side increased to 14.7% and 8.4%. Also no significant difference was observed in the soleus muscle strength, and tibialis anterior H reflex increased in exercised side, while no change was observed in the contralateral limb that reflects nervous changes mechanism in cortical level to the contralateral limb (17). This study showed that adaptation mechanisms of the nervous system to increase the strength of the contralateral limb is different from exercised side limb and all the changes occurred in strength increase refers to irritability of cortical level and neural agents. Some studies also showed the nervous system adaptation only after an exercise session. In Toca-Herrera et al (21) study, intervention group was received electrical stimulation for 10 minutes on rectus femoris muscle of one side. The control group did not perform any activity. Before and after electrical stimulation, isometric strength and muscle electrical activity was measured in the opposite side. The results of Toca-Herrera(21) study showed that after 10 minutes electrical stimulation on rectus femoris muscle of one side, the strength and EMG activity of the rectus femoris muscle in contralateral limb increased at about 5.11% and 4.67% respectively (21). The results of this study indicate that neural adaptation occurs much faster than what is expected.

Overall, the results of the present research on the comparison of young and older age groups showed that despite low levels of muscle strength in the elderly, this group has shown appropriate adaptation to resistive exercises. Thus, the increase was

greater in the elderly than in the young group. The results also showed that in the elderly people similar to young people taking exercise in one limb can cause a significant and meaningful increase in the strength of contralateral limb that discriminated high elder's ability and capacity in nervous system adaptation during exercises (18, 19, 22, 23).

Elderly people are more susceptible to damage, stroke and trauma. During the period of immobilization of a limb, we can reduce the side effects of immobilization by doing resistive exercises on the opposite side. That is, cross training may be beneficial in conditions in which the affected limb is unable to exercise. Training the healthy limb may enhance post-surgical functional outcomes and strength recovery in the immobilized or impaired limb (20).

One of the limitations of this study was lack of follow-up. Although all the subjects showed improvement in strength of trained and untrained limbs, a longer follow-up evaluation would provide more information of the long term outcomes.

Conclusion

The results showed that short-term isometric resistive exercise led to a significant increase of strength in trained and untrained limbs in older and young adults. The increased muscle strength observed during training indicates positive effect of training in old adults, and the increased muscle strength in untrained limb suggests the capacity of neuromuscular adaptation in old adults that it can be used in cases of limb immobility or unilateral impairment.

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Conflict of interests

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References

1. Milanović Z, Pantelić S, Trajković N, Sporiš G, Kostić R, James N. Age-related decrease in physical activity and functional fitness among elderly men and women. *Clin Interv Aging*. 2013;8:549-56.
2. Akbari M, Mousavikhatir R. Changes in the muscle strength and functional performance of healthy women with aging. *Med J Islam Repub Iran*. 2012;26(3):125-31.
3. Vandervoort AA. Aging of the human neuromuscular system. *Muscle Nerve* 2002; 25(1):17-25.
4. Nodehi-Moghadam A, Mohammadi R, Arab AM, Kazamnajad A. The effect of shoulder core exercises on isometric torque of glenohumeral joint movements in healthy young females. *Research Med Science*,2011;16(12) :1555-1563
5. Morey MC, Cowper PA, Feussner JR, DiPasquale RC, Crowley GM, Sullivan RJ Jr. Two-year trends in physical performance following supervised exercise among community dwelling old veterans. *Am Geriatr Soc* 1991; 39(6):549-54.
6. Province MA, Hadley EC, Hornbrook MC, Lipsitz LA, Miller JP and Mulrow CD. The effects of exercise on falls in elderly patients. A preplanned meta-analysis of the FICSIT Trials. *Frailty and Injuries: Cooperative Studies of Intervention Techniques*. *JAMA* 1995;273(17):1341-7.
7. Grimby G, Aniansson A, Hedberg M, Henning GB, Grangard U, Kvist H. Training can improve muscle strength and endurance in 78- to 84-yr-old men. *Appl Physiol* 1992;73(6): 2517-23.
8. Hagerman RC, Walsh SJ, Staron RS, Hikida RS, Gilders RM, Murray TF, Toma K, Ragg KE. Effects of high-intensity resistance training on untrained older men. I. Strength, cardiovascular, and metabolic responses. *Gerontol A Biol Sci Med Sci*. 2000 ;55(7):B336-46.
9. Hakkinen K, Kallinen M, Izquierdo M, Jokelainen K, Lassila H, Malkia E, Kraemer WJ, Newton RU, Alen M. Changes in agonist-antagonist EMG, muscle CSA, and force during strength training in middle-aged and older people. *Appl Physiol* 1998; 84(4):1341-49.
10. Tracy BL, Ivey FM, Hurlbut D, Martel GF, Lemmer JT, Siegel EL, Metter EJ, Fozard JL, Fleg JL, Hurley BF. Muscle quality. II. Effects of strength training in 65- to 75-yr-old men and women. *Appl Physiol* 1999; 86(1):195-201.
11. Frontera WR, Hughes VA, Krivickas LS, Kim SK, Foldvari M, Roubenoff R. Strength training in older women: early and late changes in whole muscle and single cells. *Muscle Nerve*. 2003;

28(5):601-8.

12. Adamson M, Macquaide N, Helgerud J, HoV J, Kemi OJ. Unilateral arm strength training improves contralateral peak force and rate of force development. *Eur J Appl Physiol* 2008; 103(5): 553–59.

13. Lee M, Carroll TJ. Cross-education: possible mechanisms for the contralateral effects of unilateral resistance training. *Sports Med* 2007; 37(1):1–14.

14. Lee M, Gandevia SC, Carroll TJ. Unilateral strength training increases voluntary activation of the opposite untrained limb. *Clin Neurophysiol* 2009; 120(4):802–808.

15. Munn J, Herbert RD, Hancock MJ, Gandevia SC. Training with unilateral resistance exercise increases contralateral strength. *Appl Physiol* 2005; 99(5):1880–84.

16. Bemben MG, Murphy RE. Age related neural adaptation following short term resistance training in women. *Sports Med Phys Fitness*. 2001; 41(3):291-9.

17. Dragert K, Zehr E. P. Bilateral neuromuscular plasticity from unilateral training of the ankle dorsiflexors. *Exp Brain Res* 2011; 208(2):217–27.

18. Evetovich TK, Housh TJ, Housh DJ, Johnson GO, Smith DB, Ebersole KT. The effect of concentric isokinetic strength training of the quadriceps femoris on electromyography and muscle strength in the trained and untrained limb. *Strength Cond Res* 2001; 15(4):439–45.

19. Farthing JP, Chilibeck PD, Binsted G. Cross-education of arm muscular strength is unidirectional in right-handed individuals. *Med Sci Sports Exerc* 2005; 37(9):1594–1600.

20. Hendy AM, Spittle M, Kidgell DJ. Cross education and immobilisation: mechanisms and implications for injury rehabilitation. *J Sci Med Sport*. 2012;15(2):94-101.

21. Toca-Herrera J L, Gallach J E, Gomis M and Gonzalez LM. Cross-education after one session of unilateral surface electrical stimulation of the rectus femoris. *Strength Cond Res* 2008; 22(2):614-8.

22. Behm DG, Sale DG. Velocity specificity of resistance training. *Sports Med* 1993; 15(6):374–388.

23. Folland JP, Williams AG. The adaptations to strength training: morphological and neurological contributions to increased strength. *Sports Med* 2007; 37(2):145– 68.