EFFICACY OF THERAPEUTIC ELECTRICAL MUSCLE STIMULATION TREATING HAMSTRINGS MUSCLES STRAIN BY FUNCTIONAL SPORTS REHABILITATION PRESCRIBED PROTOCOLS

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ABSTRACT

Electrical neuromuscular stimulation (ES) was first described over 35 years ago. Application of an electrical current to the skin stimulates lower motor nerves and muscle fibres resulting in improved contractility and greater muscle bulk. The aim of this study was to investigate the effects of EMS training on hamstring muscle strength. The study utilized a quantitative experimental research design. The intervention was assessed using a Humac Norm 7000 Dynamometer. A Chattanooga Intelect Mobile Combo muscle stimulator was used for the 4-week EMS training based on the 10-50-10 or "Russian Protocol". Inclusion criteria: The were being free of any specific injury, a body mass index (BMI) of less than 30 kg/m2, active individuals (trained three or more days per week for at least 30 minutes per day), aged between 18 and 25 years and who had a hamstring to quadriceps ratio (H/Q) of less than 60% at an isokinetic testing velocity of 60°/s. Descriptive statistics were performed and pre- to post-test changes were analyzed using dependant t-tests. Statistical significance was set at p≤0.05. The Following 4-weeks' intensive EMS training there were statistically significant increases in both the PTQ and work performed during concentric isokinetic knee flexion at 60°/s. There was also a 21.4% increase in the H/Q ratio following the EMS training.

KEYWORDS: EMS, the H/Q ratio.

INTRODUCTION

Neuro muscular Electrical stimulation originated in ancient Greece thousands of years ago. Aetius, a Greek physician, allegedly prescribed gout treatment in the form of shocks from an electric fish[6]. Early attempts to treat muscle paralysis with electricity have a history that spans over 2000 years[5]. The nineteenth century Duchenne had expanded the technique to using surface electrodes placed over nerve trunks and motor points. He also discovered that electrical stimulation could relax spastic muscles.

In 1971, the interest of US scientists in EMS grew following reports by from the then USSR that EMS training resulted in strength increases of 20% to 40% in already highly trained athletes. Historically, most research studies involving EMS training have focused on isometric training of the quadriceps femoris muscle group in both patient and healthy populations[2].

More recently, the effects of EMS alone or in combination with voluntary exercise training have been studied in a variety of patient populations which included patients recovering from total knee replacement, anterior cruciate reconstruction, knee osteoarthritis and stroke patients[1].

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Currently, there is no consensus regarding the therapeutic effectiveness of EMS in a wide variety of patient populations[7]. However, evidence from several randomized clinical trials have demonstrated that EMS combined with voluntary exercise is effective in strengthening the quadriceps femoris muscle group during the rehabilitation of anterior cruciate reconstructions[8]. There are also promising trends emerging for the inclusion of EMS during rehabilitation (especially when combined with voluntary exercise), but more randomized clinical trials are needed to make accurate conclusions on its effectiveness[2].

In healthy populations, most of the researchers conducting EMS studies have focused on the quadriceps femoris muscle group[9]. Other muscle groups that have been studied include the abdominal muscles, the elbow muscles, and the ankle plantar flexors[10]. Varying results have also been reported in healthy populations using EMS training as a strengthening modality[3]. While some researchers reported no or a very small increase in muscle strength following EMS training, others found significant increases in muscle strength[11].

Compared to the studies using EMS training for the quadriceps, there is little information available regarding the effect of EMS strength training on the hamstring muscle group[12]. Thus, the aim of this study was to investigate the effects of EMS training on hamstring muscle strength[4].

METHODOLOGY

RESEARCH DESIGN

The study utilized an experimental research design.

PARTICIPANTS

Inclusion criteria were being free of any injury, a body mass index (BMI) of less than 30 kg/m^2, active individuals (trained three or more days per week for at least 30 minutes per day), aged between 18 and 25 years and who had a hamstring to quadriceps ratio (H/Q) of less than 60% at an isokinetic testing velocity of 60°/s. Fourteen participants did not meet the inclusion criteria at the start of the study or withdrew from the study during the four weeks of intervention. Eight participants were included into the experimental group (EG) (3 men and 5 women) and eight participants were allocated to the control group (CG) (1 man and 7 women).

Each participant signed an informed consent approval form and ethical clearance was obtained from the Institute of Review board. Height and weight were measured using a calibrated scale and a standard wall stadio meter. BMI (kg/m2) was calculated by dividing the body mass in kilogrammes (kg) with the height in metres (m) squared.

If one leg had an H/Q ratio less than 60% and the other did not, EMS training was only conducted on the leg with the H/Q ratio lower than 60%. Therefore, we obtained two sets of subject data from each participant if both legs' H/Q ratios were lower than 60% and thus, both hamstring muscle groups needed to be trained with EMS. Both the left and right legs of each participant in the CG were tested, thus obtaining 16 different values.

ISOKINETIC TESTING

Participants warmed up prior to the isokinetic testing by cycling easy for 5 minutes (men cycled at 50 Watts and women at 25 Watts). Positioning was according to the standardized protocol described with the exception that hip flexion was at an angle of 120° instead of 90°[13]. This was done to allow for full knee extension from a seated position. Isokinetic testing was performed using a calibrated Humac Norm 7000 Isokinetic Dynometer[14]. The results were corrected for the effects of gravity using the customized Humac software. The range of motion was set between 90° knee flexion and 10° (0°: full knee extension). Each participant completed five reciprocal (knee extension and flexion) familiarization repetitions; two repetitions at 50%, two repetitions at 75% and one repetition at 100% of voluntary effort. A 10-second rest period was followed by five maximum effort repetitions. Participants received verbal encouragement to give their maximum effort and were also allowed visual feedback during the test. The highest of the five repetitions was used for the analysis. Variables used for analysis included peak torque (PTQ-Nm), work (J) and H/Q ratio (%)[15].

Participants from the CG and EG underwent exactly the same testing than at pre-test, following the 4-week EMS intervention period of the EG.

INTERVENTION

Each intervention session was started with a 5-minute cycle (25/50 Watts) to warm up. A Chattanooga Intelect Mobile Combo muscle stimulator (Chattanooga Group International, Tennessee, USA) was used for the EMS training. The electrical stimulator delivered a constant current symmetrical biphasic waveform with a pulse duration of 100 µs and a frequency of 50 Hz. A 2-second ramp and fall time was utilized. Commercially available adhesive electrodes (Multistik 5cm round) were used. Each EG participant was allocated his/her own electrodes to avoid any chance of contamination. The participants lay prone on a plinth, with the knee joint flexed at 90°, during the EMS training.

Prior to placing the electrodes, the skin was prepared by rubbing it with alcohol swabs to remove any oil or cream that could hinder the conduction of the electrical current. The positive electrode was placed just distally to the origin of the hamstrings (ischial tuberosity) and the negative electrode was placed on the middle of the posterior thigh between the muscle bellies of the semitendinosus and long head of biceps femoris.

Each EMS session consisted of 10 muscle contractions. Each contraction lasted 10 seconds and a rest interval of 50 seconds was observed between each contraction (10-50-10 or "Russian Protocol"). The EMS intensity (mA) was set according to each participant's tolerance level. The participant's lower leg was held still at 90° of flexion by the researcher to prevent uncontrolled movements in the knee joint. Participants were encouraged to increase the EMS intensity for every session. Participants were monitored for pain and discomfort during and after the EMS session; if needed the intensity was adjusted downwards. After each session the researcher stretched the participant's hamstring muscle group for one minute.

The EMS intervention lasted for four weeks and each EG participant received at least 10 EMS sessions. The maximum amount of EMS sessions to talled 12 sessions. At least one day's rest was observed between successive EMS training sessions to prevent undue fatigue and to allow for strength adaptations to take place. Participants were encouraged to continue with their normal everyday activities during the intervention period. On completion of the EMS intervention, at least two days' rest were observed before post testing occurred in order to allow for complete recovery following the last EMS training session.

Descriptive statistics was used and pre- to post-test changes were analyzed using dependent t-tests. Statistical significance was set at $p \leq 0.05$.

RESULTS

Thirty students volunteered for the study, but only eight complied with all the EMS inclusion criteria and they were allocated to the EG. From the remaining 22 student volunteers, eight randomly selected students were assigned to the CG (Table 1).

The CG's knee flexion PTQ at pre-test was 73.15 Nm (±36.95) and 71.08 Nm (±30.63) at post-test. Thus, there was a non-significant difference of -1.14% (p=0.47) in the CG. The EG participants had a pre-test mean knee flexion PTQ of 65.00 Nm (±28.36) and at the post-test, following the 4-weeks of EMS intervention, the knee flexion PTQ increased significantly with 14.40% (p=0.001) to 73.70 Nm (±30.63) (Table 2 and 3; Figure 1 and 2).

TABLE 1: PARTICIPANT CHARACTERISTICS BETWEEN THE CONTROL GROUP (CG) AND THE EXPERIMENTAL GROUP (EG)

Variable	Mean (±SD)		Minimum		Maximum	
	CG	EG	CG	EG	CG	EG
Gender	1M & 7F	3M & 5F				
Age (years)	22.88 ɫ (±1.81)	19.80 (±0.92)	20.00	19.00	26.00	22.00
Height (m)	1.628 (±0.099)	1.647 (±0.066)	1.490	1.580	1.820	1.770
Weight (kg)	55.50 (±11.45)	58.90 (±13.73)	43.00	47.00	81.00	86.00
BMI (kg/m^2)	20.78 (±2.20)	21.46 (±3.11)	17.001	18.83	24.450	27.45

SD: standard deviation; ɫ Significant difference between the CG and the EG ($p \leq 0.05$)

In terms of knee flexion work, there was a significant increase (p=0.002) from 68.30 J (±37.17) at pre-test to 81.30 J (±33.54) at post-test (i.e. a 26.51% increase), following the 4-weeks of EMS intervention. There was no significant change in knee extension PTQ or work done from pre- to post-test. The EG H/Q PTQ ratio was 48.08% (±6.08) at pre-test, but it increased significantly (p=0.001) with 21.14% to 58.12% (±10.15) at post-test. The EG's H/Q work ratio also increased significantly (p=0.003) by 26.84% from 46.11% (±8.51) at pre-test, to 58.22% (±12.33) at post-test. There were no significant changes in either the H/Q PTQ or H/Q work ratio of the CG (Table 2 and 3; Figure 1 and 2).

TABLE 2: PRE- AND POST-TEST ISOKINETIC RESULTS FOR THE CONTROL GROUP (CG) AND THE EXPERIMENTAL GROUP (EG)

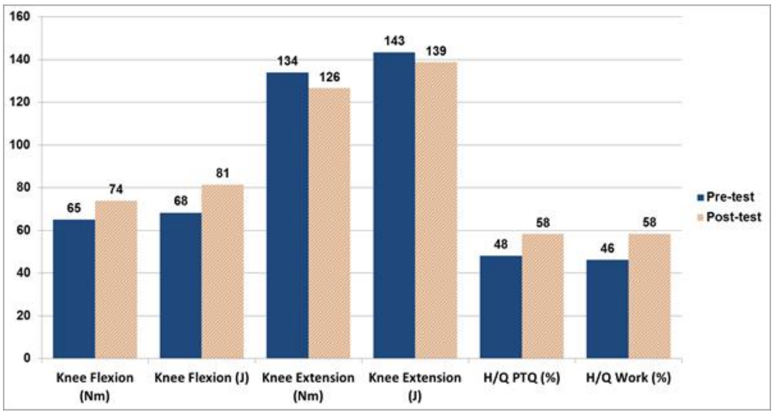
Variable	Pre-Test Mean (SD)		Post-Test Mean (SD)		% Change		p-value	
	CG	EG	CG	EG	CG	EG	CG	EG
Knee Flexion								
PTQ (Nm)	73.15 (36.95)	65.00 (28.36)	71.08 (33.11)	73.70 (30.63)	-1.14	14.40	0.47	0.001*
Work (J)	84.46 (50.67)	68.30 (37.17)	82.77 (39.72)	81.30 (33.54)	4.48	26.51	0.76	0.002*
Knee Extension								
PTQ (Nm)	112.69 (52.26)	133.90 (49.96)	110.62 (45.01)	126.40 (50.10)	1.12	-3.58	0.74	0.375
Work (J)	119.69 (50.67)	143.30 (59.23)	120.15 (39.72)	138.60 (45.84)	4.66	0.68	0.95	0.581
H/Q ratios								
H/Q PTQ ratio (%)	64.80 (10.68)	48.08 (±6.08)	63.87 (12.56)	58.12 (10.15)	-0.96	21.14	0.71	0.002*
H/Q Work ratio (%)	69.08 (11.03)	46.11 (±8.51)	68.74 (12.54)	58.22 (12.33)	0.37	26.84	0.90	0.003*

SD: standard deviation; PTQ: peak torque; H/Q: knee flexion/extension; * Significant difference between Pre- and Post-test ($p \leq 0.05$)

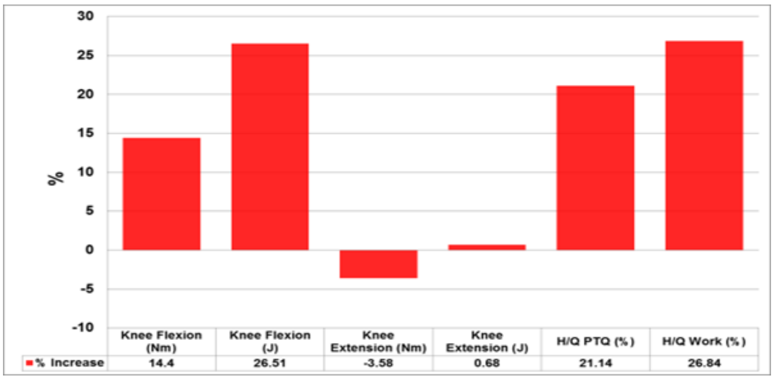
TABLE 3: INTRA-GROUP (PRE-TEST VS. POST-TEST) AND INTER-GROUP (CG VS. EG) DIFFERENCES

	p-value		p-value	p-value
	CG	EG	Pre-Test	Post-Test
Knee Flexion				
PTQ (Nm)	0.47	0.001*	0.556	0.846
Work (J)	0.76	0.002*	0.388	0.924
Knee Extension				
PTQ (Nm)	0.74	0.375	0.335	0.444
Work (J)	0.95	0.581	0.358	0.381
H/Q ratios				
H/Q PTQ ratio (%)	0.71	0.002*	0.000 ɫ	0.238
H/Q Work ratio (%)	0.90	0.003*	0.000 ɫ	0.058

PTQ: peak torque; H/Q: knee flexion/extension; * Significant difference between Pre- and Post-test ($p \leq 0.05$); ɫ Significant difference between the CG and the EG ($p \leq 0.05$)



GRAPH 1: PRE- AND POST-TEST ISOKINETIC VALUES FOR THE EG



GRAPH 2: PERCENTAGE INCREASES FOLLOWING FOUR WEEKS OF EMS TRAINING IN THE EG.

DISCUSSION

Previous research on EMS mostly reported on training of the quadriceps muscle group reported an increase of 21.2% in isometric knee extension PTQ, 21.7% in isokinetic knee extension PTQ at 60°/s and a 15.6% increase at 180°/s after four weeks of isometric EMS training of the quadriceps femoris[16]. The present study also reported significant increases of between 13.2% and 20.7%in both isometric and isokinetic PTQ of the quadriceps femoris muscle following 10 EMS training sessions. Thus, there seems to be general consensus that EMS alone or in combination with voluntary exercise is an effective mode of muscle strengthening[17]. Since very few researchers have used EMS on the hamstrings, the aim of the present study was to investigate whether EMS training would be effective in strengthening the hamstring muscles.

The present study utilized four weeks' EMS strength training of the hamstring muscle group in participants who demonstrated less than "ideal" H/Q ratios (<60%). The results were extremely favorable. Following the EMS training, there was a 14.4% increase in isokinetic knee flexion PTQ (Nm) and a 26.51% increase in isokinetic work (J) performed by the hamstrings. The EG's H/Q ratio increased by 21.14% (from 48.08% at pre-test to 58.12% at post-test). Thus, four weeks of EMS training was effective in strengthening of the hamstring muscle group.

A low H/Q ratio may to increase the risk for knee injuries, especially in athletes who are involved in sports that require sprinting, cutting, landing and rapid changes in direction like rugby, football, basketball and netball. Since isokinetic testing provides information on muscle performance during open-chain-kinetic contractions, some researchers may question the transferability of isokinetic strength gains to functional performance. However, the significant increases in functional performance after EMS training[18]. He showed that four weeks of EMS training resulted in an increase of 27.3% in one repetition maximum calf raises and 20.5% increase in leg power determined by the Margaria-Kalamen method[19].

The effectiveness of EMS on hamstring muscle strength training in the present study may provide athletes with an additional mode for correcting low H/Q ratios. Clinicians may utilize EMS to increase hamstring muscle strength especially during the early phases of musculo-skeletal rehabilitation. Future research should investigate the effects of EMS training in larger and varied samples and also on other muscle groups.

CONCLUSION

Following 4-weeks' intensive EMS training there were statistically significant increases in both the PTQ and work performed during concentric isokinetic knee flexion at 60°/s. There was also a 21.4% increase in the H/Q ratio following the EMS training. Future research may be conducted on larger samples to verify these findings. Considering the results of the present study and those of previous research, both the quadriceps and hamstring muscle groups are responsive to EMS strength training.

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