의학석사 학위논문

Effect of Superimposed Electromyostimulation with Back Extension on Back Muscle Strengthening: a Pilot Study

요부 신전과 병행한 전기자극이 요부 근육 강화에 미치는 영향: 예비 연구

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박 재 현

Thesis for the Degree of Master of Science
in Rehabilitation Medicine

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Effect of Superimposed Electromyostimulation with Back Extension on Back Muscle Strengthening: a Pilot Study by

Jae Hyeon Park, M.D.

A Thesis Submitted in Partial Fulfillment

of the Requirements for the Degree of Master of Science

in Rehabilitation Medicine

at the Seoul National University College of Medicine

December 2013

Approved by thesis committee:

Professor ____________________ Chairman

Professor ____________________ Vice Chairman

Professor ____________________

학위논문 원문제공 서비스에 대한 동의서

본인의 학위논문에 대하여 서울대학교가 아래와 같이 학위논문 제공하는 것에 동의합니다.

1. 동의사항

① 본인의 논문을 보존이나 인터넷 등을 통한 온라인 서비스 목적으로 복제할 경우 저작물의 내용을 변경하지 않는 범위 내에서의 복제를 허용합니다.

② 본인의 논문을 디지털화하여 인터넷 등 정보통신망을 통한 논문의 일부 또는 전부의 복제.배포 및 전송 시 무료로 제공하는 것에 동의합니다.

2. 개인(저작자)의 의무

본 논문의 저작권을 타인에게 양도하거나 또는 출판을 허락하는 등 동의 내용을 변경하고자 할 때는 소속대학(원)에 공개의 유보 또는 해지를 즉시 통보하겠습니다.

3. 서울대학교의 의무

① 서울대학교는 본 논문을 외부에 제공할 경우 저작권 보호장치(DRM)를 사용하여야 합니다.

② 서울대학교는 본 논문에 대한 공개의 유보나 해지 신청 시 즉시 처리해야 합니다.

논문 제목: Effect of Superimposed Electromyostimulation with Back Extension on Back Muscle Strengthening: a Pilot Study

학위구분: **석사 □ · 박사 □**
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제 출 일: 2014 년　2 월　5 일

서울대학교총장 귀하

Abstracts

Objective: To determine the additional effect of superimposed electromyostimulation (EMS) on back muscle strength in healthy adults

Design: Prospective, single blinded, randomized controlled trial

Subjects: Twenty healthy male participants without low back pain, 20-29 years of age, were recruited.

Methods: In EMS group, surface electrodes were attached to bilateral L2 and L4 paraspinal muscles. Intensity of the stimulation was set for maximally tolerabe intensity. With voluntary contraction of back extensors, EMS was superimposed for 10 seconds (s). Resting period was followed for 20s. In sham stimulation (SS) group, same procedure was applied except stimulation intensity set at the lowest stimulation intensity (5mA). All subjects performed back extension exercise using Swiss-ball, 10 contractions per set, 2 sets in a day, 5 times a week for 2 weeks.

The primary outcome measure was the change in isokinetic strength of the trunk extensor at 60°s^{-1} by using isokinetic dynamometer (Biodex System 3, Biodex Medical Systems, Shirley, NY). In addition, endurance was measured by using Sorensen test. Outcome measures were assessed at baseline and 2 weeks after the each intervention.

Results: After 2 weeks of back extension exercise, peak torque of trunk extensor and endurance increased significantly compared to baseline in both groups ($P<0.05$). The mean increase in the back muscle strength and gain of endurance after 2 weeks was greater in EMS group than SS group although there was no statistical significance.

Conclusion: This study suggests that 2 weeks of back extensor strengthening exercise on Swiss-ball was effective for strength and endurance. Superimposed EMS on back extensor during strengthening exercise could provide additional effect on increasing strength.

Key Words: Electromyostimulation, Back extensors, Muscle strength

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I. Introduction

Electromystimulation (EMS) is inducing muscle contraction electrically usually by surface electrode. EMS is well established for preventing complications by long term disuse[1]. EMS alone or EMS superimposed onto voluntary contraction (VC) has also been proposed to increase muscle strength[2-5]. In previous studies, EMS superimposed onto VC enhanced gain in strength in comparison to VC without EMS[6, 7]. However, previous reports about EMS were studied with quadriceps femoris or biceps brachii[8, 9].

Low back pain (LBP) is a common symptom affecting up to 80% of people in their lives and persists in about 40% of patients 6 months after the onset[10]. Additionally LBP recurs more than 20% within 6 months[11]. In LBP patients, lumbar muscle atrophy and weakness has been reported and back extension exercise is effective for the management of chronic LBP[12-15].

As in quadriceps or biceps brachii muscles in previous report[6, 7], superimposed EMS on back extensor may provide additional strengthening effect. However, to our knowledge, there was no study that examined the effects of back extensor strengthening exercise with superimposed EMS. If superimposed EMS with back extension exercise would be effective for back muscle strengthening, it can be applied to low back pain patients with lumbar muscle weakness. Then, the purpose of the present study is to compare the effects of back extensor strengthening exercise with or without superimposed EMS with single blind randomized controlled trial.

II. Methods

Study design

This is a single blind randomized controlled trial over a 2 week period.

Participants

From August 2011 through July 2012, twenty healthy male participants who met the following criteria were recruited in the study. Healthy non-athlete male adult aged 20 to 29 years, without low back pain during last 1 year were included. The exclusion criteria were as follows: cardiopulmonary disorder, history of surgical procedures on low back area and obese participants whose body mass index (BMI) were over 25. Additionally participants were prohibited to perform any exercise that includes back extension except the exercise protocol performed during the study period. Written informed consent was obtained for each subject before the study. This study was approved by the institutional review board of our institution.

Procedures

All participants were randomly assigned to either the electriomyostimulation (EMS) group (Group A) or the sham stimulation (SS) group (Group B) by the permuted block randomization method. Random permuted blocks of size 2 and 4 were used. All participants received electrical stimulation on their back area. Four electrodes were attached on bilateral L2 and L4 paraspinal muscles in which anodes were placed on both L2 and cathodes on both L4 (Fig. 1-A). Electrical stimulation was delivered with Bio Trac Plus (EMS Physio Ltd., Wantage Oxfordshire, England) which generated asymmetric biphasic pulse with pulse widths of 300μS and a frequency of 100Hz.

In group A (EMS group), the stimulation intensity was set for maximally tolerable intensity. The maximal stimulation intensity was defined as the highest pain or dicomfort tolerable intensity in microamperage (mA) for each participant to be able to perform exercise with stimulation. Participants in group B (SS group) was administered with intensity set at the lowest stimulation intensity (5mA). All subjects performed back extension exercise using Swiss-Ball as shown in Fig. 1-B[16]. In detail, with the participants lying on the Swiss-ball the instructor asked to straighten their trunk slowly with simultaneous electrical stimulation until their back was in line with their legs (concenctic contraction) for 1-2 seconds (s) and maintain their posture (isometric contraction) for 8-9s (Fig. 1-C). Duration of electrical stimulation was 10s. Electrical stimulation was started and stopped with beep sound. A resting period for 20s was followed. The exercsie session was consisted of 10 contractions per set, 2 sets in a day, 5 times a week for 2 weeks. To evaluate the status of fatigue during exercise, we had the participants to record their sense of fatigue after performing 2 sets of exercise each day with numeric rating scale (NRS). NRS 0 was defined as no fatigue and NRS 10 as the greatest fatigue that they have ever experienced. The participants were instructed to stop doing exercise if they experienced newly developed low back pain during the 2 weeks of exercise period.

Outcome measure

The isokinetic measurements of the back extensor torque at $60°s^{-1}$ were measured as the primary outcome using the isokinetic dynamometer (Biodex System 3, Biodex Medical Systems, Shirley, NY) (Fig. 2-A)[17]. The participants sat at the back attachment of the isokinetic dynamometer and were fastened firmly by sacral pad, femur strap, pelvic strap and torso strap. The lower extremities were fixed by compression pad. Feet were placed on foot rest adjusted for participant. The longitudinal spinal axis of subject was approximated with the fixed axis of the back attachment. The knee was adjusted perpendicular to the supporting surface. The participants performed 3 to 5 repetitions of back extension at $60°s^{-1}$ before measurement as warm up test. Participants performed 5 repetitions of back extension at $60°s^{-1}$. The peak torque of repetitions was obtained for the isokinetic strength.

The endurance of back extensor was measured as secondary outcome using Sorensen test (Fig. 2-B)[18]. The participants were asked to hold unsupported trunk horizontally while lying prone on an examination table with arms folded across the chest. Buttocks and legs were fixed to the examination table by strap during the test. The time until which the participant could no longer keep the trunk in horizontal posture was measured as seconds.

The demographic characteristics including age, height, weight, BMI, amount of exercise, history of smoking and alcohol ingestion were obtained before the experiment. The primary and secondary outcomes were measured at baseline and at 2 to 3 days after the completion of 2 weeks of intervention.

Statistical analysis

The participants' characteristics were compared between the two groups by using Mann-Whitney U test for continuous data such as age, height, weight, body mass index (BMI), exercise time per week and baseline outcome measurements. Fisher's exact test was performed for baseline categorical data such as status of smoking and alcohol. The changes of strength and endurance between baseline and post-exercise in each group were tested using Wilcoxon signed rank test. The changes at post-exercise from the baseline were compared between the two groups using the Mann-Whitney U test. P-value of < 0.05 was considered as statistically significant. Analysis was performed using the SPSS software 18.0 (SPSS Inc., Chicago, IL, USA).

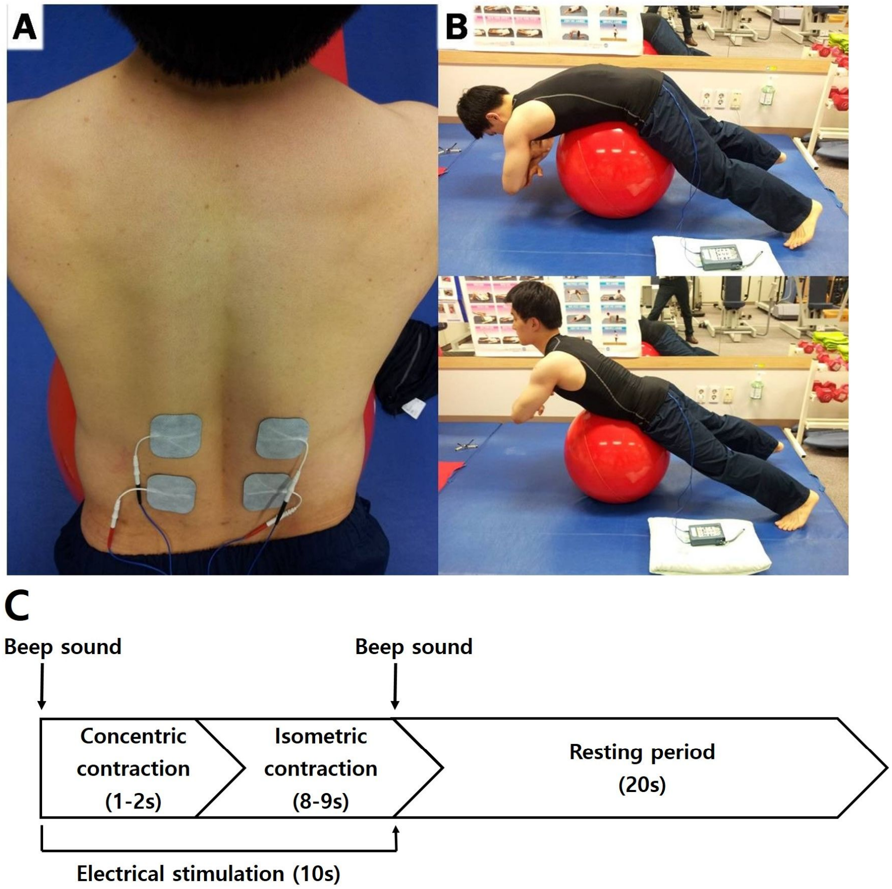

Figure 1. (A) Location of surface electrodes, (B) Back extension exercise using Swiss-ball with superimposed electrical stimulation, (C) Schematic presentation of back extension exercise with superimposed electrical stimulation.

s: Seconds

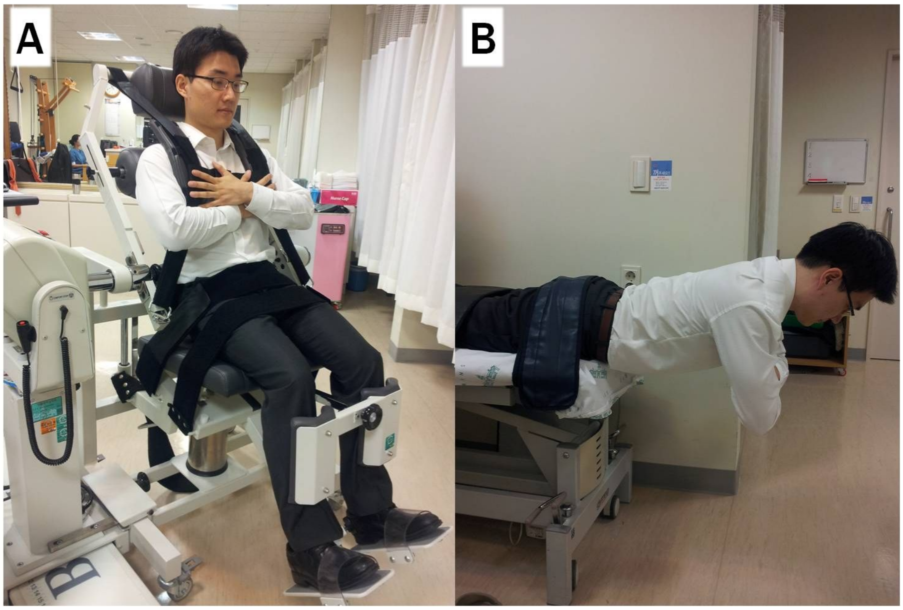

Figure 2. (A) Isokinetic strength measurement of back extensor, (B) Sorensen test for back extensor endurance.

III. Results

Demographic Characteristics

Twenty male participants were assessed and enrolled in this study. (10 subjects in each group). Demographic characteristics of the two groups did not differ significantly (Table 1). Mean values of stimulation intensity were 56.8±2.9mA (mean±SD) in group A (EMS group, maximally tolerable intensity). Mean fatigue after exercise was not different significantly between the two groups (Group A: 2.3±0.5; Group B: 2.6±0.7, p=0.39).

In-group comparison

Changes in strength and endurance parameters for each group are summarized in Table 2. In the group A (EMS group), peak torque of back extensor increased significantly from 289.6±39.1Nm to 369.7±54.4Nm at $60°s^{-1}$ (p=0.005). Endurance determined by Sorensen test increased significantly from 122.0±53.1s to 160.6±72.5s (p=0.005). In the group B (SS group), peak torque of back extensor also increased significantly from 294.3±44.7Nm to

343.7±57.1Nm at 60°s^{-1} (p=0.022). Endurance parameter also improved from 148.9±41.5s to 170.8±34.7s (p=0.047).

Between-group comparison

Changes in peak torque of back extensor after 2 weeks of exercise were greater in group A (EMS group) than group B (SS group): 80.1±41.9Nm and 49.4±52.4Nm at 60°s^{-1}. However, there was no statistically significant difference in the changes of peak torque of back extensor (p=0.143 at 60°s^{-1}) (Fig. 3-A). Changes in endurance after 2 weeks of exercise was also greater in group A (EMS group, 38.6±29.1s) than in group B (SS group, 21.9±25.7s) although there was no statistically significant difference (Fig. 3-B).

Table 1. Baseline Characteristics of the Participants

Characteristics	Group A (EMS group)	Group B (SS group)	p-value
Numbers	10	10	
Age (years)	25.0±2.2	25.3±2.9	.97
Height (cm)	177.5±4.8	175.1±6.1	.32
Weights (kg)	71.1±5.2	69.1±7.6	.53
BMI (kg/m^2)	22.6±1.5	22.5±2.0	.97
Exercise (hours/week)	3.9±1.9	3.5±2.1	.58
Smoking (yes/no)	1/9	1/9	.76
Alcohol (yes/no)	2/8	2/8	.71
Peak torque at $60^{\circ}s^{-1}$ (Nm)	289.6±39.1	294.3±44.7	.80
Sorensen test (s)	122.0±53.1	148.9±41.5	.19

Values are mean±standard deviation

EMS: Electromyostimulation, SS: Sham stimulation, BMI: Body mass index, s: Seconds

Table 2. Changes of Strength and Endurance Parameters for Back Extensor in Each Group

	Group A (EMS group)		Group B (SS group)	
	Baseline	Post-Exercise	Baseline	Post-Exercise
Peak torque at 60°s^{-1} (Nm)	289.6±39.1	369.7±54.4*	294.3±44.7	343.7±57.1*
Sorensen test (s)	122.0±53.1	160.6±72.5*	148.9±41.5	170.8±34.7*

Values are mean±standard deviation

EMS: Electromyostimulation, SS: Sham stimulation, s: Seconds

*Statistically significant compared with baseline ($p<0.05$, Wilcoxon signed rank test)

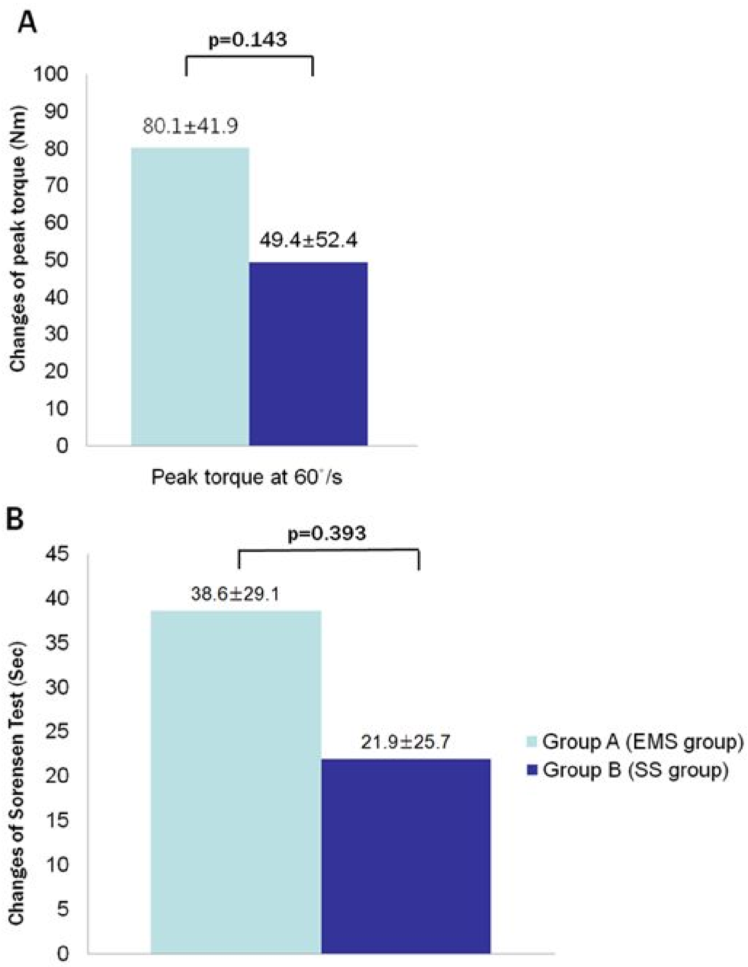

Figure 3. Comparison of change in strength (A) and endurance parameters (B) for back extensor between groups after exercise. Values are mean±standard deviation.

EMS: Electromyostimulation, SS: Sham stimulation, s: Seconds

IV. Discussion

This study is the first randomized controlled trial that investigated the effect of EMS superimposed onto back extension strengthening exercise. The primary findings of this study are (1) that 2 weeks of the back extensor strengthening exercise with or without superimposed EMS improved in both strength and endurance and (2) that the mean increase in strength and endurance was greater in superimposed EMS group although statistically insignificant.

Strength and endurance exercise of trunk extension improved after 12 weeks of Swiss-ball core strengthening training in sedentary women[16] and after 8 weeks in chronic LBP patients[19]. In this study, back extension strengthening exercise was also effective in increasing back extension strengthening. However, the duration of exercise was 2 weeks that was shorter than previous studies. The initial strength gain in a few weeks of exercise is well known as a result of neural adaptation rather than muscle hypertrophy[20-22].

Neural adaptation induced by EMS has been suggested as an underlying mechanism of strength gain in short term EMS training[2, 23, 24]. It has been reported that there were strength gain without muscle hypertrophy and increased EMG activity observed in EMS training lasting 4 weeks[2, 25]. Level of neural adaptation has been reported supraspinal which was caused by somatosensory input rather than spinal excitability[24]. Several functional magnetic resonance studies showed activation of brain regions after EMS[26, 27]. Furthermore, there was a dose-response relationship between the activation of brain regions and EMS intensity[28]. EMS superimposed onto VC was reported to activate more brain regions than EMS alone[29]. However the effect of brain activation on gain of strength is not fully understood yet. In our study, it is presumed that the strength gain of back extensor results from the neural adaptation.

Palliad et al. reviewed the effects of EMS superimposed onto VC[8]. They concluded that strength gain after superimposed EMS onto VC would be comparable to VC without EMS. However, they did not conduct meta-analysis comparing the superimposition of EMS onto VC and VC without EMS. Furthermore, Willoughby and Simpson[6] reported that EMS superimposed onto VC promoted more gain of strength than VC alone in biceps brachi after 6 weeks of 3 times a week training. They hypothesized that EMS could promote more recruitment of motor units. Additionally, Herrero et al.[7] showed that mean percentage change of isometric knee extension strength in EMS superimposed onto VC was greater than that in VC alone without statistical significance at 3 to 4 days after the end of training. However EMS superimposed onto VC increased more isometric knee extension strength than VC alone at 2 weeks after the completion of 4 week training period. It was proposed that EMS superimposed onto VC is more effective after the detraining period, a time required for the muscle to adapt to training. Our results also show greater increase of mean peak torque in EMS group without statistical significance. The statistical insignificance of our study might be caused by insufficient detraining period for back extensor muscles.

The limitations in this study are as followings. First, the number of participants was small. This study is the first randomized clinical pilot trial to investigate the effects of superimposed EMS on back extensor strength. Therefore sample size was estimated by using normal isokinetic strength values of back extensor. Based on the results of our study, 39 subjects in each group total 78subjects are required to obtain statistical power. However, we planned to enroll only 10 subjects in each group as a pilot study at the beginning of this study because there were no published report that has studied superimposed EMS on back extensors. Second, the duration of training was short to identify the effect of the superimposition EMS on muscle hypertrophy. As a pilot study, our purpose was to find any possibility of using superimposed EMS on back extensors on human subjects. The duration of treatment was minimized that we thought it is enough to show the effect. Third the outcome measurement was not carried out after the detraining period. Fouth deep spinal muscles such as multifidi were unable to stimulate by EMS which, to the knowledge of the authors, is still impossible without causing pain in normal subjects. Further study including large number of participants, longer duration of training and the detraining period is needed.

V. Conclusion

In summary, the results of our study demonstrated that 2 weeks of back extensor strengthening exercise was effective to gain strength. The EMS superimposition on back extensor strengthening exercise could provide additional effect on increasing strength.

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국문초록

목적: 건강한 성인에서 요부 신전과 병행한 전기자극이 요부 근육 강화에 미치는 영향을 확인한다.

연구 디자인: 전향적, 단일맹검, 무작위 대조군 연구

연구 대상: 총 20명, 20-29세 요통의 병력 없는 건강한 성인

방법: 전기자극군(EMS group)의 경우 표면 전극을 요추 2번과 4번 척추주위근에 부착하고 피시험자가 참을 수 있는 최대 강도로 전기자극을 적용하였다. 요부 신전근을 10초간 수축하며 동시에 전기자극을 시행 후 20초 휴식기를 가졌다. 허위자극군(Sham stimulation)의 경우 동일한 방법으로 운동을 시행하며 최저강도의 전기자극(5mA)을 적용하였다. 모든 피험자는 스위스볼을 이용한 요부 신전 운동을 한 세트에 10회, 하루에 두 세트, 일주일에 5회, 2주간 시행하였다.

일차 검사 결과는 등속성 다이나모미터(Biodex System 3, Biodex Medical Systems, Shirley, NY)를 이용하여 60° s^{-1}와 180° s^{-1}에서 체간 신전근의 등속성 근력의 변화를 측정하였다. 추가로 지구력을

소렌슨 검사 (Sorensen test)를 통해 측정하였다. 결과는 운동 전과 2주간의 운동 후에 측정하였다.

결과: 2주의 요부 신전 운동 후 체간 신전의 최대 토크값(torque)과 지구력은 두 군 모두에서 기저에 비해 통계적으로 유의하게 증가하였다(P<0.05). 요부 신전근의 등속성 근력과 지구력의 평균값 변화는 전기자극군(EMS group)이 허위자극군(Sham stimulation)에 비해 컸으나 통계적으로 유의하지 않았다.

결론: 본 연구를 통해 2주의 스위스볼을 이용한 요부 신전 강화 운동이 근력 지구력에 효과적임을 알 수 있었다. 또한 요부 신전 강화 운동과 병행한 전기자극이 근력을 향상시키는데 추가적인 도움이 될 수 있는 가능성을 관찰할 수 있었다.

주요어 : 전기 자극, 요부신전근, 근력

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