Derleme
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Kontralateral Eğitimin Kas Kuvvetine Etkisi: Derleme

Effect of Contralateral Training on Muscle Strength: A Narrative Review

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ÖZ

Kontralateral eğitim, vücudun bir ekstremitesini veya bir tarafını çalıştırmanın, doğrudan eğitim olmadan bile vücudun karşı ekstremite veya tarafında iyileştirmelere yol açabileceği olgusunu tanımlar. Başka bir deyişle, bir ekstremiteden diğer ekstremitelere veya vücudun bir tarafından diğer tarafına antrenman kaynaklı etkilerin transferini ifade eder. Bu etki, kuvvet, dayanıklılık ve motor beceri antrenmanı gibi çeşitli egzersiz ve rehabilitasyon biçimlerinde gözlemlenmiştir. Örneğin, bir kişi sadece sağ koluyla kuvvet egzersizleri yaparsa, doğrudan antrenman yapmamış olsa bile sol kolunda da kuvvet artışı görülebilir. Etkilenmeyen ekstremiteyi eğiterek elde edilmesi muhtemel kazanımlar etkilenen ekstremiteye aktarılabilir ve genel fonksiyonun iyileştirilmesine yardımcı olabilir. Bu fayda aktarımı, beyinde ve omurilikte meydana gelen nöral adaptasyonlar nedeniyle gerçekleşebilir. Kontralateral eğitim, ortopedik veya nörolojik problemleri bulunan hastaların rehabilitasyon süreçlerine yardımcı olmak amaçlı fizyoterapi ve rehabilitasyon kliniklerinde son yıllarda kullanılmaktadır. Bu derlemede eğitim alan ekstremitedeki farklı kontraksiyon tiplerinin eğitim almamış ekstremite üzerindeki kas kuvveti etkisini detaylarıyla açıklamayı amaçladık.

Anahtar Kelimeler: Rehabilitasyon, kas kuvveti, direnç antrenmanı.

ABSTRACT

Contralateral training is defined as the case where exercising one extremity or one side of the body can cause improvements to the opposite extremity or side of the body without direct training. In other words, it represents the transfer of effects due to training from one extremity to another or from one side of the body to the other. This effect is observed with exercise forms like strength, resistance and motor skills training. For example, if a person only performs strength exercises with the right arm, an increase in strength is observed in the left arm, even though direct training was not performed. The probable gains obtained by training the unaffected extremity may be transferred to the affected extremity, which may improve general function. This transfer of benefit may occur due to neural adaptations occurring in the brain and spinal cord. Contralateral training, or cross-education, has been used in recent years in the rehabilitation process for patients with orthopedic or neurological problems. In this review, we aimed to explain the effect of different contraction types in the trained extremity on muscle strength in the untrained extremity.

Keywords: Rehabilitation, muscle strength, resistance training.

1. INTRODUCTION

Currently, there is a search for new and effective methods in training and learning processes that will assist patients in using their potential at maximum levels. Within this framework, contralateral training (CT) (training of the opposite side) is a concept that has

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gained importance in recent years. CT improves the performance of the contralateral extremity after one-sided training or implementations (1). When examined in terms of the central nervous system, CT aims to provide improvement or development of brain functions on the other side (e.g., left brain hemisphere) as a result of stimulating one side of the brain with movement (e.g., left hand) (2).

The capacity for activity performed by one extremity to affect the performance of the other extremity was revealed more than a century ago. The first evidence for the effects of CT was shown by Scripture et al. in 1894, investigating the transfer of the contralateral impact between hands for muscle control and strength with a simple manometer (3). This effect, from which the term "cross-education" was derived, was later defined in many research articles encompassing both strength and motor skills transfer (4-6).

Considering the known effects of the inability to use a limb or immobilization on brain and neuromuscular system functions, researchers have paid great attention to precautions to preserve muscle function. These include strategies like exercise, neuromuscular electrical stimulation, and/or nutritional supplements (7). During unilateral immobilization/lack of use, strength training of the opposite extremity (in other words, CT) offers a better alternative precaution in situations where the activity of the immobile extremity is prevented, mainly due to injury or neurological disorder.

Not using muscles reduces muscle mass, muscle cross-sectional area (MCA) and strength capacity (8). Wall et al. reported that immobilization with a leg cast for 5 days, reduced the maximal voluntary isometric contraction torque of the knee extensors (-9.0 ± 2.3%) and quadriceps MCA (-3.5 ± 0.5%) (9). Longer durations of immobilization (4-6 weeks) were shown to cause significant reductions in cross-sectional area of knee flexors (-11%), extensors (20-32%), knee extensors (-16%), soleus (-17%) and gastrocnemius (-26%) muscles (10-12).

Based on these findings, CT may be applied with the aim of bringing muscle strength to the highest level in different stages of musculoskeletal rehabilitation and reducing muscle loss and muscle atrophy following injury. CT has significant potential in terms of understanding and managing the interactions between brain and body. Based on the concept of neuroplasticity, it may provide positive effects in areas such as compensating for loss of function, developing motor skills and neurological rehabilitation. CT is very valuable in terms of rehabilitation, and the lack of knowledge about the specific effects of exercise in training methods causes confusion about CT. As a result, the aim of this review was to examine studies analyzing the effect of contraction types used in CT on muscle strength and contribute to creating the most effective rehabilitation program.

2. METHODS

Literature review

In this narrative review, a literature search was conducted in “Medline (PubMed), Embase, and the Cochrane Library” in July 2023 to identify effects of cross-education programs on muscle strength. Searches were made using "cross-education, contralateral training, contralateral effect, muscle strength, contraction type" keywords. The articles were chosen by first reading the abstract; afterward, data were analyzed by reading the entire text via full-text resources. To undertake the study, information published about the effects of contralateral training on muscle strength was collected over 9 years (2014-2023). According to our results, 5 studies met the inclusion criteria.

3. DISCUSSION

Some research has been performed related to how the muscle movement type used during CT affects the contralateral effect size. Specifically, they compared concentric and eccentric CT during isokinetic knee extensions, isotonic knee extensions, knee flexion and isokinetic wrist flexion (13-17). Several studies showed that unilateral eccentric training provided superior results compared to unilateral concentric training and provided stronger transfer effects compared to other muscle movements. Additionally, after CT ended, eccentric CT was shown to have more a strength preservation effect than concentric CT (15,18). When the effect of unilateral eccentric training was compared with traditional unilateral isotonic training, including both muscle movements (in other words, concentric-eccentric), eccentric training provided more strength preservation effect for the immobile arm following four weeks of arm immobility (16).

To explain the case of CT, two theoretical models were suggested involving neural plasticity in brain's cortical regions. The first is the "bilateral access" model which involves the development of motor "engrams" following unilateral movements and is based on the idea that these can be accessed not only by the trained extremity but also by the untrained extremity (6,19). In other words, they are coded in a location that can be accessed to control the contralateral untrained extremity. Contrary to this, the basic principle of the "cross-activation" model, the second theory, is that bilateral cortical activity produced during unilateral training directs simultaneous neural adaptations in both cerebral hemispheres. Accordingly, unilateral training triggers task-specific changes in the configuration of the cortical motor networks controlling the muscles of the opposite (immobile) extremity (20).

The increase in strength provided by these neural interactions was shown in meta-analysis studies with high evidence value.

A meta-analysis study by Munn et al. showed that the magnitude of the increase in muscle power of the contralateral extremity was 35% of the rate in the ipsilateral trained extremity (95% CI: 20.9-49.3%) (21).

Green and Gabrial performed a meta-analysis study and found similarities in CT effect between upper and lower extremity muscles, between genders and between young and older individuals. They stated the proportion of muscle strength gain between the untrained and trained muscles varied between 48% and 77% (22).

Gülcan et al. separated 48 patients with anterior cruciate ligament reconstruction (ACLR) using hamstring tendon autograft into 3 groups of concentric, eccentric and control subjects to research the effects of concentric and eccentric CT 4 weeks after the operation on the quadriceps. All groups had the same rehabilitation program for the extremities undergoing ACLR. In contrast, the two subject groups had 8 weeks of isokinetic training at 60°/s on 3 days per week for their uninjured knees. The maximum voluntary isometric contraction (MVIC) of the quadriceps for the ACLR limb was measured in the 4th week postoperative (before training), 12th week postoperative (after training) and the 24th week postoperative. Compared with the control group, the concentric and eccentric CT groups had higher quadriceps strength in the 12th week, with no difference reported between the concentric and eccentric CT groups.

In the 24th week, only the quadriceps strength of the eccentric CT group was higher than the control group. Eccentric and concentric CT effects were revealed to provide similar developments in quadriceps muscle strength and it was emphasized that CT may be beneficial to maximize quadriceps muscle strength, especially if integrated into ACLR rehabilitation in the early stages (13). Unilateral training of the mobile extremity is known to increase or preserve cortical activity and corticospinal stimulability in the ipsilateral motor cortex responsible for activating the immobile extremity (23,24). In this research, after a period without training (12 weeks), quadriceps muscle strength was higher in the group that received eccentric CT compared to the group that received concentric CT. As a result, eccentric CT may have provided more permanent corticospinal stimulation. Additionally, there is a need for studies investigating the activities of the responsible cortex in the long term after a period without CT.

Research by Sato et al. investigated unilateral eccentric resistance training compared to concentric resistance training to determine which had larger and longer-term CT effects. They divided 31 healthy individuals into 3 groups: concentric CT, eccentric CT and controls. While the trained arm was determined randomly in the two experiment groups, the other arm was used to investigate the CT effect. The MVIC of the elbow flexors, one maximum repeat (1-RM) and biceps brachii and brachialis muscle thickness (MT) were measured repeatedly a few days before training for the trained and untrained arms, the day after training and 5 weeks later. Four out of nine participants in every group used the dominant arm for training. The dominant arm was determined as the arm used to throw a ball. All participants had unilateral progressive resistance training twice per week (total of 10 sessions) for 5 weeks for the exercised arm and then 5 weeks without exercise. During the whole experiment, participants were requested to avoid any tiring physical activity apart from training given during the study. For the untrained arm, the MVIC and 1-RM increased in similar ways after eccentric CT and concentric CT ($p>0.05$). The hypothesis that the effect of concentric CT would be more pronounced among people with eccentric CT compared to those with concentric CT was not valid at the end of the study. After finishing training, the MVIC for both training groups returned to values before training; however, the 1-RM values were preserved for both training groups. For the trained arm, there was an increase in MT only after ET ($p<0.05$), with no increase in MT observed after concentric CT. The muscle strength transfer ratio for MVIC between extremities was higher in the eccentric CT group (90.9 ± 46.7%) compared to the concentric CT group (49.0 ± 30.0%) ($p<0.05$). After 5 weeks without training, the muscle strength of the trained arm in the eccentric CT group was better preserved than in the concentric CT group (25).

The significantly greater strength transfer ratio between extremities for the group receiving eccentric training compared to the group receiving concentric training is an expected result due to the greater reduction in intracortical inhibition of eccentric contraction compared to concentric contraction and provision of intracortical facilitation (26). Additionally, eccentric contraction is known to cause stronger activation by a significant degree in the motor control network formed by the primary, secondary and related motor cortexes compared to concentric contraction (27).

Valdes et al. performed a study comparing the effects of only eccentric training and concentric-eccentric resistance training of the contralateral elbow flexors on the immobilized arm. Thirty healthy participants (18-34 years) were randomly allocated to groups with only immobilization, immobilization and eccentric CT, and immobilization and concentric-eccentric CT. All participants had the non-dominant arm immobilized for 4 weeks (8 hours per day) with eccentric CT group (4 s eccentric contraction) and concentric-eccentric CT group (2 s eccentric-2 s concentric contraction) performed 3 times per week on the dominant (mobile) arm during this period. Parameters like concentric 1 maximum repeat, MVIC strength, biceps brachii surficial electromyography (sEMG) and upper arm circumference measurements were used for assessment. The results of this study observed a greater increase in upper arm circumference, MVIC and muscle activity of the trained (mobile) arm in the group receiving only eccentric training compared to the group receiving concentric-eccentric training. Additionally, the eccentric CT group developed more MVIC and muscle activity in the elbow flexors of the contralateral immobilized arm compared to the concentric-eccentric CT group. The researchers proposed that contralateral eccentric resistance training was a better choice than concentric-eccentric training to bring contralateral effects related to strength and muscle activation to the highest level during immobilization (16).

During maximum eccentric contraction, nearly 50% more strength is produced compared to concentric contraction (28). As a result, it is expected that MVIC strength in the trained arm will be higher in the group receiving only ET. Similarly, the MVIC strength on the contralateral side was higher in the groups receiving only eccentric training. Eccentric training increases cortical stimulability more than concentric training and provides more reduction in cortical inhibition (29). As a result, the higher muscle strength in the group receiving only ET is compatible with the literature.

Kidgell et al. performed a study with the aim of determining whether eccentric or concentric unilateral strength training modulated corticospinal stimulability, inhibition and cross-strength transfer in different ways. For 4 weeks, young adult groups with eccentric exercise, concentric exercise and no training of the right wrist flexor were analyzed for concentric strength, eccentric strength, short-duration intracortical inhibition and changes in silent period duration in the contralateral side (left extremity). After training, a significant strength increase was observed in the exercised extremity in both groups (increases of concentric strength 64% in concentric group and eccentric strength 62% in eccentric group). The cross-strength transfer scope was 28% and 47% in the concentric and eccentric groups, respectively (p=0.031). At the same time, the transcranial magnetic stimulation imaging method identified that eccentric training reduced intracortical inhibition (37%) and silent period duration (15-27%) and increased corticospinal stimulability (51%) for the untrained extremity compared to concentric training (p=0.033). No change was observed in the control group. At maximal intensity, there is a straight model that eccentric training reduces cortical inhibition and silent period duration and thus increases the cross transfer of strength. These findings have important clinical outcomes. Previous research (23,30) showed that unilateral strength training may reduce muscle function loss and atrophy in periods with extremity immobilization and wrist/ankle fractures. More importantly, this study (Kidgell et al.) shows that high effort eccentric training resulted in higher levels of strength transfer modulated by a reduction in corticospinal inhibition (17).

This study found a significant reduction in intracortical inhibition after eccentric training compared to concentric training. Linked to this, the CT effect was more effective. The reason for this positive effect was shown to be the liberation of pyramidal neurons from inhibition due to synaptic efficacy of GABAA receptors in neurons comprising the cortico-cortical networks within the untrained primary motor cortex (31).

4. CONCLUSION

CT has significant potential in terms of understanding and managing the interactions between brain and body. CT provides a low-cost, accessible rehabilitation strategy for individuals who cannot exercise extremities due to injury or neurotrauma. Clinicians may use this review as a road map to develop unilateral rehabilitation interventions encouraging positive results for the affected extremity in patients with asymmetric extremity functions. The implementations may be integrated into sports-patient care at several levels. The experiments included in our research show that unilateral eccentric training supports prominent CT effects compared to concentric training in non-clinical and clinical populations. However, more research and clinical studies will assist in better understanding CT methods and effects.

Conflict of Interest

The authors declare that they have no conflict of interest.

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