TENSION REDUCTION IN STRIATE MUSCLE
WITH STEADY-STATE MAGNETIC FIELDS

A Thesis

Presented to

the Faculty of the Department of Psychology

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

By

Richard A. Berg

December, 1975

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ABSTRACT

Clinical reports have indicated that a magnetic field will result in the relaxation of muscle cramps. Two experiments were designed to study the phenomenon. Experiment I was designed to determine if the observed phenomenon is physiologically or psychologically based. In the event that the results of Experiment I indicated a physiological basis for the magnetic field effect, Experiment II was designed to determine the mechanism through which a magnetic field acts.

In Experiment I, muscle tension was induced with a cold pressor ice bath. For each subject, muscle tension was significantly reduced ($p < 0.01$) in the presence of the magnetic field.

In Experiment II, muscle tension was induced in one of three ways: a cold pressor ice bath, physical exercise, or electrical stimulation. Exposure to the magnetic field resulted in a significant decrease ($p < 0.0001$) induced by the cold pressor while tension induced by physical exercise or electrical stimulation was not significantly affected by the magnetic field.

The results are discussed in terms of a possible magnetic field effect on blood circulation. In addition, magnets are offered as a theraputic aid in the relief of cramps.

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CHAPTER I

INTRODUCTION

Biomagnetism

Biomagnetism is a relatively young branch of science, yet, quite an extensive bibliography on various aspects of the subject has developed in recent years (e.g., Barnothy, 1964; Barnothy, 1969; Presman, 1970). If this bibliography is examined, however, it becomes evident that there is virtually no information available concerning the effects of a magnetic field on muscle tissue.

Several good summary articles (Mulay, 1964; Kauffman, 1951; Figgis and Lewis, 1960) dealing with the general theory of magnetism are available. The majority of biological materials are diamagnetic while some are paramagnetic. Diamagnetism refers to the phenomenon in which "the intensity of magnetism induced in a body by an applied field is less than that produced in a vacuum by the same field." (Mulay, 1964). In actual practice, the net effect manifests itself as one of repulsion between the body and the applied field. Compounds having filled atomic shells are diamagnetic.

Essentially, the magnetic susceptibility of a substance arises from its electrons. An electron spinning around an axis may be said to behave like a tiny magnet. In diamagnetic substances, electrons forming a closed or filled electron shell in an atom or a molecule are grouped under their mutual interactions, in pairs of opposed spin and orbital movements (Martin, 1967). Thus, the magnetism created due to the spin of an electron is cancelled out in some fashion by that of another electron spinning in an opposite direction. Hence, when a magnetic field is applied no effect would be expected. However, a very feeble, yet significant, repulsion is observed. This diamagnetic behavior is attributed entirely to the effect of the magnetic field distorting the orbital motion of the electrons (Mulay, 1964). Since all electrons exhibit orbital motion, diamagnetism is considered to be a universal property.

If the intensity of the induced magnetization is greater in a substance than the applied field in a vacuum, the substance is called paramagnetic and the phenomenon of attraction towards the magnetic field is observed. Free radicals and certain compounds containing transition metal ions with unfilled atomic shells are paramagnetic. When unfilled electron shells exist within the ions or within the bonds, the substance will already have a magnetic moment. Thus, such a system will be appreciably attracted toward an applied field (Williams, 1966). The attraction is so strong that the underlying diamagnetism of the substance is completely masked (Mulay, 1964). Some metals and inorganic compounds have ferromagnetic properties where a very strong attraction exists between the substance and the applied field.

Magnetism and Medicine

Magnetic fields and their effects on biological material are being used with increasing frequency for medical applications (Treloar, 1975). The magnetic field of the heart, first detected by Baule and Mc Fee (1963), and the changes in the field caused by the heart beating are successfully being used to record magnetocardiograms (Baule, 1967) which are very similar to electrocardiograms in their diagnostic applications (Plonsey, 1972). In a manner analogous to magnetocardiography, a fluctuating magnetic field around the head may be recorded - a magnetoencephalogram which resembles an electroencephalogram (Cohen, 1968). Magnetic field variations from the human brain which are produced by visual stimulation have been observed by Brenner, Williamson, and Kaufman (1975). In addition, the results of several experiments, reviewed by D'Souza et. al. (1969) indicate that the use of magnetic fields to control tumor growth may be possible. Thus, magnetism appears to have some potential as a diagnostic and theraputic aid in medicine.

Muscle Cramps

Reid (1975) has estimated that millions of people suffer from a type of muscle cramping which is non-exercise related. Typically, the cramps occur in older persons, and almost always, at night. A history of circulatory problems such as phlebitis appears to be closely associated with people who suffer from this type of cramping although this is not always the case. In addition, the cramps often occur in the left leg of an individual.

Many different types of treatments have been offered for this type of cramping. Reid (1972) has reported that immersion of the affected limb in near scalding water, wearing heated bed socks, or the use of blanket supports result in neither quick nor sure relief. Another folk remedy offered by Zimmet (1973) involves placing the cramped muscles over a wine-bottle cork. He also states that "double blind trials using plastic stoppers confirm the superiority of cork". Fowler (1973) insists that passive stretching of the contracted muscle will relieve the cramp. Lastly, raising the foot of the bed precisely nine inches will alleviate cramping. However, if the individual uses two pillows, the bed must be raised additionally (Rivlin, 1973).

None of the aforementioned treatments has been reported to be successful to any great degree. However, a number of clinical reports (Reid, 1972) have indicated that a magnetic field can reduce muscle tension. Generally, the reports deal with the effect of a magnetic field on muscular cramps. The reports may be thought of as just another folk remedy, however, there is some evidence to the contrary. Reid (1975) has reported that hundreds of people who suffer from this type of cramping have attained some measure of relief by placing the affected part of the body over a permanent magnet. In addition, Bücking (1974) indicates that a strong magnetic field can significantly reduce muscle contraction. The magnet apparently causes the cramped muscle to relax within ten seconds although the magnet will not prevent the onset of the cramp.

The nature of the clinical reports is such that it is unclear as to whether the magnetic field effect on muscle is psychological or physiological. If a physiologically based magnetic field effect does in fact exist, three broad physiological areas appear to be the possible sites upon which a magnetic field may have its effect: blood circulation, the molecular basis for muscular contraction, the myoneural junction, or an interaction of the three areas.

Blood Circulation. Blood circulation is the most likely area upon which a magnetic field may act for a number of reasons. First, the non-exercise related cramps referred to in the clinical reports almost always occur at night when people are asleep or lying in bed. Hence, blood circulation is slower and less efficient than during active hours. Also, the majority of reported folk cures such as heated socks, immersion in near scalding water and so on would seem to act to improve circulation in some way since an increase in temperature leads to blood vessel dilation. In addition, muscle and nerve tissue are dependant upon the circulatory system for cell survival. Furthermore, a number of studies in the literature indicate that magnetic fields can influence circulation (e.g., Beischer, 1969; Kordyukov, 1969).

A magnetic field could directly affect actual blood flow resulting in an increase or decrease in the volume of blood flowing past a given point per unit time. Additionally, red blood cells, white blood cells, hemoglobin, myoglobin, free ions in the blood stream, proteins in the blood, or any number of single constituents or combinations of constituents of blood are affected by a magnetic field (Senftle and Hambright, 1969).

Muscle Cells and the Molecular Basis for Contraction. In causing a muscle to relax, a magnetic field may exert its influence directly upon muscle tissues or the molecules which comprise such tissues. This area appears to be the most doubtful because the information that is available is contradictory in nature. For example, Degen (1970) reports that a magnetic field has no effect on muscle tissue while Young (1969) reports that magnetic fields cause a decrease in the contractility of muscle tissue. However, if a magnetic field does act upon some aspect of muscle cell contraction leading to relaxation, a number of possible sites exist. These include some portion of the actin-myosin reaction, the sarcoplasmic reticulum, free calcium in the muscle cell, adenosinetriphosphate (ATP) production, ATP usage, and transportability of various ions in muscle cell tissue. Also, muscle cell metabolism or metabolic by-products of cell metabolism such as lactic acid may be influenced by the presence of a magnetic field.

Nervous System. Some aspect of muscle innervation may be altered by the influence exerted by a magnetic field. Various reports indicate that magnetic fields affect nerve action potential propagation and other aspects of nervous stimulation (Miro and Chalazonitis, 1972; Reno, 1972; Young, 1969). Reports on a possible magnetic effect on nervous tissue, however, tend to be contradictory depending upon the strength and orientation of the field used in the particular study.

A number of aspects of the nervous system upon which a magnetic effect might be seen exist. Action potential propagation along the entire nerve or some portion of it may be influenced by the presence of a magnetic field. Magnetic fields may affect transmitter release or reuptake. Other possible areas of influence include the motor end plate, the synapse between the axon and muscle tissue, the hyperpolarization or hypopolarization of the nerve fiber, the resting potential of the fiber, or any of the ions associated with nerve fiber action.

Since the three physiological areas are so complexly intertwined, it is also quite possible that the magnetic field exerts its influence in such a way that certain aspects of each of the areas interact resulting in relaxation of a severely contracted muscle.

Statement of the Problem

Since research in the area of magnetic field effects on muscle is relatively recent and published reports are sparse, one of the goals of this study was to constitute a "first look" at the effect of a magnetic field on striate muscle. Another of the major goals of this study was to attempt to replicate the phenomenon of decreased muscle tension in the laboratory and determine if there is a physiological basis for the phenomenon.

If there exists a physiologically based magnetic field effect on muscle that is so tense that it is "cramped", it seems reasonable to assume that a magnetic field will exert a similar effect on muscle that is not so severely contracted. For this reason and due to ethical considerations, muscular cramping per se was not investigated. Rather, a high level of induced muscle tension was studied in order to determine the effects of a magnetic field.

If a magnetic field could be shown to reduce induced muscle tension, then an attempt was to be made to ascertain which, if any, of the aforementioned physiological areas was affected most by a magnetic field. In order to study each of the areas, three specific tasks were chosen, each designed to approximate the major aspects of the physiological areas which could lead to muscle tension: a cold pressor ice bath - blood circulation; physical exercise - molecular basis for muscle contraction; electrical stimulation - nervous system, specifically the myoneural junction.

Inasmuch as folk remedies usually have some basis in fact, and since much of the current literature points towards a magnetic effect on circulation, it was expected that a magnetic field would reduce muscle tension induced by decreased circulation to a greater extent than tension induced by other means.

CHAPTER II

METHODS

Subjects

Fifty-three male and female students, ages 18 - 35, were drawn from the Human Subject Pool at the University of Houston.

Apparatus

The commercially available Bio-Electric Information Feedback System (Boulder, Colorado) was used to record integrated (peak-to-peak, millivolt minute, readout accuracy ± 3%) action potentials (EMG) in a digital readout as a measure of muscle tension. Muscle tension was induced by a standard cold pressor ice bath, a Lafayette ergometer (kg.) (Lafayette, Indiana), or an "Electric Aid" Nerve Finder (New York). The magnets used were the commercially available "STOPCRAMP" distributed by Nelco (France) with a magnetic field of approximately 150 gauss.

Procedure

Throughout both experiments, all subjects were blind with respect to the presence of the real magnet. In addition, for all subjects, the magnetic field was oriented parallel to the subject's arm with the North/South pole orientation randomized.

Experiment I - Demonstration of the Magnetic Effect.

Subjects were seated and recording electrodes were placed over the flexor carpi ulnaris muscle group of the right arm approximately 6 cm. from the inner elbow. With the right arm completely at rest, four 30 second baseline EMG recordings were made. Each of the baseline recordings was separated by a 15 second interval. Subjects then immersed the right hand and forearm in a standard cold pressor ice bath ($0^{\circ} - 1^{\circ}C$) for 63 seconds. The arm is placed in the ice bath such that the electrodes are just above the water line and are not immersed in the bath.

During this period, two 30 second EMG recordings were made. Subjects then removed the limb from the ice bath and returned it to the original resting position. Subsequently, either a magnet or dummy magnet was introduced and held 5 cm. above the muscle group and approximately 5.5 cm. below the recording electrodes (in the direction of the subject's hand). A series of five 30 second EMG recordings separated by 15 second intervals were made.

At the end of the trial, a five minute rest period was allowed, that being the optimal rest period as determined by pilot studies. The entire procedure was then repeated introducing the magnet or dummy magnet in counterbalanced order.

In this experiment, a total of six subjects, three males and three females, participated.

Experiment II-Determination of the Physiological Area.

Condition 1 - Cold Pressor. Subjects were seated and recording electrodes were placed over the *flexor carpi ulnaris* muscle group of the right arm approximately 6 cm. from the inner elbow. Five to ten minutes was allowed for subjects to habituate to the experimental situation. Subjects then immersed the right hand and forearm in a standard cold pressor ice bath (0°- 1°C) such that the electrodes were positioned just above the water line and were not immersed in the ice bath. At the end of a 63 second period, subjects removed the limb from the bath and returned it to a resting position. Subsequently, either a magnet or a dummy magnet was introduced 5 cm. over the muscle group and approximately 5.5 cm. below the recording electrodes (in the direction of the hand), and a 30 second EMG recording was made. Five minutes of rest time was permitted - one minute on a heating pad (37.5°C) and four minutes at room temperature (22°- 23°C). The procedure was then repeated three more times, for a total of four times, presenting the magnet or dummy magnet in counterbalanced order.

Seventeen subjects, seven males and ten females, participated in this condition.

Condition 2 - Physical Exercise. A second group of subjects; seven males and nine females, were habituated and electrodes were positioned on the subjects as previously described. The subjects were then asked to pull the ergometer as hard as possible and release using the right hand. After two minutes rest, as determined by pilot studies, the subjects pulled on the ergometer at 33 1/3 percent of theor maximum pull for 30 seconds. The arm was then returned to a resting position and either a magnet or dummy magnet was introduced 5 cm. above the muscle group and approximately 5.5 cm. below the recording electrodes and a 30 second EMG recording was made. Five minutes rest was allowed and the procedure was then repeated three more times, for a total of four times, presenting the magnet or dummy magnet in counterbalanced order.

Condition 3 - Electrical Stimulation. A third group of subjects, seven males and seven females, were habituated and electrodes were positioned on the subjects as previously described. The motor point of the flexor carpi ulnaris muscle group was then stimulated a number of times to acquaint the subjects with the stimulation of seven pulses per second, 120 volts peak-to-peak, 0.05 milliamps. After five to ten minutes rest, electrical pulses were delivered to the subjects' motor point for 150 seconds. Subsequently, either a magnet or dummy magnet was introduced 5 cm. over the muscle group and approximately 5.5 cm. below the recording electrodes and a 30 second EMG recording was made. Five minutes rest was allowed and the procedure was then repeated three more times, for a total of four times, presenting the magnet or dummy magnet in counterbalanced order.

CHAPTER III

RESULTS

Experiment I

As Figures 1a through 1e indicate, muscle tension was significantly reduced for each of the six subjects

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Insert Figures 1a - 1e about here

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in the presence of the magnetic field ($p < 0.01$, Sign Test, Hayes, 1973). Figure 1f illustrates the time course for return to baseline for one subject.

Insert Figure 1f about here

Experiment II

Muscle tension induced by the cold pressor task was elevated significantly above baseline ($t = 16.93$, $df = 16$, $p < 0.001$) while tension induced by physical exercise ($t = 1.62$, $df = 15$, $p < 0.1$, N.S.) and electrical stimulation ($t = 1.70$, $df = 13$, $p < 0.1$, N. S.) was not raised above baseline as is illustrated by Figure 2a.

Figures 1a - 1f: Illustrate the effect of a magnetic field on induced muscle tension. Time blocks 1 - 4 represent baseline EMG recordings. Time blocks 5 and 6 represent the level of tension induced during the cold pressor task. Time blocks 7 - 11 represent EMG recordings in the presence or absence of the magnetic field.

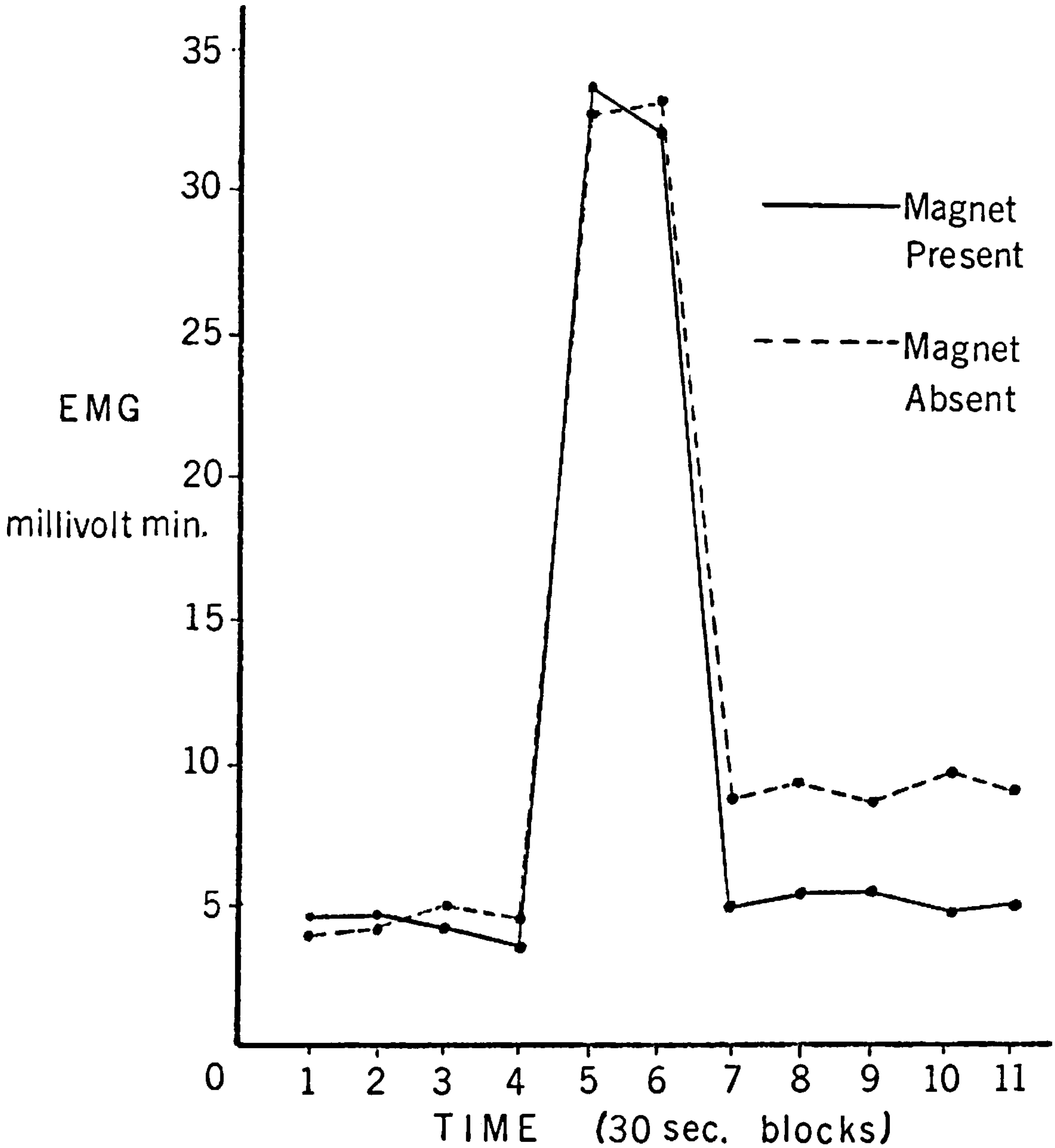

Figure 1a

MAGNETIC FIELD EFFECT ON TENSION
(female)

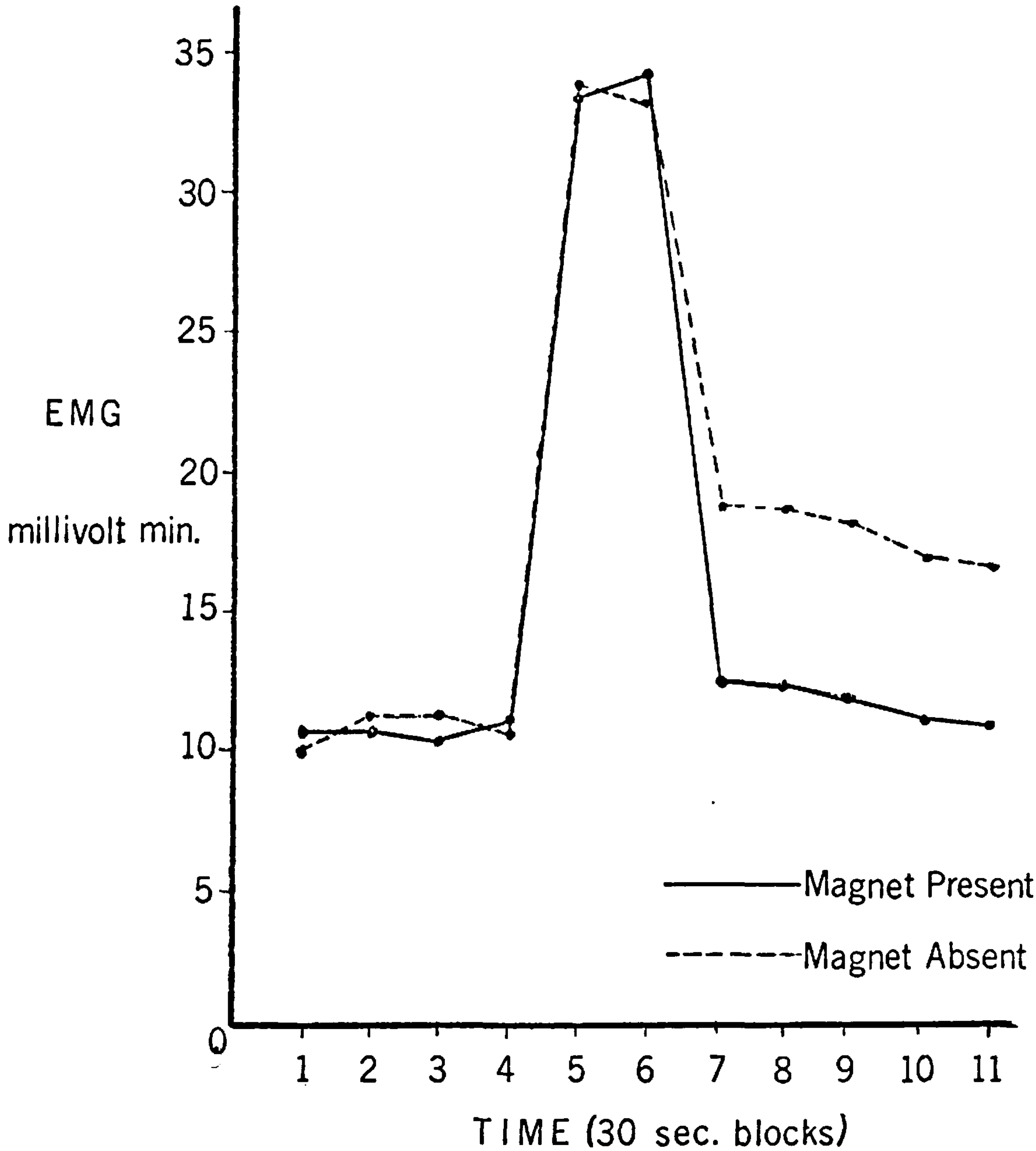

Figure 1b

MAGNETIC FIELD EFFECT ON TENSION

(male)

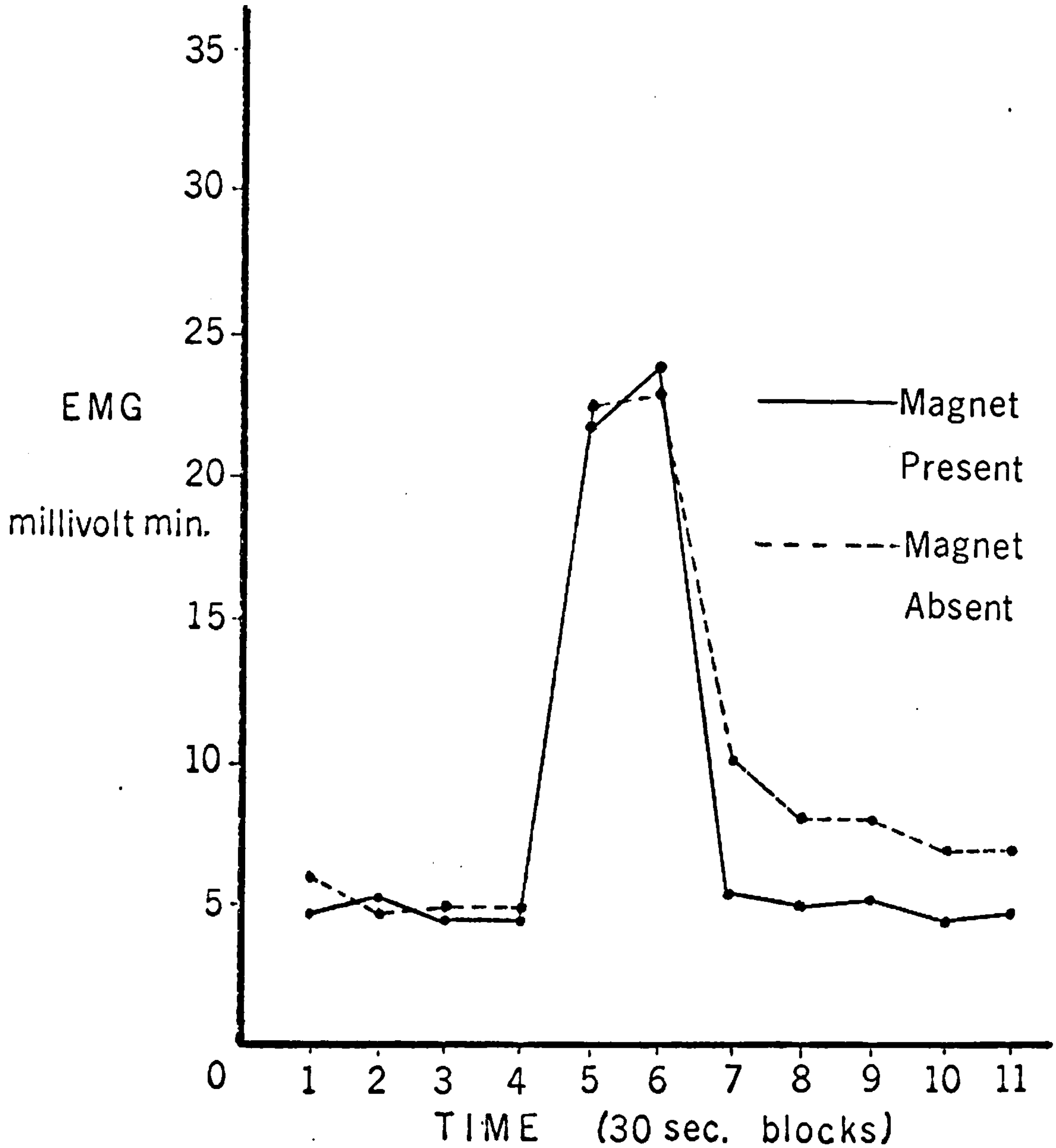

Figure 1c

MAGNETIC FIELD EFFECT ON TENSION
(female)

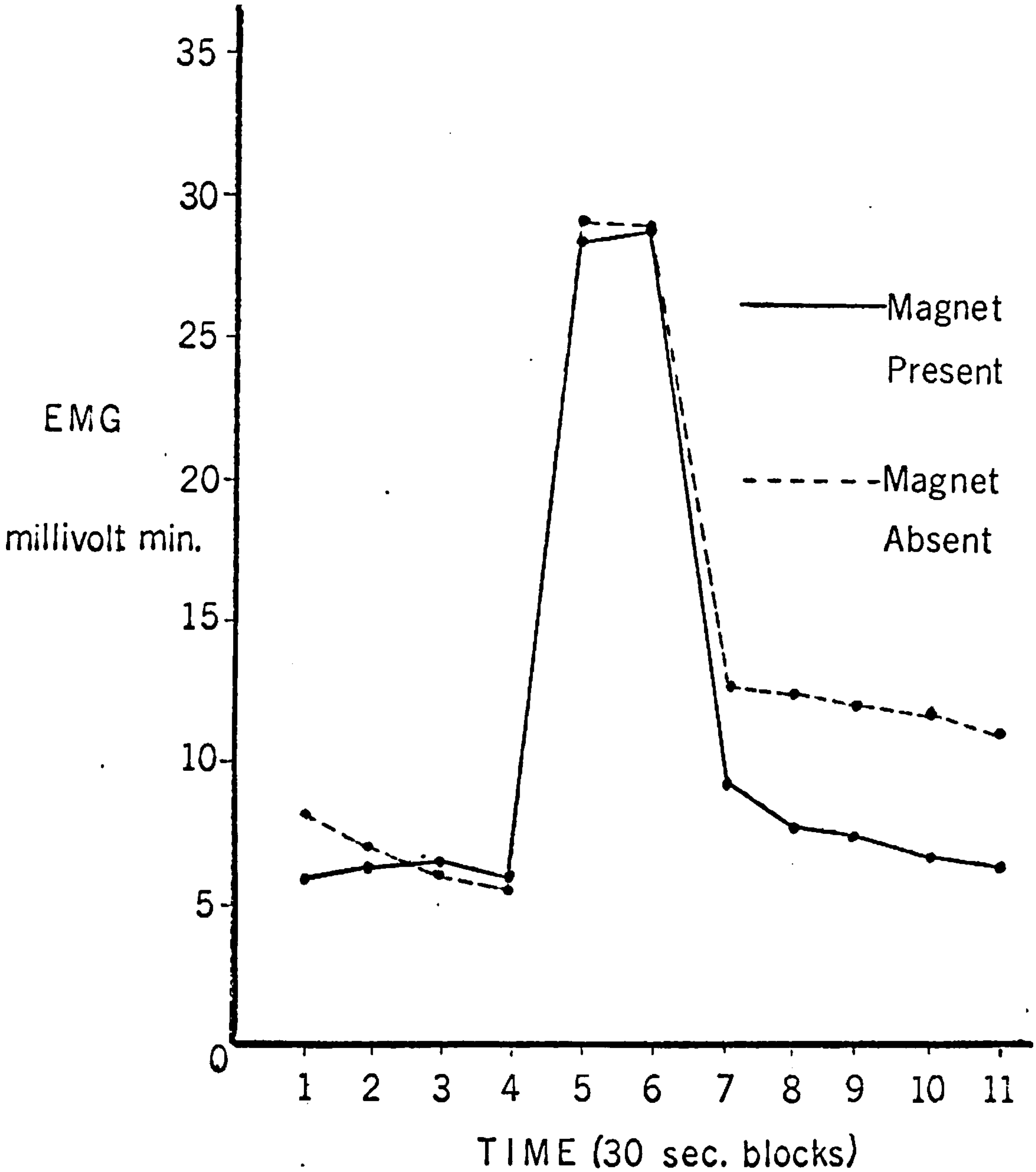

Figure 1d
MAGNETIC FIELD EFFECT ON TENSION
(male)

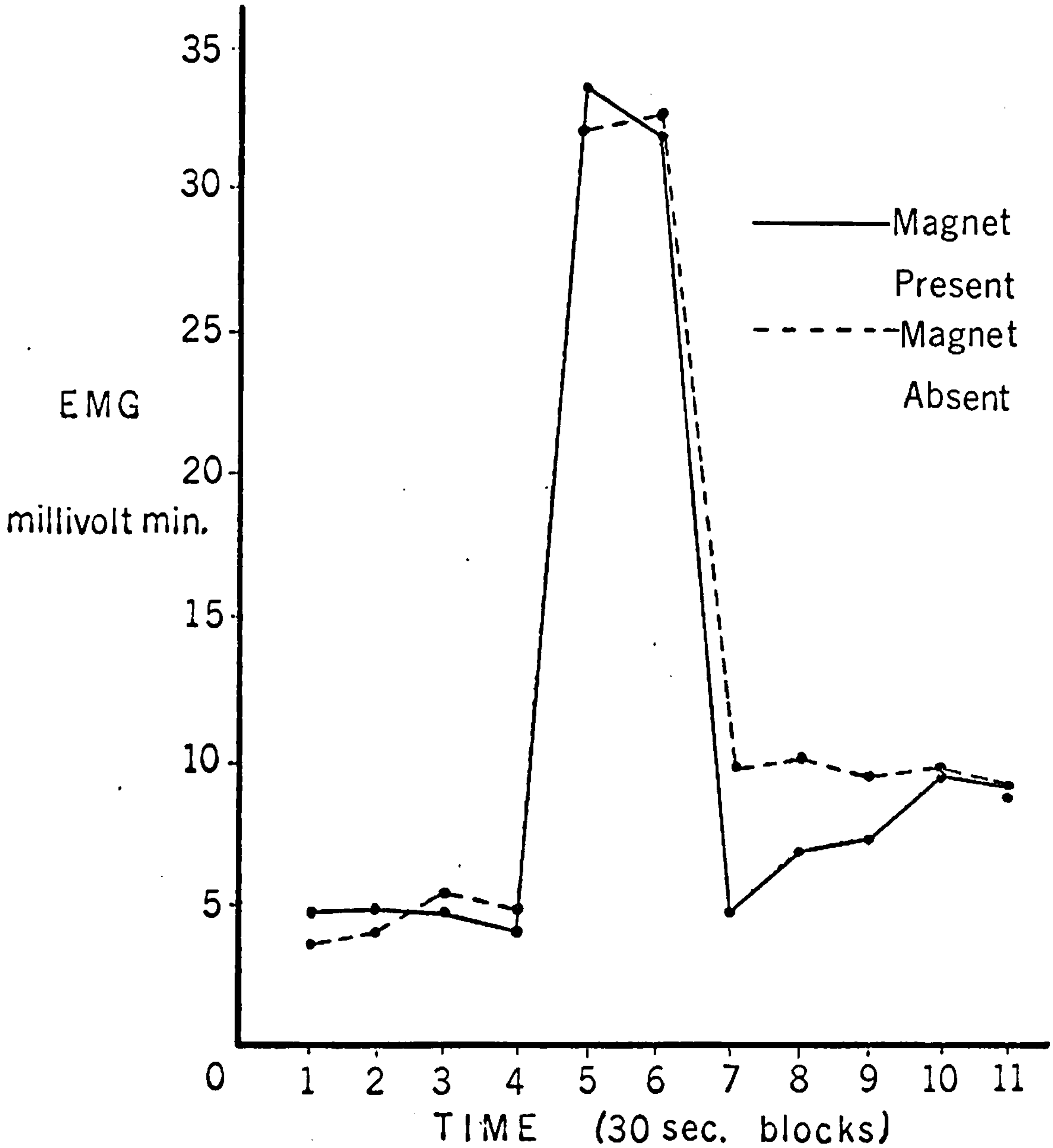

Figure 1e

MAGNETIC FIELD EFFECT ON TENSION
(female)

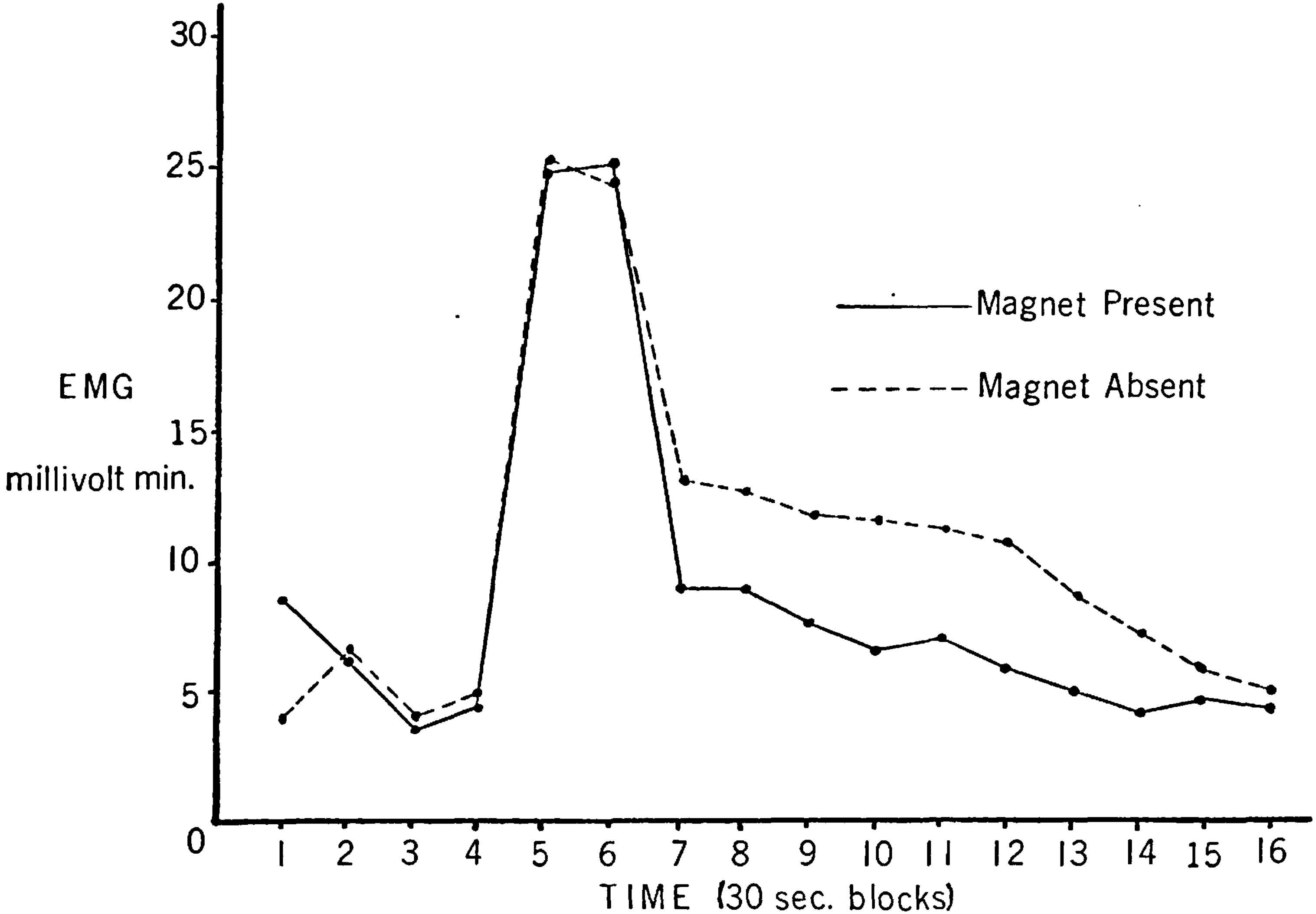

Figure 1f

MAGNETIC FIELD EFFECT ON TENSION

Insert Figure 2a about here

A least squares analysis of variance for nonorthogonal data (Winer, 1962; Overall and Spiegel, 1969) performed on each condition independantly revealed that the presence of the magnetic field lead to a significant decrease in muscle tension induced by the cold pressor task ($F = 160.43$, $df = 1/15$, $p < 0.0001$) while tension induced by physical exercise or electrical stimulation was not significantly affected by the magnetic field (Figure 2a).

No significant interactions were observed on any of the three conditions of tension induction. However, in the cold pressor consition, the interaction of sex by order of magnet presentation approached significance ($F = 3.50$, $df = 1/15$, $p < 0.08$) as is illustrated in Figure 2b.

Insert Figure 2b about here

Figure 2a: Illustrates the mean level of muscle tension immediately after induction, and the mean level of muscle tension 30 seconds after induction in the presence or absence of the magnetic field.

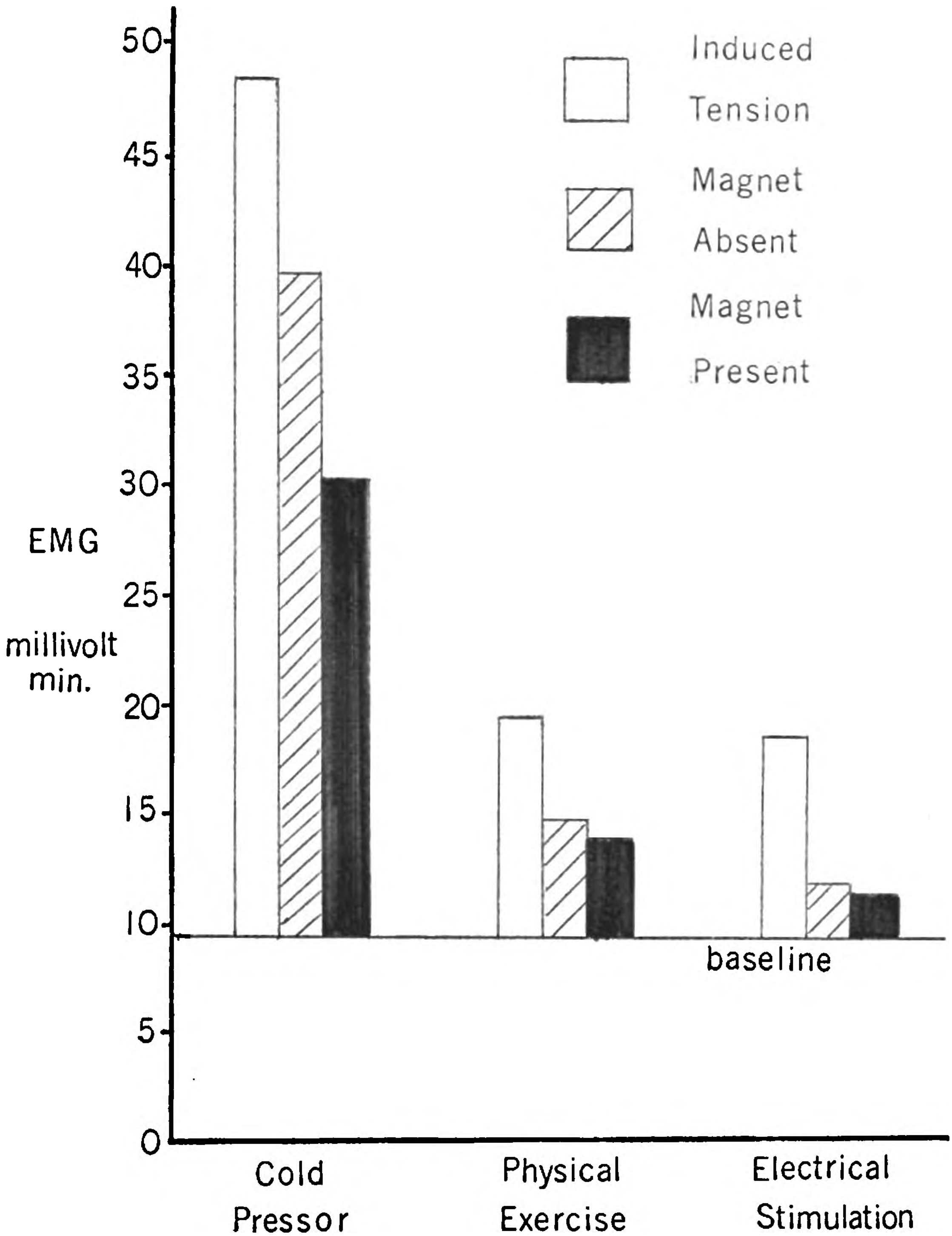

Figure 2a

MEAN EMG 30 SEC. AFTER TENSION INDUCTION

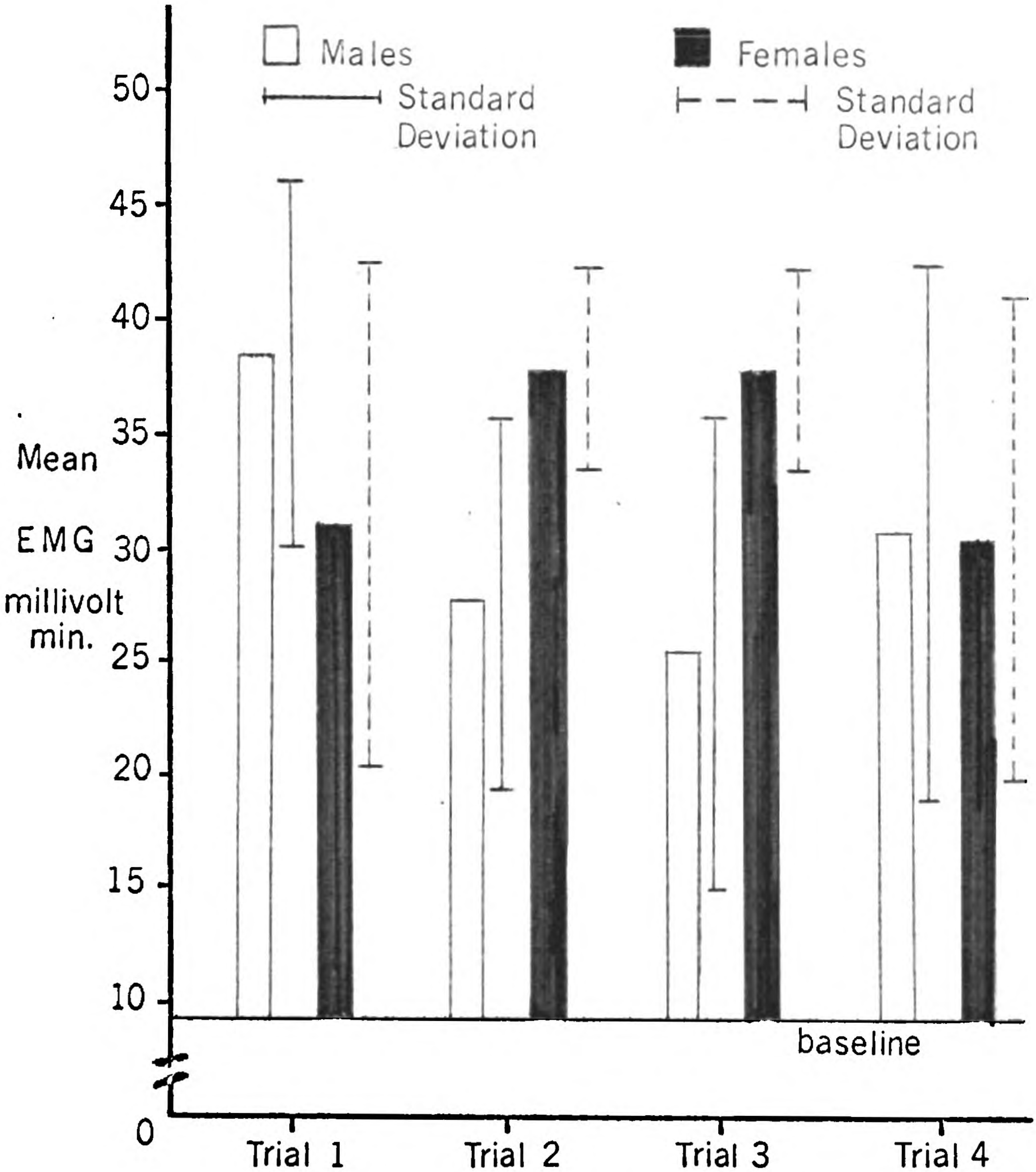

Figure 2b

INTERACTION OF SEX BY ORDER OF MAGNET PRESENTATION

CHAPTER IV

DISCUSSION

A magnetic field of approximately 150 gauss was shown to be effective in lowering muscle tension induced by the cold pressor task. In the presence of the magnetic field, the muscle tension of each and every subject in the cold pressor condition was decreased. The results of the present study thus suggest that there is some basis in fact to the clinical reports stating that magnets relieve muscle cramps. Since subjects were run blind throughout the study to control for a possible "placebo effect", a physiological basis for the observed action of magnetic fields on cramps apparently does exist.

Experiment II was designed to deal with the question of the mechanism through which the magnetic fields exerts its influence in a very broad sense. Since the manipulations employed under the physical exercise and electrical stimulation conditions failed to raise muscle tension above baseline to a satisfactory level, the question of mechanism cannot be addressed. However, this study does allow for speculation about a magnetic field effect on blood circulation.

Immersion of the arm in very cold water leads to a state of ischemia as blood flow is decreased due to a marked and rapid vasoconstriction (Vander, Sherman and Luciano, 1970). In addition to vasoconstriction to prevent heat loss, cold temperature also results in increased muscle activity. Characteristically, the increased activity takes the form of oscillating rhythmic muscle contractions at the rate of about 10 to 20 per second.

During the period of restricted blood flow, the oxygen concentration in the muscle decreases, the concentration of carbon dioxide and hydrogen ion increases, and the concentration of certain ions, particularly potassium, frequently increase, perhaps as a result of increased activity of muscle cells (Vander et. al., 1970).

A return to normal blood flow rapidly increases oxygen concentration to normal levels, carbon dioxide concentration and hydrogen ion concentration decrease, and ion concentration homeostasis is achieved. When dealing with prolonged vasoconstriction in combination with prolonged cold temperature, the return to the normal state is not as rapid as a situation where mechanical occlusion of blood flow has occurred such as when a tourniquet is removed. Immersion of the arm in an ice bath for more than a few seconds results in a good deal of heat loss from the arm. Consequently, when the arm is removed from the ice bath, the internal and external temperature of the arm is still below normal. The blood vessels remain constricted until the temperature of the arm approaches that which is normal.

A magnetic field may, in some way, increase blood circulation and thereby increase the internal temperature of the arm at a faster rate than when a magnetic field is not present. As the internal temperature of the arm increases due to improved circulation, muscle activity would decrease as a function of the rise in the internal temperature of the arm.

Some evidence does exist to support a circulatory hypothesis. In 1969, Kordyukov reported that exposure to a magnetic field resulted in improved hemodynamics of patients suffering from obliterative diseases of the blood vessels of the lower extremities. Furthermore, Toroptsev (1968) noted that a strong magnetic field (7000 gauss) induced disturbances of hemodynamics and lymph circulation in guinea-pigs, frogs, and fish. Histology on some of these animals revealed a paretic dilation of capillaries, however, "dynamic investigations pointed to normalization of the morphological picture 30 days after the field action." In Toroptsev's study, animals were exposed to magnetic fields for a total of 13 hours. Thus, approximately 30 days after 13 hours of exposure to strong magnetic fields, the morphology of the animals returned to normal. Patients with acute thrombophlebitis were exposed to a magnetic field of 200 to 400 gauss and received no other treatment. Edlinskiy (1969) reports that as a result of exposure to the field, their general clinical picture improved.

Exactly what components of circulation may be affected by the presence of a magnetic field remains unknown. The effect may be due entirely to the paretic dilation of capillaries reported by Toroptsev, or due to an influence on some of the components of blood itself. Cassiano, Carta, and Tronconi (1967) showed that exposure to a magnetic field (33.8 gauss) decreased blood sugar levels in both normals and diabetics. Edlinskiy (1969) reported that the iron content of the blood increased and that the copper content of the blood decreased after exposure to a magnetic field (200 - 400 gauss). Exposure to a magnetic field results in an increase in blood coagulation (Degen and Potashnik, 1970; Piruzyanm Rozenfel'd, Glezer, and Lomonosov, 1969). A study by Chachava, Charkviani, Zhgenti, Kintraya, Nishianidze, Lominadze, and Chachava (1969) reported that exposure of both rats and humans to magnetic fields, 10 minutes daily for 10 days, lead to an increase in erythrocytes in the blood. In addition, magnetic fields have been shown to increase the hemoglobin content of the blood (Ivanov-Muromshiy and Lukhachev, 1967; Likhachev, 1969). The number of leukocytes in the blood stream has been shown to increase due to the presence of a magnetic field (Ivanov-Muromskiy and Lukhachev, 1967). Barnothy and Barnothy (1970) demonstrated that exposure to a magnetic field increased the number of platelets in the blood of mice by up to 28 percent.

The question of the specific aspect of blood circulation upon which a magnetic field may exert its influence is an extremely complex one. The question becomes further confused when one takes into account a number of reports stating that a magnetic field actually decreases blood flow (Bresson and Bellossi, 1969; Likhachev, 1968; Likhachev, 1969).

Such contradictory reports indicate that although blood circulation may be a potential mechanism through which the magnetic field acts, it is unlikely to be the sole component of muscle tension upon which the magnetic field exerts its influence. Reduction of muscle tension upon exposure to a magnetic field is more likely to be a result of a combined magnetic effect on blood circulation, muscle, and nerve tissue. Indeed, evidence exists to support this notion. Bücking et.al. (1974) report that exposure of isolated skeltal muscle to a strong magnetic field (50000 gauss) reduces the contraction of the muscle approximately 8 percent. Such a finding indicates that although there may be a magnetic effect on muscle tissue, the effect on muscle tissue alone is insufficient to account for the clinical observations. Young (1969) wrote that magnetic fields of 2700 to 4000 gauss appear to decrease cardiac contractility. He further suggests that, based on his observations, the likely site of the magnetic action is acetylcholinesterase activity at the myoneural junction. The findings of Bücking _et. al._ and Young in addition to the fact that in the present study muscle tension induced by the cold pressor was reduced by over 33 percent in the presence of the magnetic field indicate that magnetic fields act through an interactive mechanism involving aspects of muscle tissue, blood circulation, and nerve tissue.

The task of determining the exact sites upon which magnetic fields act is obviously a complex one which requires much more research. Thus, these investigations are to be continued in an effort, first, to determine if a magnetic effect exists on muscle tension which is a result of induction by means other than a cold pressor. Subsequently, research on an animal model is being planned in an attempt to localize those physiological areas which may be affected by magnetic fields.

For the present, however, a magnet has been shown to be effective in reducing muscular tension significantly. The study of magnetic fields, therefore, may offer vast potential as a threaputic aid to the millions of people who suffer nightly from non-exercise related muscle cramping. To be used effectively to relieve muscle cramping, the precise mechanism of the magnetic action is irrelevant. Aspirin has been used for many years and the mechanism of action of aspirin is not yet fully understood. In the interest of furthering scientific knowledge, the discovery of exactly how magnetism affects human physiology is quite important. However, magnets do appear to offer a simple and relatively inexpensive means of relief from painful muscle cramps.

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APPENDIX A

Raw Data - EMG in Millivolt Minutes

EXPERIMENT I

Subject	Baseline EMG	Induced Tension	EMG Mag. Present	EMG Mag. Absent
Males				
1	10.11	33.86		18.23
Trial 1	11.12	33.59		18.29
	11.23			18.10
	10.59			17.59
				17.54
Trial 2	10.57	33.29	13.01	
	10.86	34.51	13.12	
	10.64		13.05	
	10.75		12.87	
			12.51	
2	8.07	27.99	9.34	
Trial 1	6.97	28.67	7.65	
	6.50		7.50	
	6.56		6.49	
			6.40	
Trial 2	6.03	28.98		12.75
	6.47	28.54		12.53
	6.25			12.04
	6.44			11.87
				11.03
3	4.25	25.14		12.52
Trial 1	6.16	24.82		11.17
	4.44			11.77
	5.01			11.02
				10.70

Subject	Baseline EMG	Induced Tension	EMG Mag. Present	EMG Mag. Absent
				9.76
				7.11
				6.46
				5.65
				4.40
3	8.39	24.13	8.49	
Trial 2	5.49	24.82	8.45	
	4.01		7.20	
	4.59		6.40	
			6.45	
			5.91	
			4.93	
			4.23	
			4.50	
			4.40	
Females				
4	4.24	33.68	4.84	
Trial 1	4.43	32.03	7.15	
	4.71		7.60	
	3.67		8.53	
			8.42	
Trial 2	3.42	28.04		8.31
	3.28	25.97		9.17
	3.49			8.26
	4.02			9.17
				8.38

Subject	Baseline EMG	Induced Tension	EMG Mag. Present	EMG Mag. Absent
5	1.65	11.08		4.80
Trial 1	3.85	12.93		2.71
	4.67			2.52
	6.19			3.77
				4.85
Trial 2	0.90	10.78	2.92	
	2.55	10.97	2.01	
	3.96		1.89	
	1.91		1.98	
			1.97	
6	4.59	22.07	6.40	
Trial 1	4.40	20.91	5.98	
	4.63		5.96	
	4.01		5.10	
			4.99	
Trial 2	5.92	21.01		8.90
	4.59	23.40		7.65
	4.68			7.68
	4.63			6.54
				6.50

Mean EMG (Baseline) = 9.47 S.D. = 2.66
Mean EMG (Tension Induction) = 23.97 S.D. = 6.87
Mean EMG (Magnet Present) = 6.82 S.D. = 2.16
Mean EMG (Magnet Absent) = 10.21 S.D. = 4.40

EXPERIMENT II

Cold Pressor

Subject*	Induced Tension	Trial 1	Induced Tension	Trial 2
Males				
M NM NM M**				
1	65.79	43.86	59.73	49.46
2	65.57	43.71	57.75	47.82
3	40.61	27.07	41.09	34.03
NM M M NM				
4	31.28	25.90	29.48	19.65
5	51.21	42.41	58.29	38.86
6	49.95	41.36	49.79	33.19
7	28.28	23.42	29.06	19.37
		Trial 3		Trial 4
M NM NM M				
1	56.16	46.51	66.14	44.09
2	57.71	47.96	49.76	33.17
3	39.63	32.82	23.96	15.97
NM M M NM				
4	19.02	12.68	29.97	24.82
5	56.28	37.52	58.28	48.26
6	51.96	34.64	48.93	40.52
7	24.08	16.05	37.29	30.88
Females		Trial 1		Trial 2
M NM NM M				
8	55.41	36.94	52.20	43.23
9	35.85	23.90	43.07	35.67
10	17.24	11.49	19.15	15.86
11	66.41	44.27	60.02	49.70
12	59.96	39.73	57.22	47.38
13	52.22	34.81	51.21	42.41
NM M M NM				
14	56.27	46.60	59.99	39.99
15	58.91	48.78	63.81	42.54
16	48.97	40.55	45.15	30.07
17	49.78	41.22	54.02	36.01

Subject	Induced Tension	Trial 3	Induced Tension	Trial 4
M NM NM M				
8	51.94	43.01	58.65	39.10
9	40.20	33.29	38.42	25.61
10	19.71	16.32	16.29	10.86
11	66.27	54.88	56.99	37.99
12	55.58	46.03	60.86	40.57
13	37.95	31.43	44.73	29.82
NM M M NM				
14	48.14	32.09	56.54	46.82
15	67.55	45.03	60.69	50.26
16	53.87	35.91	52.01	43.07
17	52.74	35.16	50.46	41.79

Mean EMG (Tension Induction) = 48.17 S.D. = 11.54

Mean EMG (Magnet Present) = 32.11 S.D. = 10.15

Mean EMG (Magnet Absent) = 39.89 S.D. = 10.66

* Numbering of subjects is for presentation only. Subjects were run randomly.

**M = Magnet Present
NM = Magnet Absent

Physical Exercise

Subject*	Induced Tension	Trial 1	Induced Tension	Trial 2
Males **				
M NM NM M				
1	27.15	19.23	31.19	23.18
2	13.68	9.69	9.19	6.83
3	11.32	8.02	35.44	26.34
4	26.96	19.10	29.72	19.86
NM M M NM				
5	23.40	17.39	8.22	5.82
6	38.05	28.28	46.50	32.94
7	21.62	16.07	20.51	14.53
M NM NM M		Trial 3		Trial 4
1	19.34	14.37	32.37	22.93
2	7.91	5.88	2.47	1.75
3	29.08	21.61	34.23	24.25
4	27.60	20.51	34.45	24.40
NM M M NM				
5	10.42	7.38	10.70	7.95
6	37.21	26.36	33.97	25.25
7	23.25	16.47	27.07	20.12
Females		Trial 1		Trial 2
M NM NM M				
8	14.68	10.40	6.57	4.88
9	17.35	12.29	29.26	21.75
10	16.05	11.37	14.42	10.72
NM M M NM				
11	24.53	18.23	22.64	16.04
12	6.65	4.94	7.17	5.08
13	32.76	24.35	32.89	23.30
14	5.13	3.81	2.60	1.84
15	13.86	10.30	11.77	8.34
16	3.55	2.64	5.05	3.58

Subject	Induced Tension	Trial 3	Induced Tension	Trial 4
M NM NM M				
8	6.63	4.93	9.85	6.98
9	18.54	13.78	27.32	19.35
10	19.07	14.17	16.08	11.39
NM M M NM				
11	26.17	18.54	27.96	20.78
12	15.97	11.31	15.90	11.82
13	50.95	36.09	36.32	26.99
14	8.12	5.75	4.16	3.09
15	7.33	5.19	9.62	7.15
16	3.70	2.62	7.36	5.47

Mean EMG (Tension Induction) = 19.51 S.D. = 11.74

Mean EMG (Magnet Present) = 13.82 S.D. = 8.91

Mean EMG (Magnet Absent) = 14.50 S.D. = 9.71

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* Numbering of subjects is for presentation only. Subjects were run randomly.

**M = Magnet Present
NM= Magnet Absent

Electrical Stimulation

Subject*	Induced Tension	Trial 1	Induced Tension	Trial 2
Males				
M NM NM M**				
1	11.35	7.32	18.74	12.26
2	36.43	23.50	27.30	17.86
3	15.83	10.21	8.97	5.87
4	21.56	13.91	27.17	17.77
NM M M NM				
5	32.50	21.26	40.04	25.83
6	12.54	8.20	14.21	9.17
7	11.30	7.39	9.49	6.12
		Trial 3		Trial 4
M NM NM M				
1	10.64	6.96	6.40	4.13
2	31.66	20.71	28.89	18.64
3	7.57	4.95	6.59	4.25
4	12.47	8.16	10.20	6.58
NM M M NM				
5	36.77	23.72	39.58	25.89
6	9.78	6.31	11.18	7.31
7	13.72	8.85	14.17	9.26
Females		Trial 1		Trial 2
M NM NM M				
8	10.88	7.02	11.36	7.43
9	38.53	24.85	32.41	21.20
10	27.41	17.68	31.17	20.39
NM M M NM				
11	14.99	9.81	16.46	10.62
12	8.55	5.59	21.98	14.18
13	14.39	9.41	12.82	8.27
14	15.49	10.13	18.52	11.95
		Trial 3		Trial 4
M NM NM M				
8	11.36	7.43	10.88	7.02
9	39.58	25.89	37.19	23.99
10	16.02	10.48	14.56	9.39

Subject	Induced Tension	Trial 3	Induced Tension	Trial 4
NM M M NM				
11	23.20	14.97	19.34	12.65
12	13.75	8.87	18.44	12.06
13	5.21	3.36	11.48	7.51
14	15.70	10.13	18.27	11.95

Mean EMG (Tension Induction) = 18.88 S.D. = 9.99

Mean EMG (Magnet Present) = 12.18 S.D. = 1.70

Mean EMG (Magnet Absent) = 12.35 S.D. = 6.21

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* Numbering of subjects is for presentation only. Subjects were run randomly.

**M = Magnet Present
NM = Magnet Absent