Acute Effect of Unilateral Muscle Training Supported with Visual Feedback on Contralateral Muscle Strength and Joint Position Sense*

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Abstract

Aim: Unilateral exercise training is an effective and useful technique, especially in immobilization and neurological conditions, but the effect of unilateral muscle exercise training on muscle strength is modest. Therefore, the aim of this study is to detect the acute concomitant effect of mirror therapy and unilateral exercise training on muscle strength and joint position sense in healthy adults.

Method: Thirty-one participants were randomly enrolled in two groups the mirror (n=16) and control groups (n=15). Hand grip (HG), pinch grip (PG) strengths, and joint position sense (JPS) of the wrist were assessed in both hands before and after a single exercise session which include 300 repetitive ball squeezing exercises by right (exercised) hand for all groups. The participants in the mirror group were asked to watch the mirror to see the reflection of their exercised hands, the control group only watched their exercised and unexercised hands without any visual feedback support during the exercise session. Repeated Measure ANOVA and Mixed ANOVA tests were performed to analyze in- and between-group differences.

Results: The statistically significant differences were determined in unexercised hand HG and PG strength in the mirror group (F=10,105; p=0,006, ηp2=0,403; F=5,341; p=0,035; ηp2=0,263, respectively). However, any group×time interaction was found in JPS, HG, or PG tests (p<0;05). Additionally, no difference was shown in JPS in-group comparisons (p<0;05).

Conclusion: The result of the study suggested that unilateral exercise training should apply concomitant with visual feedback. Further studies are needed to compare the effect of different sensory feedbacks on unilateral exercise training.

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ETHICAL STATEMENT: The experimental procedure was approved by Istanbul Atlas University Human Research Ethics Committee, and the experiments were performed in accordance with the Declaration of Helsinki (Approval number: E-22686390-050.01.04-15143 and Approval Date: 04.15.2022).

Keywords: Exercise, muscle strength, feedback.

Görsel Geri Bildirim Destekli Tek Taraflı Kuvvet Eğitiminin Kontralateral Kuvvet ve Eklem Pozisyon Hissine Etkisi

Öz

Amaç: Tek taraflı egzersiz eğitimi, immobilizasyon ve nörolojik durumlarda faydalı ve etkin bir yöntemdir. Ancak, unilateral egzersiz eğitiminin kas kuvveti üzerine etkisi azdır. Bu sebeple, çalışmanın amacı sağlıklı kişilerde ayna tedavisi ile birlikte uygulanan tek taraflı egzersiz eğitiminin kas kuvveti ve eklem pozisyon hissi üzerine etkisini belirlemektir.

Yöntem: Otuz bir katılımcı rastgele yöntemle ayna ve kontrol grubuna dahil edildi. Her iki elde, el kavrama (EK), çimdik kavrama (ÇK) kuvvetleri ve el bileğinin eklem pozisyon hissi (EPH) bir seanslık egzersiz eğitimi öncesi ve sonrasında değerlendirildi. Tüm gruplar için tek seanslık egzersiz eğitimi sağ elle yapılan 300 tekrarlı top sıkma egzersizini içeriyordu. Ayna grubundaki katılımcılardan egzersiz sırasında egzersiz yapan ellerinin aynadaki görüntüsünü izlemeleri istenirken, kontrol grubu egzersiz yapan ve yapmayan ellerini herhangi bir görsel geribildirim desteği olmadan izlediler. Repeated Measure Anova ve Mixed Anova testleri grup içi ve gruplar arası farklılıkların analizi için kullanıldı.

Bulgular: Ayna grubunun egzersiz yapmayan elinin EK ve ÇK kuvvetlerinde istatistiksel olarak değişiklik saptandı (sırasıyla F=10,105; p=0,006, ηp2=0,403; F=5,341; p=0,035; ηp2=0,263). Ancak, EPH, EK ve ÇK'da grup×zaman interaksiyonu bulunmadı (p>0,05). Ek olarak, EPH grup içi karşılaştırmalarda herhangi bir farklılık göstermedi (p<0,05).

Sonuç: Çalışmanın sonuçları, tek taraflı egzersiz eğitiminin görsel geri bildirimle birlikte uygulanmasını tavsiye etmektedir. Farklı duyusal geri bildirimlerin tek taraflı egzersiz eğitimi üzerindeki etkilerini karşılaştırmak için ileri çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Egzersiz, kas kuvveti, geribildirim.

Introduction

Force irradiation is referred as an involuntary muscle activity that occurs in contralateral muscles or any other body segment during a strong unilateral muscle contraction[1]. The mechanisms underlying the contralateral effects of training are uncertain and may be caused by the muscular, neural, spinal cord, cortical and subcortical influence[2,3]. Force irradiation is likely to be one of the mechanisms underlying unilateral exercise training which is defined as the strength gains of the contralateral untrained homologous muscles[4-6].

The effect of unilateral muscle exercise training on muscle strength is modest, thus the researchers have investigated the way of improving the effect of force irradiation. The studies showed that the electrical stimulation and cutaneous afferents or inputs from muscle spindles concomitant with the unilateral exercise were increased force irradiation[7-9]. Additionally, it was revealed that the sensorial inputs provided via a mirror box, which reflects the exercised limb, also improved the cross effect[10,11]. The mirror therapy method is based on the activation of mirror neurons which are activated during the superimposition of a mirror-reflected image of the active extremity over the opposite extremity by placing a midsagittal-plane mirror in front of the person[12,13]. It is claimed that this method facilitates unexercised limb joint position sense or kinesthetic sense and modulates corticospinal activity[14]. However, there is no consensus on the effects of mirror training on motor function in healthy individuals[15].

Some studies also presented that muscle strength augmentation in both unilateral exercise training and mirror therapy is related to alteration in activation of brain areas covered by areas having mirror neurons[16-18]. Thus, hypothesized that simultaneous application of these two techniques may enhance the effect of unilateral exercise training on muscle strength and joint proprioception. Therefore, the aim of this study was to determine the acute concomitant effect of mirror therapy and unilateral exercise training on muscle strength and joint position sense in healthy adults.

Material and Methods

Thirty-one participants who have no history of any neurological or acute musculoskeletal injury were recruited and randomly assigned to group mirror (n=16) and control (n=15) groups using an electronic random sequence generator (www.random.org). The participants who have acute or chronic pain, have any history of immobilization, and are diagnosed with any chronic diseases, including strengthening programs in the last 12 months were excluded. Written informed consent was obtained from all subjects. The experimental procedure was approved by Istanbul Atlas University Human Research Ethics Committee, and the experiments were performed in accordance with the Declaration of Helsinki (Approval number: E-22686390-050.01.04-15143 and Approval Date: 04.15.2022).

All participants performed the joint position sense (JPS) test, hand grip (HG) test, and Pinch grip (PG) test for both hands before and after the exercise session by the same physiotherapist. The participants were seated in an upright position on a chair, feet in contact with the ground, arm at the side of the trunk, elbow flexed at 90°, and forearm and wrist fixed in the neutral position for all tests and the exercise session.

A passive position–active reposition method was used to evaluate the JPS test via targeting 45° and 60° wrist extension angles. Wrist joint angles were measured using a universal plastic goniometer which was placed according to American Society of Hand Therapists recommendation[19]. The arms of the goniometer were positioned parallel to the radius and middle finger metacarpal to provide midcarpal and radiocarpal joint axis markers. A demonstration was given before the test. The visual cues have been removed with a blindfold placed over the participants' eyes before the assignment of the random test positions. The physiotherapist introduced the passive target position for 5 seconds with a minimal contact. Prior to actively repositioning in the targeting position, the participants moved their wrists to the neutral position. The angle was measured and recorded in a 1° sensitivity.

The HG test was evaluated with a Jamar hand dynamometer in a neutral elbow position. The participant was asked to squeeze the dynamometer with their hand on maximum isometric effort for approximately 5 seconds. The best result of three trials for each hand is recorded as the score of tests, with at least 15 seconds recovery between each trial.

PG test was performed in the same sitting position using the Baseline hydraulic pinch meter. The participants were asked to apply maximum pinching between the pad of the thumb in opposition to the pads of the index and middle finger. PGT was performed three times and randomly in each side. The highest score was recorded as the final test score of the participant. A three-minute resting period was given between each test to prevent fatigue.

All exercise practices were done by the same physiotherapist 3 minutes after the assessment session in the sitting position. The participants in the mirror group placed left hand (unexercised hand) in a mirror box, right hand (exercised hand) was positioned on the table in the neutral position. On the other hand, the participants in the control group placed both hands on the table. Both groups performed 300 repetitive ball squeezing exercises with their exercised hands. While the participants in the mirror group were asked to watch the mirror to see the reflection of their exercised hands, the control group only watched their exercised and unexercised hands without any visual feedback support during the exercise session. All the tests were performed after 3 minutes of the exercise session.

Statistical Analysis

The statistical analysis was performed using SPSS program (Statistical Package for the Social Sciences, version 17.0, SPSS Inc, Chicago). Normality of all variables was tested using Shapiro-Wilk's test. The differences in demographic and clinical characteristics of groups were analyzed using Independents Sample T test and Mann-Whitney U test according to the normality of data. The Chi-square test was used to compare gender distributions between groups. In groups differences between pre-and post-session were examined using Repeated Measure ANOVA test. A mixed ANOVA was used to determine the difference of pre-and post-session JPS, HG, PG test scores between the groups. A p-value of less than 0,05 was considered statistically significant.

Results

Thirty-one subjects completed to the study. The mean age of the participants was 30,5±12,3 years and 27,7±12,4 years in the mirror and control groups, respectively. Additionally, there was no difference in gender distribution between mirror and control groups (p=0,135). Only two participants had left dominant hand preference. Unexercised hand HG and PG strengths were improved merely in the mirror group (F=10,105; p=0,006; ηp2=0,403; F=5,341;p=0,035; ηp2=0,263; respectively). However, any group×time interaction was found in JPS, HG, or PG tests (p<0,05). Besides, there was no difference determined in JPS in-group comparisons (p<0,05) (Table 1).

Table 1. HG, PG and JPS scores of the mirror and control groups for pre- and post-sessions

	Mirror Group (n=16)			**Control Group (n=15)**			**Between Groups**
	Pre-session	**Post-session**	**In-group comparison**	**Pre-session**	**Post-session**	**In-group comparison**	
Exercised Hand Grip Strength (kg)	26,4±10,5	26,1±10,8	F= 0,069 p=0,797 η_p^2=0,005	34,3±9,9	32,6±11,7	F= 1,296 p=0,274 η_p^2=0,085	F= 0,787 p=0,382 η_p^2=0,026
Unexercised Hand Grip Strength (kg)	24,3±9,5	27,3±8,3	**F= 10,105 p=0,006 η_p^2=0,403**	31,7±9,7	32,2±9,7	F= 0,181 p=0,677 η_p^2=0,013	F= 2,698 p=0,111 η_p^2=0,085
Exercised Hand Pinch Strength (kg)	9,1±2,2	9,0±2,1	F= 0,491 p=0,494 η_p^2=0,032	9,5±3,0	9,2±3,1	F= 2,250 p=0,156 η_p^2=0,138	F= 1,019 p=0,321 η_p^2=0,034
Unexercised Hand Pinch Strength (kg)	8,6±2,1	8,1±1,6	**F= 5,341 p=0,035 η_p^2=0,263**	9,1±2,6	8,6±2,5	F= 3,429 p=0,085 η_p^2=0,197	F= 0,036 p=0,851 η_p^2=0,001
Exercised Hand Wrist 45° Extension Joint Position Sense (°)	3,2±4,1	1,5±2,0	F= 2,614 p=0,127 η_p^2=0,148	2,2±2,7	2,6±4,2	F= 0,150 p=0,704 η_p^2=0,011	F= 2,017 p=0,166 η_p^2=0,065
Unexercised Wrist 45° Extension	2,5±2,9	1,9±2,8	F= 0,543	2,5±2,4	2,3±2,9	F= 0,106	F= 0,070

Joint Position Sense (°)			p=0,473 η_p^2=0,035			p=0,750 η_p^2=0,008	p=0,793 η_p^2=0,002
Exercised Hand Wrist 60° Extension Joint Position Sense (°)	2,2±3,9	1,7±2,8	F= 0,187 p=0,672 η_p^2=0,012	1,7±2,9	1,2±2,0	F= 0,587 p=0,456 η_p^2=0,040	F= 0,006 p=0,939 η_p^2=0,000
Unexercised Wrist 60° Extension Joint Position Sense (°)	1,7±3,2	1,8±3,8	F= 0,038 p=0,847 η_p^2=0,003	0,8±1,5	1,1±2,1	F= 0,142 p=0,712 η_p^2=0,010	F= 0,022 p=0,883 η_p^2=0,000

Discussion

In this study, aimed to determine the effect of visual feedback, in addition, to force irradiation on muscle strength and joint position sense after one session. Found that while the unexercised hand HG and PS of the mirror group have improved, the control group did not show any statistically significant difference both in HG and PS. Any differences were not determined between the mirror and control groups in HG and PS of both hands. Furthermore, HG and PS of exercised hand and wrist extension JPS also did not change between pre-and post-session assessments in both groups.

An improvement in motor output is associated with either structural alterations or functional/neurological adaptations[20]. However, the contractile proteins related to muscle hypertrophy only synthesize during real repetitive muscle contractions and provide an increment in muscle strength or output[21,22]. Contrary, in unilateral exercise training, unexercised limb gains strength without a real movement via neural adaptations[23,24]. A recent meta-analysis reported that only 11.9% augmentation was obtained in muscle strength following unilateral exercise training with a 6–8-week duration[25]. The researchers have investigated the way of increasing the contralateral effect[26,27]. There are the limited number of studies investigating the immediate effect of unilateral training on muscle strength[7,28]. In the present study, only evaluated the effect of a single session (300 contractions) and determined improvement in contralateral muscle strength among the participants in the mirror group who performed unilateral muscle contraction with visual feedback. The contralateral muscle strength of the control group did not alter. In line with this results, Hendy et al. applied anodal-tDCS during unilateral exercise training and presented enhancement of contralateral muscle strength only in the anodal-tDCS group, any difference neither in unilateral strength training with sham-tDCS nor a-tDCS alone[28]. Cattagni et al. reported that while neuromuscular electrical stimulation during unilateral exercise training increased the contralateral quadriceps muscle strength, alone unilateral exercise training did not affect[7]. Another point in common with Cattagni et al. is claiming that alteration of the contralateral effect probably occurs via changing somatosensory afferent inputs. Although these effects are shown in other studies with different sensorial inputs by parameters such as muscle activity or motor evoked potentials, the acute effect of concomitant visual feedback to unilateral exercise training on contralateral muscle strength was revealed in the present study[11,29,30]. On the other hand, although a few possible mechanism of acute unilateral exercise training is explained in the literature such as stabilization mechanism, ipsilateral activation theory, and transcallosal facilitation theory, only one mechanism may explain this results in mirror group. The probable explanation is that additional visual feedback to unilateral exercise training may disrupt contralateral hemisphere inhibition via increasing afferent input more than unilateral exercise group[31]. Nevertheless, despite the statistically significant improvement of contralateral muscle strength presented in the mirror group, did not show any superiority between the groups.

Providing unilateral limb visual feedback is called mirror therapy which works on the mirror-neuron system. The mirror neuron system provides a connection between sensory and motor neurons which are active for the same task. This association results in alteration in corticospinal activity and reflection of the pattern of muscle activity of observed action[32]. Another theory is about the huge effect of visual input on proprioception[33]. The advantages of mirror therapy are to create a cross-limb transfer, increase corticospinal excitability and activate the sensorimotor cortex. Thus, utilized mirror therapy to increase the modest effect of unilateral exercise training. In the literature, the mirror therapies in which performed functional tasks without maximal contraction of muscles in exercised limbs did not show any acute contralateral effect in healthy adults[34,35]. Besides, a present meta-analysis revealed that the effect of mirror training performed with the functional tasks on motor performance is weak in healthy individuals[15]. The studies about cross-education revealed that the level of contraction force affects cross-activation[36,37]. Therefore, in this study, asked to all participants squeeze the ball as stronger as they can, and muscle strength values were improved after one session.

There is a limited number of studies about the influence of unilateral exercise training on JPS. Gohary et al determined an enhancement of contralateral knee JPS after eight-week unilateral proprioceptive training in healthy subjects[38]. Another study revealed that eccentric unilateral training provides more improvement in elbow JPS than concentric unilateral training after elbow immobilization[39]. To this best knowledge, there is no study focused on the acute effect of unilateral exercise training on JPS. In this study, did not found any difference before and after the unilateral exercise training session, and also between the groups.

When the results of exercised hands were analyzed, minimal reductions of HG and PS were noticed in both groups, but none of them were statistically significant. Speculated that 300 repetitive ball squeezing exercises may cause exercise-induced muscle soreness reactions, although one session of strength training enhanced net output from motoneurons projecting to the trained muscles[40,41].

The lack of finger flexion JPS measurement might be accepted as the limitation of the study. It may be measured in addition to wrist JPS and may provide contributions to this results. Additionally, this study was performed with healthy participants, which has to be considered, therefore this results should not be generalized on people with diseases in physiotherapy management.

Conclusion

In conclusion, this study presented that a single session of unilateral exercise training with visual feedback may improve unexercised hand HG and PG strength, but could not show any difference with the control group which only performed unilateral exercise training. The unilateral exercise training with or without visual feedback did not provide alteration in JPS and exercised hand HG and PG strength. According to the result of the study, suggested that unilateral exercise training should apply concomitant with the visual feedback. Further studies are needed to compare the different sensory feedbacks on unilateral exercise training.

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