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EFFECT OF PULSED MAGNETIC FIELD ON PEAK TORQUE OF QUADRICEPS/HAMSTRING MUSCLES AND KNEE PROPRIOCEPTION IN ATHLETIC SUBJECTS: A RANDOMIZED CONTROLLED STUDY

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ABSTRACT

Background: Many therapeutic uses for Pulsed magnetic fields have been extensively studied. Beneficial effects on the musculoskeletal system were established including bone healing, pain relief, and inflammatory conditions. The study aimed at investigating the possible effects of the pulsed magnetic field on quadriceps muscle torque, hamstring muscle torque and knee proprioception accuracy in athletic subjects.

Methods: A randomized controlled trial which was carried out at the Faculty of Medical Rehabilitation Sciences, Taibah University, Saudi Arabia. Thirty healthy male athletic subjects, aging from 18 – 24 years were divided into two groups, study group (15 subjects) & control group (15 subjects). The pulsed magnetic field was applied for subjects of intervention group, while control group participants received sham pulsed magnetic field for 12 sessions over a period of 4 weeks. Quadriceps muscle torque, hamstring muscle torque & knee proprioception accuracy were measured before & after treatment for all participants using Biodex system 4 pro isokinetic dynamometer.

Results: Multiway ANOVA was carried out to detect any significant differences within and between groups. Statistically significant differences between study and control groups were found after pulsed magnetic field application in quadriceps peak torque (at 60 and 120deg/sec) & hamstring peak torque (at 60 and 120deg/sec) and in knee proprioception accuracy (p-value was 0.004, 0.0001, 0.02, 0.03, 0.0001 respectively).

Conclusion: Pulsed magnetic field has beneficial effects on quadriceps muscle peak torque, hamstring muscle peak torque and knee proprioception accuracy in healthy athletic subjects and can be advised as an adjunctive tool in rehabilitation programs.

Keywords: Pulsed Magnetic Field, Muscle Torque, Knee Proprioception Accuracy.

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INTRODUCTION

Pulsed electromagnetic fields have been extensively used for therapeutic purposes for many years, mainly for their positive effects on bone healing (Vallbona et al, 1999) [1], fibromyalgia (Thomas et al, 2007) [2], and knee osteoarthritis (Nicolakis et al, 2002) [3]. Pulsed electromagnetic field (PEMF) was documented to have beneficial effects in pain relief, healing of wounds and ulcers and treatment of inflammatory diseases of the musculoskeletal system (Quittan et al, 2004) [4].

The muscle strength has a very important role in everyday life of every human to allow good performance of activities of daily living such as walking & other activities (Perry, 1993 and Bohannon 1997) [5,6]. Sufficient muscle strength is very important for every day's life activities of healthy subjects such as walking & other activities (Perry, 1993) [5]. The importance of muscle strength increases drastically in athletes to help them achieve the best-aimed sport performance. There is a strong relationship between increasing muscle power and improvement of sport performance (Wisløff1 et al, 2004) [7]. Therefore, there is an important need for using a reliable and accurate testing tool for the measurement of muscle performance parameters to detect individual's abilities and limitations (Thompson et al, 1999) [8].

One of the most accurate measuring tools for testing muscle performance parameters is the isokinetic dynamometry. The use of isokinetic machines in measuring dynamic muscle strength has increased considerably (Lord et al, 1992, Rochcongar et al, 1988, Akima et al, 2001 and Westing et al, 1988) [9-12]. This increasing interest in isokinetic testing as a measure of muscle performance may be attributed partly to that isokinetic dynamometry can give correct and precise data concerning the dynamic nature of muscle contraction & also due to isokinetic measurement was proven to be extremely accurate and repeatable (Hislop, 1967 and Ostering 1998) [13,14]. One of the most valuable somatic senses of the nervous system is proprioception. Proprioception is a combination of kinesthesia or movement sense which inform the nervous system about rate and direction of movement, and position sense, which determine the orientation of the body parts with respect to another (Grob et al, 2002) [15]. Proprioception it is a key component of active joint stability, because afferent signals indirectly induce and modify the efferent response that allow the neuromuscular system to keep a balance of stability and mobility. In essence, active joint stability is the "product" of the proprioceptive system (Laskowski et al, 1997) [16]. Proprioception has a role in the maintenance of joint stability and prevention of joint and muscle trauma. Improvement of proprioception accuracy can be positively reflected on muscle performance in sport.

There is much debate about the impact of magnetic field on neuromuscular system and microcirculation (Malikova et al, 1989, Krylov et al, 1990, Bickford et al, 1987 and Smith et al, 2004) [17-20]. If beneficial effects for the pulsed electromagnetic field (PEMF) on the neuromuscular system can be proved, this may be implemented in training programs that target muscle performance parameters such as muscle strength and endurance. So this controlled trial was conducted to examine the effects of magnetic field on quadriceps muscle torque, hamstring muscle torque and knee proprioception accuracy in athletic subjects.

MATERIALS AND METHODS

A randomized controlled study to examine the possible effects of the pulsed magnetic field on quadriceps muscle torque, hamstring muscle torque and knee proprioception accuracy in athletic subjects. A computer program generated a random list, with each consecutive subject referred to the study assigned to either intervention group or control group according to that list.

Subjects:

Thirty healthy male athletic subjects, aging from 18 – 24 years free of any musculoskeletal or neurological problems were randomly selected from the students of the college of medical rehabilitation sciences, Taibah University, 2016 to participate in this study. Subjects were excluded if they have a history of recent trauma to the lower extremities, musculoskeletal or neurological injury with residual deficits, a metabolic or vascular disease with a neurological component such as diabetes, previous history of infective inner ear problems with related deficits in equilibrium. All subjects accepted to join study by completing an informed consent form. More subjects than needed were selected, to compensate for any drop-outs (see, Figure 1: Study flow chart). A computer program generated a random list, with each consecutive subject referred to the trial allocated to either study group A or control group B according to that list. The first group (intervention group) received pulsed magnetic field over knee area for 12 sessions over a period of 4 weeks (3 sessions/week). The second group (control group) received sham pulsed magnetic field over knee area (the pulsed magnetic field device was not turned ON during the application).

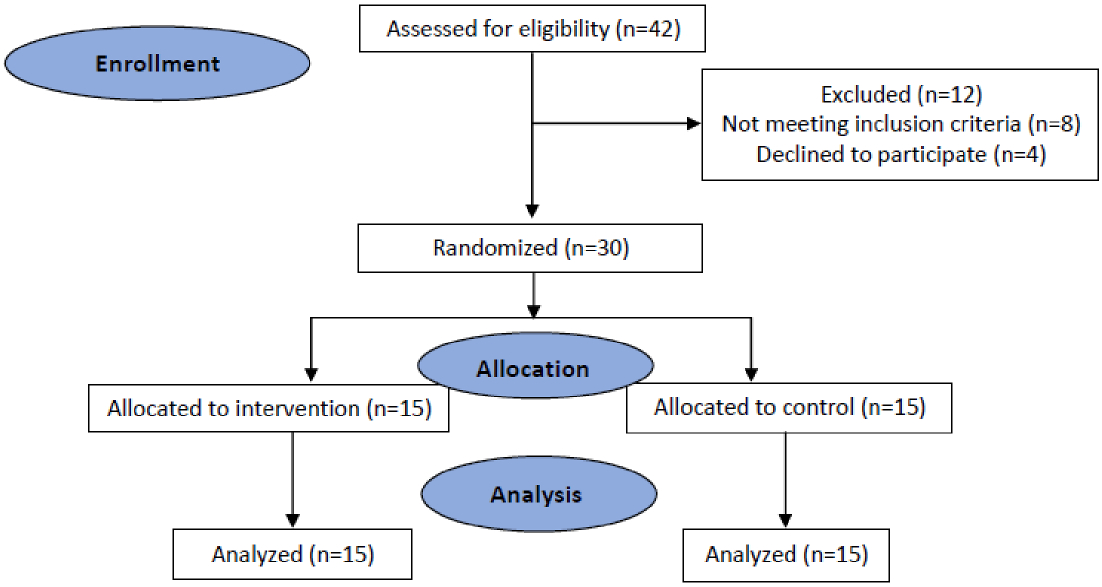

Figure 1: study flow chart

Measurement procedures

Quadriceps/hamstring muscle torque & proprioception accuracy of the knee joint were measured before and after treatment by using Biodex isokinetic dynamometer 4 Pro (Biodex Medical Inc, Shirley, NY).

Measuring quadriceps/hamstring torque:

All subjects were tested by using Biodex Isokinetic dynamometer at two angular velocities (60 & 120 degrees per second) for the knee extensor/flexor group during isokinetic contraction (isokinetic mode) with the subject's hips slightly reclined posteriorly for about 10 to 15 degrees, and knees flexed 90 degrees. A warm-up through doing two light contractions of extension/flexion at 120 degrees per sec and two medium contractions of extension at 120 degrees per sec. After warming up, subjects were requested to push their dominant legs forwards using maximal effort against the lever arm for five repetitions of extension/flexion at 60 degrees per sec. then a rest period of sixty seconds was given. Another five repetitions of extension/flexion at 120 degrees per sec, with sixty seconds rest.

Knee repositioning accuracy measurement:

Active repositioning test as a measure of proprioception accuracy was assessed for dominant knees of both groups by using the Biodex isokinetic dynamometer 4 Pro. The validity and reliability of this test were documented [21,22]. The anatomical reference angle or the target angle was set at 45°. Each subject was asked to actively move tested leg to target angle (45°), then the leg was fixed by the device for 10 seconds as a teaching process. After that, each subject was requested to actively move the tested leg to the predetermined angle (45°). Three trials with rest thirty seconds. The absolute error which is angular differences between the preset angle and the participant's perceived end range position was recorded in degrees and used for statistical analysis [23].

Treatment procedures:

Pulsed magnetic field device (ASA magnetic field instrument, Italy) was used for delivering magnetic field treatment. Subjects of the first group (intervention group) received pulsed magnetic field over knee and thigh areas for 12 sessions over a period of 4 weeks (3 sessions/week). Removal of metals or things that can be affected by a magnetic field was assured prior to magnetic field application. Each participant was requested to assume a lying posture on the treatment bed. The device was aligned directly over knee and thigh area. The treatment parameters were set as 15 Hz frequency, 20 gauss amplitude, and 20 minutes as a total treatment duration [24]. Subjects of the second group (control group) received sham pulsed magnetic field over knee and thigh areas for 20 minutes.

Statistical Analysis:

Data collected were analyzed by the SPSS version 20.0. Quadriceps muscle peak torque, hamstring muscle peak torque in N.M and the absolute error was calculated and used for statistical analysis. Mixed MANOVA was conducted for comparing quadriceps muscle peak torque, hamstring muscle peak torque and repositioning accuracy between before and after magnetic field application within and between groups. The P value was set at ≤ 0.05).

RESULTS

Subject characteristics:

The mean and standard deviation were 21.6 ± 1.53 yrs, 72.9 ± 8.03 kg, and 164.55 ± 7.09 cm for age, weight, and height of study group were respectively, while in the control group were 22.5 ± 1.93 yrs, 70.7 ± 6.39 kg, and 163.65 ± 8.22 cm respectively, with no significant difference between both groups ($p > 0.05$). (Table 1)

Table 1: *Descriptive statistics and t-test for the mean age, weight, and height of study and control groups*

	Study group	Control group	MD	t- value	p-value
	$\overline{X}$ ±SD	$\overline{X}$ ±SD			
Age (years)	21.6 ±1.53	22.5 ±1.93	-0.9	-1.63	0.11*
Weight (kg)	72.9 ±8.03	70.7 ±6.39	2.2	0.95	0.34*
Height (cm)	164.55 ±7.09	163.65 ±8.22	0.9	0.37	0.71*

$\overline{X}$, Mean; SD, standard deviation; MD, Mean difference; p-value, level of significance. *Non-significant

- Comparison between groups:

Knee extensors and flexors peak torque

- No significant difference was detected between both groups in Knee extensors and flexors peak torque at 60° and 120°/sec before treatment ($p > 0.05$). Comparison between both groups after treatment showed a significant increase of quadriceps and hamstring peak torque in the study group compared to control group at both velocities ($p < 0.05$) (Table 2).

Repositioning accuracy

- No significant difference was detected between both groups in repositioning accuracy before treatment ($p > 0.05$). After treatment, the comparison between both groups revealed a significant decrease of absolute error in the study group compared to control ($p < 0.05$) (table 2).

Table 2: *Comparison between study and control groups pre and post-treatment:*

	Study group	Control group			
	$\overline{X}$ ±SD	$\overline{X}$ ±SD	MD	t-value	p-value
Pre-treatment					
Flexors peak torque at 60°/sec (Nm)	79.46 ± 16.09	82.38 ± 14.61	-2.92	-0.51	0.6*
Flexors peak torque at 120°/sec (Nm)	43.54 ± 13.8	42.38 ± 14.61	1.16	0.22	0.82*
Extensors peak torque at 60°/sec (Nm)	120.1 ± 21.72	118.77 ± 23.23	1.33	0.16	0.87*
Extensors peak torque at 120°/sec (Nm)	92.44 ± 25.06	86.63 ±17.83	5.81	0.73	0.47*
Repositioning accuracy	3.8 ± 0.71	4.04 ± 0.59	-0.24	-0.97	0.33*
Post-treatment					
Flexors peak torque at 60°/sec (Nm)	98.42 ± 14.43	85.98 ± 15.02	12.44	2.31	0.02**
Flexors peak torque at 120°/sec (Nm)	58.54 ± 13.56	47.11 ± 14.42	11.43	2.23	0.03**
Extensors peak torque at 60°/sec (Nm)	151.5 ± 23.94	124.3 ± 24.15	27.2	3.09	0.004*
Extensors peak torque at 120°/sec (Nm)	122.42 ± 22.24	92.16 ± 18.84	30.26	4.02	0.0001**
Repositioning accuracy	2.01 ± 0.68	3.04 ± 0.64	-1.03	-4.24	0.0001**

$\overline{X}$, Mean; SD, standard deviation; MD, mean difference; p-value, level of significance. * Nonsignificant. ** Significant.

- Results of study group:

Knee extensors and flexors peak torque

- A significant increase in hamstring peak torque at 60° and 120°/sec was found post-treatment compared with pre-treatment ($p = 0.0001$). The percent of the increase in hamstring peak torque were 23.86 and 34.45% at 60 and 120°/sec respectively. Also, a significant increase in quadriceps peak torque at 60 and 120°/sec was found post-treatment compared with pretreatment ($p = 0.0001$). The percent of the increase in quadriceps peak torque were 26.14 and 32.43% at 60 and 120°/sec respectively. (Table 3, figure 2).

Repositioning accuracy

- A significant decrease in absolute error after treatment in comparison with pretreatment ($p = 0.0001$). The percent of decrease of absolute error was 47.1.

Results of control group:

Knee extensors and flexors peak torque

- A significant increase in hamstring peak torque at 60° and 120°/sec was found post-treatment compared with pre-treatment ($p = 0.0001$). The percent of the increase in hamstring peak torque was 4.36 and 11.16% at 60 and 120°/sec respectively. Also, a significant increase in quadriceps peak torque at 60 and 120°/sec was found after treatment in comparison with before treatment ($p = 0.0001$). The percent of the increase in extensors peak torque were 4.65 and 6.38% at 60 and 120°/sec respectively. (Table 3, figure 7).

Repositioning accuracy

- A significant decrease in absolute error after treatment in comparison with pretreatment ($p = 0.001$). The percent of decrease of absolute error was 24.75.

Table (3): ***Comparison between pre and post-treatment in study and control groups:***

	Pre-treatment	Post-treatment			
	$\overline{X}$ ±SD	$\overline{X}$ ±SD	MD	% of change	p-value
Study group					
Flexors peak torque at 60°/sec (Nm)	79.46 ± 16.09	98.42 ± 14.43	-18.96	23.86	0.0001**
Flexors peak torque at 120°/sec (Nm)	43.54 ± 13.8	58.54 ± 13.56	-15	34.45	0.0001**
Extensors peak torque at 60°/sec (Nm)	120.1 ± 21.72	151.5 ± 23.94	-31.4	26.14	0.0001**
Extensors peak torque at 120°/sec (Nm)	92.44 ± 25.06	122.42 ± 22.24	-29.98	32.43	0.0001**
Repositioning accuracy	3.8 ± 0.71	2.01 ± 0.68	1.79	47.1	0.0001**
Control group					
Flexors peak torque at 60°/sec (Nm)	82.38 ± 14.61	85.98 ± 15.02	-3.6	4.36	0.0001**
Flexors peak torque at 120°/sec (Nm)	42.38 ± 14.61	47.11 ± 14.42	-4.73	11.16	0.0001**
Extensors peak torque at 60°/sec (Nm)	118.77 ± 23.23	124.3 ± 24.15	-5.53	4.65	0.0001**
Extensors peak torque at 120°/sec (Nm)	86.63 ±17.83	92.16 ± 18.84	-5.53	6.38	0.0001**
Repositioning accuracy	4.04 ± 0.59	3.04 ± 0.64	1	24.75	0.001**

$\overline{X}$, Mean; SD, standard deviation; MD, mean difference; p-value, level of significance. * Nonsignificant. ** Significant.

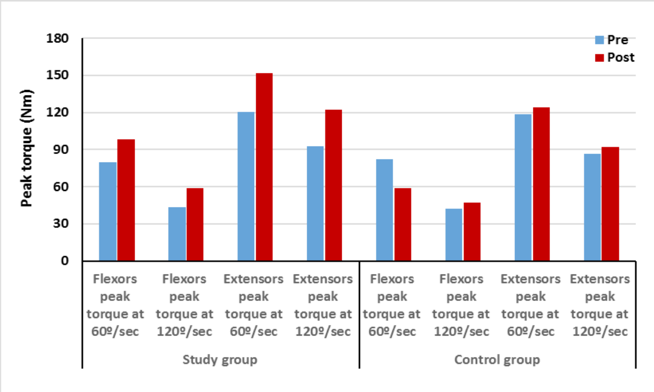

Figure 2: Knee flexors and extensors peak torque at 60° and 120°/sec pre and post-treatment of study and control groups

DISCUSSION

In this study, the effects of the pulsed magnetic field on quadriceps muscle torque, hamstring muscle torque and knee proprioception accuracy in athletic subjects were investigated. For these purposes, 30 healthy male athletes from students of College of Medical Rehabilitation science, Taibah University, Saudi Arabia participated in this study.

In the current study, statistically significant differences between study & control groups after pulsed magnetic field application in quadriceps & hamstring peak torque and in knee proprioception accuracy were shown. The current data of this study demonstrate an increase in the peak torques particularly in the study group, as differences were statistically different for flexion, extension peak torque between the study and the control group. This was supplemented by higher proportions of the extensors peak torque and flexors peak torque in the study group compared to control group noted in this study.

The results of this study showed within-group statistical significant differences in the study group and the control group. However, the changes in the peak torque of the control group might be influenced by the unaccounted level of strength achieved by usual training of athletics subjects during the period of the study [25].

To our knowledge, this the first study that investigates the effects of the pulsed magnetic field on quadriceps muscle torque, hamstring muscle torque and knee proprioception accuracy in athletic subjects.

The positive changes in muscle torque may be attributed to possible stimulatory effects of the pulsed magnetic field on the neuromuscular system [20], which in turn may help to recruit more motor units during muscle contraction that finally increase muscle torque and force production abilities. Also, strength changes in experimental group may be related to the microcirculatory effects of pulsed magnetic effects which were stated by Smith et al (2004) [21] who found that local application of PEMF waveform can elicit significant arteriolar vasodilatation. Increased circulation may improve blood supply of skeletal muscle fibers and in turn, may affect their force production capabilities. This hypothesis is stated by Diniz et al, (2002) [26] who referred to the pulsed magnetic field can improve buildup of nitric oxide and improve local circulation in the tissues subjected to PEMF including muscle fibers. The highly significant positive effects observed in favor of the pulsed electromagnetic field group immediately post application might be attributed to possible stimulatory effects of PEMF.

Kartush et al, (1989) found that both magnetic and electric stimulation of the extratemporal facial nerve led to nearly similar compound muscle action potentials, indicating that the locations and the underlying mechanisms of neural depolarization are similar; also, transtemporal magnetic stimulation seems to help triggering depolarization of the proximal intratemporal nerve [27]. Those findings are intriguing as it may explain the ability of the pulsed magnetic field to directly stimulate motor nerves leading to the production of action potentials that result in muscle stimulation which if repeated and continued for enough time may improve muscle force production abilities and maybe muscle cross-section.

Our findings are similar the results of the study of Madariaga et al, (2007) [28], who investigated the effect of direct magnetic stimulation on quadriceps muscle. Study participants could perform contractions of the quadriceps muscle in isometric contraction mode equivalent to 80% of the maximum twitch stimulation which considered being good enough for direct stimulation by the magnetic field and can be used in muscle rehabilitation.

The findings of this study are promising and are of high clinical importance. The treatment procedures included in this study is beneficial, short and used unsophisticated equipment which is available in most physiotherapy departments. Therefore, the adoption of the same technique into clinical practice is readily feasible. Further studies with greater sample number could be used to assure the results and further research need to be conducted to investigate the effect of different treatment parameters other than that was used in the current study and also other skeletal muscles are to be investigated.

CONCLUSION

Pulsed magnetic field showed positive effects on quadriceps muscle peak torque, hamstring muscle peak torque and knee proprioception accuracy in healthy athletic subjects. In the light of positive findings of the present study and the general absence of undesired effects, PEMF may represent challenging area for future research.

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