AN EMG ANALYSIS

OF

THE VALIDITY OF USING WEIGHTED HOCKEY STICKS

FOR

SPECIFIC OVERLOAD TRAINING

by

© Herbert W. Madill

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ABSTRACT

This investigation was undertaken to determine the effectiveness of weighted hockey sticks in overloading selected muscles involved in the execution of the ice hockey snap shot.

Four varsity hockey players performed snap shots using a control hockey stick and three weighted experimental sticks. An EMG investigation was conducted on six muscles - the pectoralis major, triceps brachii, flexor carpi ulnaris, biceps brachii, teres major and rhomboid major. The measure of comparison was the computer calculation of integrated sums.

All three experimental sticks placed an overload on three of six muscles tested - the pectoralis major, rhomboid major and teres major. All six muscles were overloaded by the stick with the weighted blade and only the triceps brachii and biceps brachii failed to respond to any overload provided by the two remaining experimental sticks.

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RÉSUMÉ

Cette étude avait pour but de déterminer l'efficacité de bâtons de hockey avec poids dans le surchargement de muscles sélectionnés et impliqués dans l'exécution du lancer mi-frappé au hockey sur glace.

Quatre joueurs de hockey interuniversitaires ont effectué les lancers mi-frappés utilisant un bâton de hockey contrôlé et trois bâtons de hockey expérimentaux avec poids. Une étude de l'EMG fut réalisée sur six muscles - le pectoralis major, le triceps brachii, le flexor ciarpi ulnaris, le biceps brachii, le teres major et le rhomboid major. Le calcul des sommes intégrées fait par ordinateur servait de mesure de comparaison.

Les trois bâtons expérimentaux produisirent un effet de surcharge sur trois des six muscles évalués - le pectoralis major, le rhomboid major et le teres major. Tous les six muscles furent surchargés par les bâtons possédant une lame avec poids et seulement le triceps brachii et le biceps brachii ne répondirent pas à un effet de surcharge provoqué par les deux autres bâtons expérimentaux.

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Dedicated to

Bridget K. Madill

my wife

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The investigator is further indebted to the Department of Mechanical Engineering under the guidance of Dr. Louis Vroomen. The able assistance of Louis Vroomen Jr. and technician George Dedic provided us with an apparatus unique in the field of electromyography.

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CHAPTER I

INTRODUCTION

The purpose of this study was to investigate the effects of weighted hockey sticks as a functional overload on selected muscles involved in the execution of the ice hockey snap shot.

In recent years Canadians have begun to realize that our reputation as world leaders in ice hockey is at stake. In 1971, after review of the literature of hockey research conducted during the previous two and one-half decades, De Stefano stated that advances made in that time had been more political than scientific in nature (De Stefano, 1971). In the application of hockey research, there has been little change since the year 1971. It is obvious that in neglecting the scientific approach to improving hockey skills we have allowed other countries to close the gap.

To date, techniques adopted for the development and improvement of shooting skills have been implemented on the basis of empirical observations. As a result, there are conflicting opinions as to which warm-up method, if any, is best. Electromyography is a reliable means of determining the muscles involved in a given movement and the extent to which they are involved (Basmajian, 1967). Since there is a need for biomechanical data to support or refute traditional claims, it was decided to use EMG to determine if weighted hockey sticks place a functional overload on selected skeletal muscles of the upper limbs that are involved in the snap shot.

The snap shot was chosen for this study because it combines the positive characteristics of both the wrist and slap shots and it is becoming the most popular shot in hockey.

Statement of the Problem

The purpose of this study was to determine if any of three differently weighted hockey sticks acted effectively as a functional overload on upper limb skeletal muscles during the execution of the ice hockey snap shot. The muscles investigated were the pectoralis major, triceps brachii, flexor carpi ulnaris, biceps brachii, teres major and rhomboid major.

The measure of muscle response used to compare the effects of experimental weighted sticks with the control stick was the integrated sum.

Rationale

This study will provide evidence as to which, if any, weighted hockey stick is most effective in overloading the identified muscles involved. Hopefully, it will provide some impetus for further studies in the sport of ice hockey using EMG and other biomechanical techniques.

Limitations

1. The use of surface electrodes limited the choice of muscles which could be investigated to superficial skeletal muscles.
2. The high cost of computer time necessary did not allow for the testing of a large number of subjects.

Delimitation

1. The weighted puck was excluded from the study as an experimental device because of the ballistic nature of the snap shot. The muscles involved initiate contraction before actual contact is made with the puck.

Definitions

Hockey Related:

Snap Shot: A shot executed by raising the heel of the stick blade and drawing the tip of the blade back 12-18 inches beyond the puck before flexing the wrists and driving the blade down and through the puck contacting the ice at a point just behind the puck.

Slap Shot: A shot executed by taking the hockey stick back a considerable distance behind and above the puck (hip height, shoulder height or even higher) then bringing it forcefully down contacting the ice at a point three or four inches behind the puck.

Wrist Shot: A shot executed by drawing the puck back behind the body with the stick then sweeping it forward across the front of the body keeping the blade of the stick in contact with the puck throughout the shot.

Bottom Hand (shooting hand): The hand placed down the shaft towards the blade of the stick.

Top Hand: The hand positioned at the end of the shaft of the stick.

Back Foot: The right foot of a person shooting right-handed.

Front Foot: The left foot of a person shooting right-handed.

Definitions (continued):

Biomechanics Related:

Ballistic Movement: A high velocity movement of a body part or limb through a range of motion assisted in part or wholly by momentum of that part through the range of motion.

Electromyography Related:

Electromyography (EMG): A technique for recording the electrical changes that occur in muscle tissues.

Muscle Action Potential (MAP): The measurable electrical potential generated by a muscle.

Motor Point: That point within the body of a muscle which causes the maximum muscle response when stimulated electrically, ie. it is the most excitable area of a muscle.

Amplitude: The size of the electromyographic response to a given stimulus in a muscle measured in millivolts and described by the height of the spike above the baseline.

Frequency: The number of emg responses in a muscle to a given stimulus, described by the number of spikes on the EMG per unit of time.

Functional Overload: The overload on a muscle during the actual movement phase of a skill pattern.

Integrated Sum: The time integral of the absolute value of the signal.

List of Abbreviations

AC	alternating current
ADC	analogue to digital converter
ASR	automatic send and receive terminal
BBLH	biceps brachii (long head)
DC	direct current
DTMT	program (disc to magnetic tape)
EMG	electromyography
emg	electromyographic (adj.)
FCU	flexor carpi ulnaris
IDVM	integrating digital volt meter
MAP	muscle action potential
MTTD	program (magnetic tape to disc)
PMCH	pectoralis major (clavicular head)
RM	rhomboid major
RMS	root mean square
S/H	sample and hold
SMC	skeletal muscle contraction
TBMH	triceps brachii (medial head)
TM	teres major

CHAPTER II

REVIEW OF THE LITERATURE

A review of the literature covering the past twenty-five years failed to produce evidence of one study performed on ice hockey through the use of electromyography. The following review of literature, therefore, focuses on related sports skills and other studies which have been performed in the area of muscular contraction.

Selection of Contributory Muscles

Since the mechanics of some sports skills are similar to those in others, it is possible to relate work done in other areas. Studies by Hermann (1962) and Kitzman (1964) were designed to investigate the functions performed by a few selected muscles. There is no evidence to show that a complete mechanical analysis led to the selection of these muscles. Slatter-Hammel (1948), while looking at contraction-movement relationships, found that data collected during his study disagreed on many points with the traditional kinesiological analysis of the golf stroke. The suspicion that this might also be the case in the ice hockey snap shot led this author in a number of directions before finally selecting six muscles for analysis.

Certain phases of the golf swing resemble the action of the snap shot, especially in the right arm (bottom hand). Slatter-Hammel (1948) found that the right pectoralis major contracted sometime after the start of the downswing and continued up to or beyond impact. There was no evidence to show that the right anterior deltoid contributed to the acceleration of the limbs and club.

Travill (1962) found the long head of the triceps to be quite inactive during active extension of the elbow regardless of the position of the arm. In addition, he found the medial head was always active and appeared to be the prime extensor of the forearm. He also found that against resistance, the lateral and long heads are recruited.

Basmajian (1967) noted that the brachioradialis does not supinate or pronate the extended forearm unless these movements are performed against resistance. Travill and Basmajian (1961) found that fast supination in the extended position required only the supinator but fast unresisted supination with the elbow flexed is assisted by the action of the biceps. Basmajian (1967) found that during supination of the forearm the long head of the biceps showed more activity than the short head and that the biceps is generally active during flexion of the supine forearm under all conditions. Basmajian concluded that in wrist flexion the flexores carpi radialis, ulnaris and digitorum superficialis act synchronously and none is the prime mover.

Basmajian (1967) stated that the rhomboid muscles (major and minor) imitate the middle trapezius, being most active in abduction and least during early flexion. Basmajian (1976) found that the rhomboids retract the protracted scapula with considerable force and they turn the glenoid cavity downward, thus forcibly lowering the raised arm.

Basmajian (1967) describes the teres major as one of the chief muscles acting upon the shoulder joint. Tortora (1977) says the teres major extends the humerus and draws it down and assists in adduction and medial rotation of the arm.

Choice and Placement of Electrodes

Basmajian (1967) criticized the use of surface electrodes claiming that their usefulness was restricted to the investigation of the interplay between widely separated muscle groups in preliminary studies. However, Visser and De Rijke (1974) said that ". . . with surface electrodes a more precise impression is gained of the overall activity of the entire muscle. Needle electrodes register only the local activity of a limited number of motor units at a fairly random site in the muscle." Bouisset and Maton (1972) examined the relationship between the surface EMG and the intramuscular EMG for voluntary isotonic contractions. Submaximal movements of flexion of the right forearm were performed in a horizontal plane at various velocities and against light inertia at voluntarily limited amplitudes. Three fine platinum wires were inserted into the biceps brachii around surface electrodes. The intramuscular lead-offs were algebraically added and their sum was integrated (QE). The surface activity was also integrated (QG). The existence of a linear relationship between QE and QG was demonstrated. The relationship was found for each subject and was independent of the velocity and inertia opposed to the movement. A linear relationship was also shown between QE and the work done (W). It was suggested that the activity of muscle fibers near the surface is representative of all the fibers involved in the given activity. The linearity of the relationship between QE and QG also seemed to signify that each measure of QG was a measure of QE multiplied by a constant coefficient.

Inman (1952) found a parallelism between isometric tension and integrated EMG irrespective of whether measurements were taken using skin electrodes, wire electrodes or coaxial electrodes. Lippold (1952) also found a linear relationship between tension and EMG recording even though he used "non-standard" positions for placement of the electrodes. As long as the two recording electrodes were sited over the muscle belly or its tendons, the linear relationship was observed.

In concluding a discussion of the relative merits of surface and wire electrodes, Grieve (1975) stated:

> "Whether experiments are done by the medically qualified or not, the ethics of leaving wire fragments in the body and resorting to radiographs to locate the electrode sites for non-clinical purposes seems questionable to say the least. The reader would doubtless refer to the published work . . . but it may be that surface electrodes are not only safer, easier to use and more acceptable to the subject; but for superficial muscles at least, provide a degree of quantitative repeatability that compares favourably with wire electrodes."

Instrumentation

Electromyographic apparatus has become much more sophisticated since 1948 when Slatter-Hammel investigated the golf stroke. Kitzman (1964) used a Grass electromyograph equipped with four channels of amplification and four ink writing instruments. To prevent atmospheric electrical interference from being recorded, the subjects performed in an electrically shielded room. Hermann (1962) used similar equipment in his analysis of the shot put. Grieve (1975) stated that "It is increasingly the practice to quantify the EMG in some way e.g. integrate or count spikes. It is a wise precaution to obtain a visual record at the same time as a check that the signals are normal in appearance and free from artifact. The quantification places a much higher premium upon such factors as stability and linearity. The capacity for simultaneous quantification of several channels on-line with hard wired devices, apart from its expense, may prove very restrictive. As far as the quantification of phasic electromyographic signals is concerned, there is no general agreement at present as to the most suitable technique (or even whether a quantitative result is more useful than a visual judgement). In the present state of the art it is advisable for laboratories to choose general purpose rather than specialized electromyographic equipment. Investment in custom-built multi-channel machines which are only capable of performing one type of quantification is not justified at present."

Grieve (1975) suggests that "The flexible approach at modest cost is to use an F.M. tape recorder and process the data either by multiple replays through selected single channels of custom built analogue analysers. An alternative is to digitise the information and use a small general purpose computer to process the data. A digitised record gives enormous flexibility to the processing of EMG data. If sufficient storage capacity exists then the same signals can be processed in many alternative ways. The cost of amplifying, digitising, processing and storing multi channel EMG data can be very high indeed.

. . . Final results drawn in Indian ink on a Calcomp plotter may be very beautiful but the laboratory staff pay heavily for it in time and machine involvement.

. . . Much wider agreement about the significance of a quantitative result, i.e. its repeatability, applicability and predictive value, is needed before standardised machines are accepted. The modest number of laboratories with access to the large digital machines can make a useful contribution here, not particularly by making kinesiological discoveries but by exploring the relative merits of simple analogue or hybrid EMG analyses which can be simulated in the first instance by the large general purpose machine. The sooner this phase in the development of electromyographic kinesiology is over the better as far as standardisation and effective communication are concerned."

Today it is possible to wire subjects directly to a computer by means of a belt worn around the waist and a lead-off cable. EMG potentials are digitized and recorded on magnetic tape where they are stored until further analysis is required. Data can then be transferred to computer disc for plotting and numerical analysis. Sophistication of equipment now allows EMG studies to be performed without traditional electrical shielding.

CHAPTER III

EXPERIMENTAL PROCEDURES

Subjects

Four male hockey players proficient at the university level served as volunteer subjects. All four subjects were members of the McGill Redmen Varsity team and all were right hand shots. Subjects were selected on the basis of height and body type to ensure that stick length was comfortable for each and that excessive adipose tissue levels would not interfere with muscle to EMG electrode connections. All subjects were caucasian, ranged in age from 20 to 24 years, in height from 1.73 to 1.78 meters, in weight from 70.5 to 77.3 kilograms and in body fat as per skin fold caliper measures from 8 to 14 percent.

Experimental Apparatus

Four identical pattern made professional hockey sticks produced by the Sherwood Hockey Stick Company of Sherbrooke, Que., were used in the study. All were exactly 1.77 m in length measured from the top of the shaft to the lower tip of the blade and originally, all weighed exactly 443 g. Stick A was retained as the control device and the others were treated as follows: Stick B had exactly .91 kg of weight inserted into the shaft and equally distributed from the top of the shaft to the bottom. Strips of lead tape were used to ensure the exact weight increase and distribution. Stick C had exactly .91 kg of weight distributed from heel to toe along the back surface of the blade of the stick and the weight was held securely with white hockey tape. Stick D had a .91 kg weight located at a point on the shaft just below the shooting hand and it was held in place by a collar made of masking tape. In all cases, the weight of the tape used was considered. Table 1 indicates the stick codes.

A normal 171.4 g Canadian Amateur Hockey Association (CAHA) official puck served as the projectile in each series of tests.

Experimental Muscles

Pilot studies by this author consisted of mechanical and kinesiological analyses followed by extensive EMG investigation. A mechanical analysis of the snap shot determined the movement patterns of the upper limbs. For a right hand shot, the movements on the right side are: adduction, flexion, horizontal flexion, and medial rotation of the humerus; elbow extension; wrist flexion and supination-pronation of the right forearm. Left side movements included: adduction, extension and outward rotation of the humerus; elbow flexion; supination of the left forearm; and adduction of the scapula. Based on these movements, EMG was used to select six muscles (three on each side) which were considered to be crucial to the execution of the snap shot. These muscles consistently demonstrated muscle activity in the execution of the shot across all tested subjects. Table 2 indicates the coding of the muscles for the EMG analysis of the snap shot.

TABLE 1: CONTROL AND EXPERIMENTAL STICKS

CODE	STICK
Stick A	Normal (control stick)
Stick B	Weighted Shaft
Stick C	Weighted Blade
Stick D	Weight below Bottom Hand

TABLE 2: SELECTED MUSCLES FOR EMG ANALYSIS OF THE SNAP SHOT

CODE	MUSCLE	BODY SIDE	EMG CHANNEL
Muscle 1	Pectoralis Major (clavicular head)	Right	1
Muscle 2	Flexor Carpi Ulnaris	Right	2
Muscle 3	Triceps Brachii (medial head)	Right	3
Muscle 4	Biceps Brachii (long head)	Left	1
Muscle 5	Rhomboid Major	Left	2
Muscle 6	Teres Major	Left	3

Selection of Motor Points

Location of the motor points for each muscle was determined according to (Quiring and Warfel, 1967). A Multitone Stimulator was used to locate the most excitable area of the designated muscles which were then marked with a blue skin pencil and defined as the motor point.

Skin Preparation

The skin areas on which the electrodes were placed were first shaved, rubbed with alcohol in order to remove body oils and then abraded with a Quinton Biobrade until the skin was a pinkish color. A neutral (pH = 7.0) electrolytic jelly was then applied to the abraded area and almost immediately removed. This procedure reduces skin resistance and improves the electrical conduction between muscle and electrode cup. A Quinton Biotest Galvanometer was used to ensure that electrical resistance between the electrode and the skin was less than 1500 Ohms for each muscle preparation. All tests were positive.

Attachment of Electrodes

Two Quinton Biomed electrodes (16 mm diameter, 10 mm silver-silver chloride electrode cups with shielded 1.2 m leads) were attached to each muscle by adhesive discs after they were filled with the neutral electrolytic jelly. In addition, surgical tape was applied to further secure the electrodes. A large loop was made in the electrode wire and the wire was then secured to the skin to prevent movement of the cup. One electrode was placed directly over the motor point and the other was placed 25 mm distally (measured center to center) such that the two electrodes were in line with the direction of pull of the muscle fibers. A single ground electrode was used to help prevent 60 cycle interference and was attached to the bony acromion process. The lead wires were arranged and secured on a waist belt so as not to interfere with the subject's performance of the skill.

Testing Procedure

Since the computer would only allow the recording of four channels at one time, each subject was tested by right and left sides. Three muscles on the left side were placed on three of four channels on the left side of the belt. The fourth channel was shorted out. The three remaining muscles on the right side were hooked up to three of four channels on the right side. Again, the fourth channel was shorted out. Tests on the left side were conducted immediately after testing the right side and vice versa. A wall switch consisting of four plugs allowed an expedient changeover to the four channel operation on either side. Subjects were systematically rotated into each of the experimental conditions (right and left sides considered) in order to avoid experimental bias. See Figure 1.

Treatment (Stick) Order

Subjects	Side	1st	2nd	3rd	4th
1	R	A	B	C	D
	L	C	D	A	B
2	L	B	C	D	A
	R	D	A	B	C
3	R	C	D	A	B
	L	A	B	C	D
4	L	D	A	B	C
	R	B	C	D	A

FIGURE 1. Subjects by Treatments Repeated Measures Design

All subjects wore rubber soled running shoes and were asked to stand facing the target with their right foot on a line perpendicular to the direction of the shot drawn on the shooting board. The puck was placed with its back edge on the border line of this same line. The stick was initially placed on the starting line eighteen inches behind the puck. This set-up was used to reduce lower body motion and put the onus on the upper body muscles concerned. One of the positive characteristics of the snap shot is that it can be effectively released with the weight on either foot.

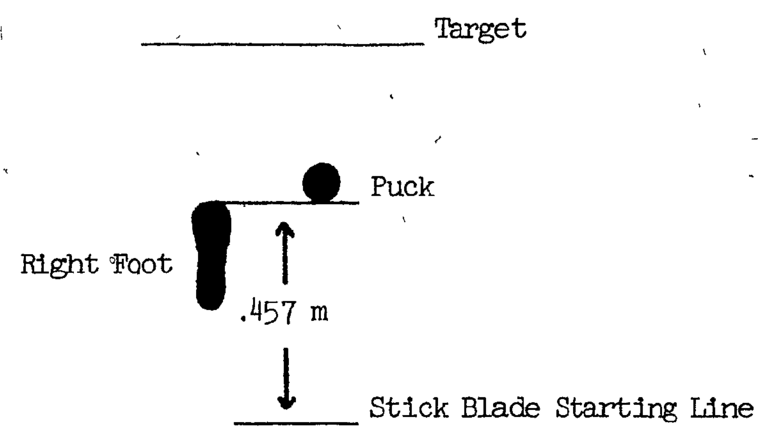


FIGURE 2. Relative position of subject on shooting board

Subjects were given a ten minute warm-up and familiarization session with all sticks and testing began after a ten minute rest period. They were instructed to shoot each puck with maximum effort and after the shot was made, to drop the stick immediately during follow through and relax all upper body muscles.

The lab, located one floor above the computer center, was equipped with a starter button which activated the computer program and an indicator box with a light which came on when the computer was ready to accept data. The time between shots was from three to five minutes so the fatigue factor was not of great concern. Once the light was on, the subject stood over the puck (hands in position but totally relaxed so that a quiet EMG baseline could be established) and was given the signal to shoot within a second after the starter button was activated. A three second period was allowed for each shot following activation of the starter button. This made possible a pre and post data baseline, as the computer had to take into account the offset voltage (half cell potential) that was generated at the interface between the electrode and the skin.

Subjects took three shots with each of the four sticks for both left and right sides - a total of twenty-four shots for each subject. The shots were numbered and labeled according to stick and side (numbers 101-124 for subject 1; numbers 201-224 for subject 2, etc.). All data was stored on magnetic tape. All channels were checked at the beginning of testing for each side to ensure that offsets were within acceptable limits. This was done by plotting the first shots and reading the graphs. Separate programs were used to transfer the data to disc (MTTD) then to plotter using DTMT (for graphic copies of the data) and to disc, then to digitizer using DTMT for numerical peak values. A special program was developed (See Appendix B) to find consistent starting and ending points for all muscle action potential readings. This program also included times for start, end and duration of contraction. Integrated sum was the calculation called for as the measure of comparison because it is a measure of the total activity of the muscular contraction.

Myograms of the recorded muscle activity of shots using the control and experimental sticks are shown in Appendix C. In the first example on page 41, using the control stick, channels 1, 2 and 3 recorded the electrical activity from PMCH, FCU, and TBMH on the right side of the body, respectively. The start and end of muscle contraction, duration of contraction, and the integrated sum of the muscle activity can be found on the computer printout on page 42. For a visual check of the computer determination of the start and end of muscle contraction, the reader can refer to the time sequence included at the top of the myogram.

CHAPTER IV

RESULTS

The results of the EMG investigation of four subjects performing three shots with each of four hockey sticks is included in Table 3.

TABLE 3: MEAN SCORES (INTEGRATED SUMS) FOR EACH MUSCLE

STICK	SUBJECT	PMCH MUSCLE 1	FCU MUSCLE 2	TBMH MUSCLE 3	BBLH MUSCLE 4	RM MUSCLE 5	TM MUSCLE 6
A	1	352.88	152.65	283.90	288.41	141.72	283.98
	2	183.80	328.73	329.15	188.95	133.85	234.59
	3	224.63	206.51	487.74	130.80	276.91	215.09
	4	226.86	328.27	229.61	243.38	44.06	155.28
	Mean	247.04	254.04	332.60	212.88	149.14	222.24
B	1	358.31	105.25	356.65	343.92	177.24	313.97
	2	189.31	336.81	387.75	141.70	78.96	259.95
	3	294.62	234.52	286.43	57.28	297.97	202.69
	4	252.44	389.87	256.67	254.07	104.81	188.34
	Mean	273.67	266.61	321.88	199.24	164.75	241.24
C	1	409.57	126.08	357.85	277.94	82.13	350.24
	2	186.74	426.67	411.63	231.99	121.42	305.36
	3	266.00	300.03	436.87	108.37	385.14	189.68
	4	234.29	479.81	195.15	262.86	79.03	160.74
	Mean	274.15	333.15	350.38	220.29	166.93	251.51
D	1	393.26	120.94	257.31	253.30	96.03	305.16
	2	239.64	336.15	388.78	205.00	139.86	284.75
	3	300.77	262.86	398.28	149.64	335.05	208.37
	4	183.08	274.05	191.21	217.85	35.54	171.49
	Mean	279.19	248.50	308.90	206.45	151.62	242.44

TABLE 4: MEAN SCORES (INTEGRATED SUMS) FOR EACH MUSCLE OVER ALL SUBJECTS SHOWING PERCENTAGE INCREASES WITH STICKS B, C AND D COMPARED TO STICK A.

Muscle	Mean A	Mean B	B-A % Increase	Mean C	C-A % Increase	Mean D	D-A % Increase
1. PMCH	247.04	273.67	10.8	274.15	11.0	279.19	13.0
2. FCU	254.04	266.61	5.0	333.15	31.2	248.50	-2.2
3. TBMH	332.60	321.88	-3.2	350.83	5.4	308.90	-7.1
4. BBLH	212.88	199.24	-6.4	220.29	3.5	206.45	-3.0
5. RM	149.14	164.75	10.5	166.93	11.9	151.62	1.7
6. TM	222.24	241.24	8.6	251.51	13.2	242.44	9.1

Discussion

In examining the results presented in Table 4, it was interesting to see the percentage change in mean score integrated sum for each muscle comparing each of the weighted sticks to the control. Using stick B (weighted shaft) the pectoralis major showed a 10.8 percent increase, the flexor carpi ulnaris a 5.0 percent increase and the triceps brachii a 3.2 percent decrease. On the left side of the upper extremities, the biceps brachii showed a 6.4 percent decrease while the other two muscles, the rhomboid major and teres major showed increases of 10.5 percent and 8.6 percent respectively. Only two muscles, the triceps brachii on the right side and the biceps brachii on the left side, failed to show a percentage increase while stick B was being used.

Using stick C (weighted blade), the pectoralis major showed an 11.0 percent increase, and flexor carpi ulnaris a 31.2 percent increase and the triceps brachii a 5.4 percent increase. The biceps brachii showed an increase of 3.5 percent while the rhomboid major and teres major showed respective increases of 11.9 and 13.2 percent (Table 4). Although all six muscles tested showed percentage increases, again it was the triceps brachii and biceps brachii showing the least positive responses. The flexor carpi ulnaris showed the greatest percentage increase of any muscle under any condition while stick C was being used. This finding is attributed to the fact that in this particular stick the weight is concentrated at a considerable distance from the point of application of force and the right forearm was burdened with the task of moving the blade through the puck.

Using stick D (weight below the bottom hand), the pectoralis major showed a 13.0 percent increase while the flexor carpi ulnaris and triceps brachii showed respective decreases of 2.2 and 7.1 percent. This response was similar to response shown while using sticks B and C except for the decrease of 2.2 percent shown by the flexor carpi ulnaris. This decrease was totally uncharacteristic but may be explained by the fact that the moment arm was considerably shorter in stick D compared to sticks B and C. The biceps brachii responded negatively, as it did using stick B, with a decrease of 3.0 percent. Again, as they did throughout, the rhomboid major and teres major showed percentage increases. The rhomboid major showed a considerably smaller increase of 1.7 percent while the teres major showed a 9.1 percent increase (Table 4).

Overall, stick C (weighted blade) appeared to be the most effective in terms of overloading the six muscles tested. Percentage increases were evident in all six. Stick B caused increases in all but the triceps brachii and the biceps brachii. Stick D caused increases in all but the flexor carpi ulnaris, triceps brachii and the biceps brachii.

The triceps brachii on the right side of the upper extremities and the biceps brachii on the left side were the only two muscles which showed consistent decreases and, in the case of the weighted blade (stick C), relatively low increases. It is obvious that these two muscles, although they are active in the performance of the snap shot, are not called upon as much as the others in the overload situation. The other four muscles (pectoralis major, flexor carpi ulnaris, rhomboid major and teres major), with the exception of the flexor carpi ulnaris and the 2.2 percent decrease using stick D, showed fairly consistent increases and appear to be the most important of the six tested muscles in terms of dealing with the task of overload.

Since the computer program identified the starting and ending points for each muscle contraction it was possible to determine the order of firing of muscles by sides and the duration of muscle contraction. The complete order of firing of the six muscles could not be determined because the right and left sides were not tested simultaneously. For muscles on the right side subjects one, two and three showed a high predominance of firing in the order of 1, 2, 3 ie. pectoralis major followed by flexor carpi ulnaris followed by triceps brachii, for all sticks except the weighted blade which caused variance in the muscle contraction order. (The only times a muscle firing order of 1, 2, 3 was not observed was when starting points were extremely close together.)

Subject number four showed a predominance of 2, 1, 3 in firing order (flexor carpi ulnaris, pectoralis major, triceps brachii) with no effect on this order by stick C (the weighted blade). This difference in firing order may be attributed to the different styles of release found between shooters or it may be attributed to a difference in shooting ability. Subject four was the most experienced player and was, unquestionably, the best shooter. The fact that stick C did not affect his firing order may be no coincidence.

Starting points of muscle contractions were extremely close for all three muscles on the left side. However, in 37 of 48 shots, the biceps brachii was the last to fire. This was to be expected because during the mechanical analysis in pilot studies it appeared that adduction of the humerus preceded elbow flexion. The rhomboid major and teres major alternated almost 50/50 as firing leader. This variance and the variance occurring in the 11 shots where the biceps brachii was not the last to fire can be attributed to individual differences in shooting mechanics and again, to the closeness of starting points of muscular contractions.

For muscles on the left side, the average duration of contraction over all subjects using stick A (control stick) was .133 seconds. With stick B (weighted shaft) the average duration of contraction was .135

seconds and with stick D (weight below bottom hand) it was .140 seconds. Stick C (weighted blade) caused the greatest increase in duration of contraction at an average of .179 seconds. The muscles on the right side showed relatively greater durations of contraction than did those on the left side. With stick A (control stick) the muscles showed an average duration of .191 seconds. The average duration with stick B (weighted shaft) was .204 seconds and with stick D (weight below bottom hand) .224 seconds. Again, stick C (weighted blade) showed the greatest increase in duration with an average of .237 seconds. The weighted sticks all resulted in increased durations of muscle contraction.

Interpretation of results with small sample sizes must be done with caution as individual differences do exist. For example, in Table 4 the pooled results from four subjects indicated that there was a 13 percent increase in PMCH response when stick D was compared to stick A. However, in Table 3 it can be seen that subject four demonstrated a 19.3 percent decrease in PMCH from A to D. Again, it should be pointed out that subject four was the most highly skilled and experienced shooter.

CHAPTER V

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

The purpose of this study was to determine the effectiveness of weighted hockey sticks in overloading some of the muscles involved in the ice hockey snap shot. Four male hockey players proficient at the university level were used as subjects. One normal stick was used as the control device and three weighted sticks acted as experimental devices in the study. The muscles used for the study and located on the right side of the body were the pectoralis major (clavicular head), triceps brachii (medial head) and flexor carpi ulnaris. Muscles located on the left side of the body and also studied were the biceps brachii (long head), teres major and rhomboid major.

Subjects were systematically rotated into each of the experimental conditions using a subjects by treatments repeated measures design. Subjects took three shots with each of four sticks for both left and right sides for a total of twenty-four shots each. Shots were numbered and labelled according to stick and side and all data was stored on magnetic tape.

The Integrated Sum calculation was used as the measure of comparison.

Conclusions

The conclusions that can be drawn from this study are as follows:

1. All three experimental sticks used in the study placed an overload

on three of the six muscles tested. These muscles were: pectoralis major located on the right upper extremity; rhomboid major and teres major, both located on the left upper extremity.

2. The flexor carpi ulnaris located on the right upper limb was overloaded with all sticks except the stick with the weight below the bottom hand.
3. The triceps brachii located on the right upper limb and the biceps brachii located on the left upper limb failed to respond to the overload produced by the stick with the weighted shaft and the stick with the weight below the bottom hand.
4. The stick with the weighted blade caused an overload in all six muscles tested.

Recommendations

1. Further studies could include sticks B and D but with substantial increases in the magnitudes of the weights applied.
2. Stick C should be considered for further study using a weight of considerably less magnitude.
3. A similar study using a single stick (B, C or D) with weights of various magnitudes may prove to be useful for purposes of short duration overload.
4. For statistical analysis, a similar study using more subjects and fewer muscles could be considered.
5. A comparative study of professional and amateur hockey players should be considered.

6. A study closely paralleling this study should be done prior to and following a normal six month season during which subjects have used experimental sticks regularly.
7. A study on puck velocity increase after longer training periods with weighted sticks would be cheaper and extremely helpful.

It is this writer's opinion that weighted sticks can be useful in developing the skill of shooting and future EMG students are encouraged to follow up on studies of this nature. The surface has barely been scratched in scientific hockey research in this country and even seemingly insignificant contributions will be welcomed.

BIBLIOGRAPHY

BIBLIOGRAPHY

Alexander, J. F., J. B. Haddow and G. A. Schultz, Comparison of the ice hockey wrist and slap shots for speed and accuracy. Res. Quart, 34: 259-266, 1963.

Alexander, J. F., C. J. Drake, P. J. Reichenbach and J. B. Haddow, Effect of strength development on speed of shooting of varsity ice hockey players. Res. Quart, 35: 101-106, 1964.

Basmajian, J. V., and A. A. Travill, Electromyography of the pronator muscles in the forearm. Anat. Rec., 139: 45-49, 1961.

Basmajian, J. V., Muscles Alive - Their Functions Revealed by Electromyography. Baltimore: The Williams and Wilkins Co., 1967.

Basmajian, J. V., Recent advances in the functional anatomy of the upper limb, Amer. J. Phys. Med., 48: 165-177, 1969.

Basmajian, J. V., Primary Anatomy. Baltimore: The Williams and Wilkins Co., 1976.

Bouisset, S. and B. Maton, Quantitative relationship between surface EMG and intramuscular electromyographic activity in voluntary movement. Amer. J. Phys. Med., 51: 285-295, 1972.

Buchtal, F., C. Guld and P. Rosenfalck, Multielectrode study of the territory of a motor unit. Acta. Physiol. Scand., 39: 83-103, 1957.

De Stefano, D., Research in Hockey. J.C.A.H.P.E.R., 37, 19, 39 March-April, 1971.

Gottlieb, G. L. and G. C. Agarwal, Filtering of electromyographic signals. Amer. J. Phys. Med., 49: 142-146, 1970.

Grieve, D. W., D. Miller, D. Mitchelson, J. Paul and A. Smith, Techniques for the Analysis of Human Movement. London, Lepus Books, 1975.

Grossman, W. I. and H. Weiner, Some factors affecting the reliability of surface electromyography. Psychosom. Med., 28: 78-83, 1966.

Hayes, D., A mechanical analysis of the hockey slap shot. J.C.A.H.P.E.R., 31: 17, 31-32, 39, 1965.

Hermann, G. W., An Electromyographic study of selected muscles involved in the shot put. Res. Quart., 33: 85-93, 1962.

Inman, V. T. et al, Relation of Human Electromyogram to Muscular Tension. Electroenceph. Clin. Neurophysiol. 4: 187-194, 1952.

Kitzman, E. W., Baseball: Electromyograph study of batting swing. Res. Quart., 32: 166-178, 1964.

Lippold, O. C. J., The relation between integrated action potentials in a human muscle and its isometric tension. J. Physiol., Vol. 117, 492-499, 1952.

Quiring, D. P. and J. H. Warfel, The Extremities. Philadelphia: Lea and Febiger, 1967.

Slatter-Hammel, A., Action current study of contraction-movement relationships in golf stroke. Res. Quart., 19: 164-177, 1948.

Slatter-Hammel, A., Action current study of contraction-movement in the tennis stroke. Res. Quart., 20: 424-431, 1949.

Tortora, G. J., Principles of Human Anatomy. San Francisco: Canfield Press, 1977.

Travill, A. A. and J. V. Basmajian, Electromyography of the supinators of the forearm. Anat. Rec., 139: 557-560, 1961.

Travill, A. A., Electromyographic study of the extensor apparatus of the forearm. Anat. Rec., 144: 373-376, 1962.

Van Huss, W. D., L. Albrecht, R. Nelson and R. Hagerman, Effect of overload warm-up on the velocity and accuracy of throwing. Res. Quart., 33: 472-475, 1962.

Visser, S. L. and W. De Rijke, Influence of sex and age on EMG contraction pattern, Europ. Neurol. 12: 229-235, 1974.

APPENDICES

APPENDIX A

COMPUTER DESCRIPTION AND OPERATION

COMPUTER

The Honeywell HS 4020 computer in the DATAC laboratory at the MacDonald Engineering Building (Mechanical Engineering Department) is a 24 bit, medium scale, real time, multiprogrammed, timesharing data-acquisition and process control computer. In addition to the standard computing facilities normally found in business or scientific computers, it also has the capability to interface directly to the real, analogue world. It is equipped with two Analogue to Digital converter sub-systems, one 320 channel, high accuracy, low speed IDVM and one 2 or 4 channel medium accuracy, high speed successive approximation type. Furthermore, analogue outputs, digital inputs (contact sensing), digital outputs (controlled switches) and interrupts are available.

For the EMG work the high speed ADC was used even though only four channels were available, ie. only four muscles can be analyzed simultaneously. This high speed ADC contains two converters such that two measurements are made simultaneously in time. Using a "windshield wiper" type multiplexor in front of each converter operating at the same rate as the ADC's, four channels can be measured whereby each pair of two signals is offset in time one half the sampling interval. A sampling rate of 4000 per second was chosen resulting in an effective sampling rate of 2000 per second on each channel, with a .25 millisecond offset between successive pairs.

The high sampling rate is required as frequencies as high as 500 HZ can show up in myoelectric signals. Even with this 4 to 1 ratio, low pass filtering was employed (in this case with a 1 KHz breakpoint) to ensure that aliasing did not occur.

Each converter is equipped with a Sample and Hold (S/H) amplifier as the actual conversion time (the time required to generate the digital bipattern as a function of the applied analogue signal) of the ADC's is too slow (20 microseconds) to properly digitize high frequency signals. The S/H have an aperture time of 100 nanoseconds providing a fractional error of less than .002 at 5 KHz.

CONDITIONS

Amplifier gain = 200, ±25 m V range to allow for DC offset.
Sampling rate = 4000/sec. (2000/sec. effective rate for each channel)
Four channel operation (Continuous/On Line)

TESTING

Data are collected via program 10, a special program that stores data from ADC's for a predetermined length of time on disc. To start program 10 one must initialize from the ASR. Data gathering starts after pressing of the "interrupt" button (used for non-scheduled events, in this case to start the ADC's). After pressing the "interrupt" button, the subject must wait at least 25 milliseconds to establish baseline offset as the system is completely DC coupled. (DC coupling allows all signals from DC to maximum frequency and problems with offset are calculated out. AC coupling allows only signals between a lower and upper limit of frequency no offset problem but there is a loss of possible important low frequency data).

Data are stored on 9 track 800 bpi IBM compatible magnetic tape using a standard utility program (DTMT).

PLOTTING

Plotting is done by a Calcomp 565 digital plotter with an 11" wide drum, .01" step size both in X and Y and a maximum 300 steps/sec. Data are either on disc or transferred from tape to disc using MTTD. Using program PHYSD3, all four channels were plotted (first three seconds). Each trace had an artificial zero baseline determined by the DC offset measured in the first 25 milliseconds on a vertical scale indicating millivolts/inch. The X scale was 11" = .05 secs. A time scale, the data, the test number and conditions were also plotted. On demand via switches on the console, this program also printed (1) all data points collected and (2) peaks or reversal points.

APPENDIX B

PROGRAM

FOR

DETERMINATION

OF

START AND STOP OF MUSCLE CONTRACTION

START-STOP OF CONTRACTION

A "moving window" technique was used to determine the onset and termination of the SMC (skeletal muscle contraction). The parameter used was the RMS value of the the data. RMS was chosen as the parameter because it gives an instantaneous measure of the data.

An initial 100 datapoint window (=50 milliseconds) starting at t_0 (time zero) was selected and the RMS value of the signal in the window was calculated. The window was moved to the next 100 points and the RMS was again calculated. This process continued until two consecutive windows showed RMS values in excess of a predetermined value. The starting point and the RMS values of the first of these two windows were saved. The latter served as the criteria for the end determination. The window was moved further until two consecutive windows with an RMS value below the initial value was detected. This indicated a possible end of SMC. The starting point of the first of these two windows was also saved.

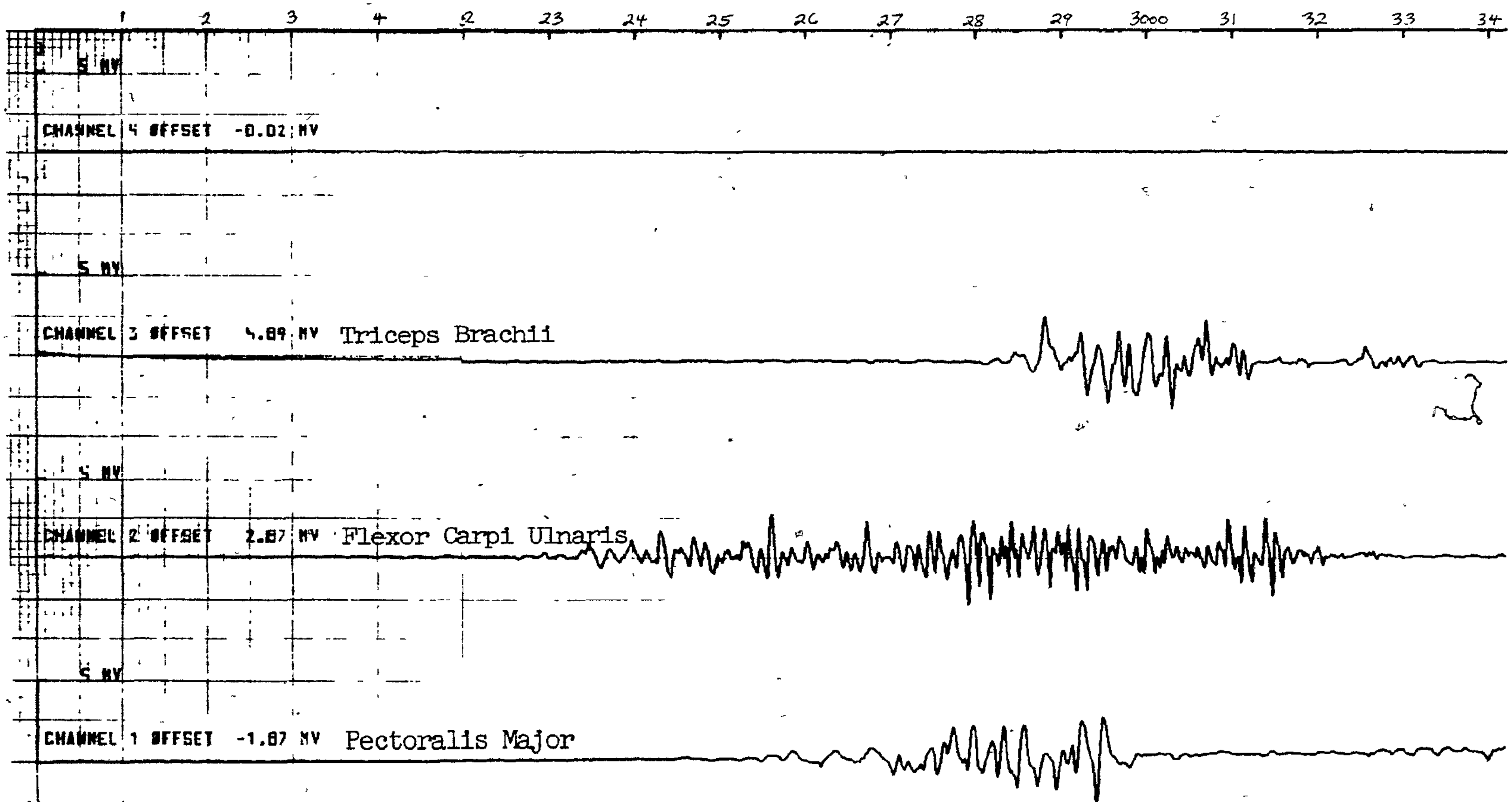
The whole cycle was repeated with window sizes of 85, 70 and 55 data-points. To determine the true onset of SMC the data in a 100 point window before the earliest detected "start-point" was examined for a peak exceeding ±1 mV from the artificial baseline. This point was taken as the onset. If no such point could be found, the first peak, regardless of magnitude, "after" this "start-point" was selected. Using this four window type approach, the probability of finding the correct onset is statistically very high.

The termination of SMC was determined differently. It was found that after the SMC of interest, the baseline was noisier than before the onset. This may be explained by the fact that all test EMG data were collected during the investigation of high velocity gross human movement patterns. Relying on the same criteria as at the onset will therefore usually result in a realistic end point.

Since in these tests the actual SMC's are always less than .5 secs in duration, any stopping point determined by the four windows that was larger than the onset (+1024 data points) was ignored. The data starting at the latest of the remaining stopping points was examined going backwards ($t-t_0$) and the first peak detected was taken as the termination of SMC. The points selected by this algorithm coincided to a large degree with points selected by subjective assessment of the myogram.

APPENDIX C

MYOGRAMS AND PRINTOUTS



06-21-77 TEST NUMBER 422 NORMAL RIGHT

TEST #422 NOR RIGHT

OFFSETS(MV) -1. 87 2. 87 4. 89

CHANNEL 1

START= 2638 END= 2979 DURATION= 341 UNITS
START= 1. 32 END= 1. 49 DURATION= 0 17 SECS.

AVERAGE SUM= 98. 43
RECTIFIED SUM= 228. 05
INTEGRATED SUM= 227. 92

AVERAGE= 0. 29
RECTIFIED= 0. 67
RMS= 98. 75
INTEGRAL= 0. 11

CHANNEL 2

START= 2367 END= 3224 DURATION= 857 UNITS
START= 1 18 END= 1. 61 DURATION= 0. 43 SECS

AVERAGE SUM= 136. 83
RECTIFIED SUM= 490. 92
INTEGRATED SUM= 491. 23

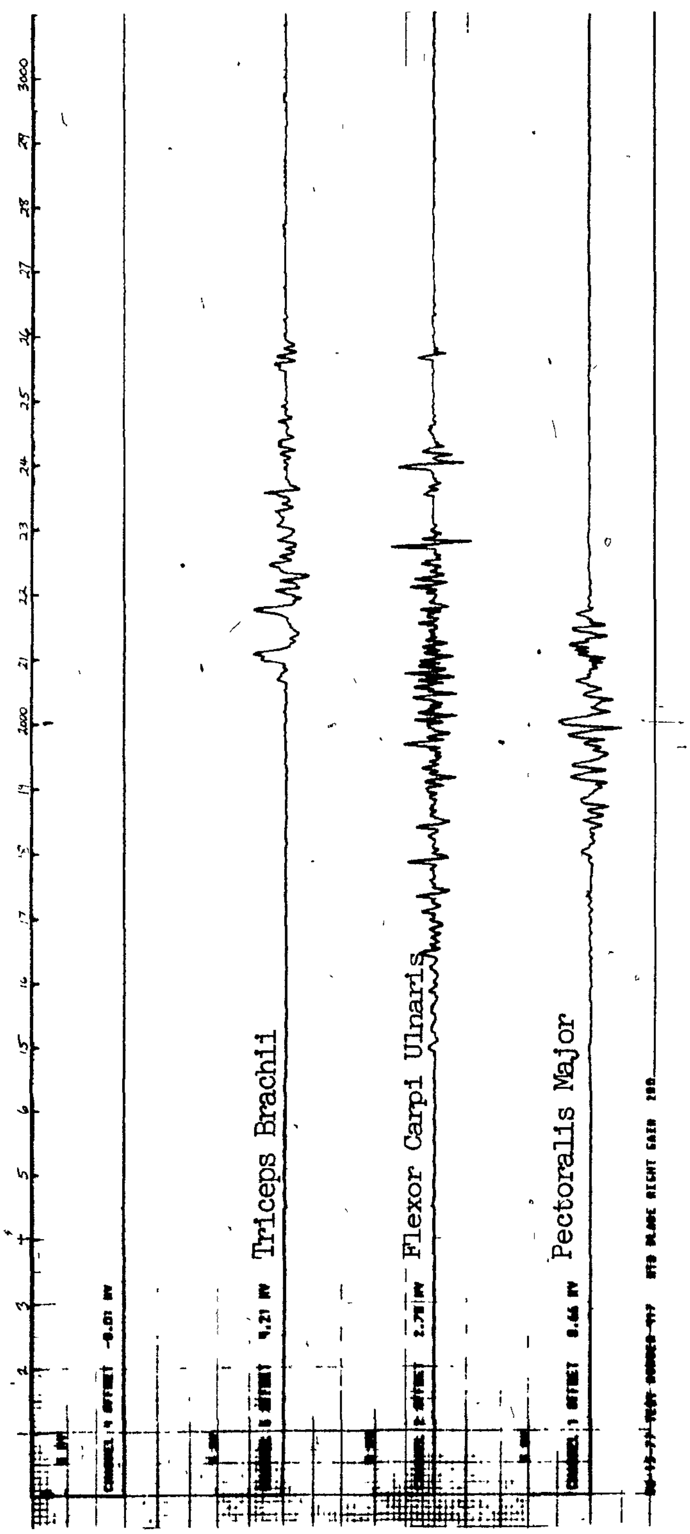
AVERAGE= 0. 16
RECTIFIED= 0. 57
RMS= 52. 33
INTEGRAL= 0 25

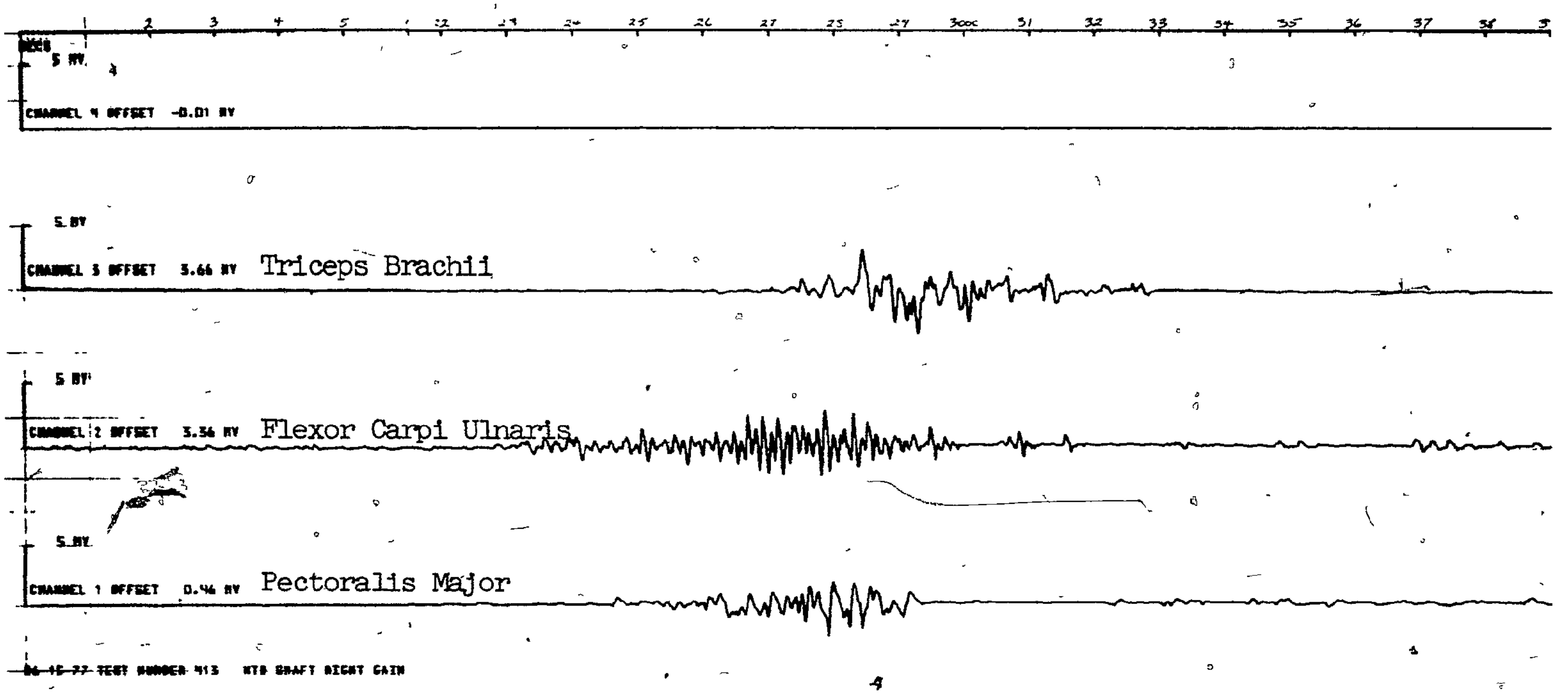
CHANNEL 3

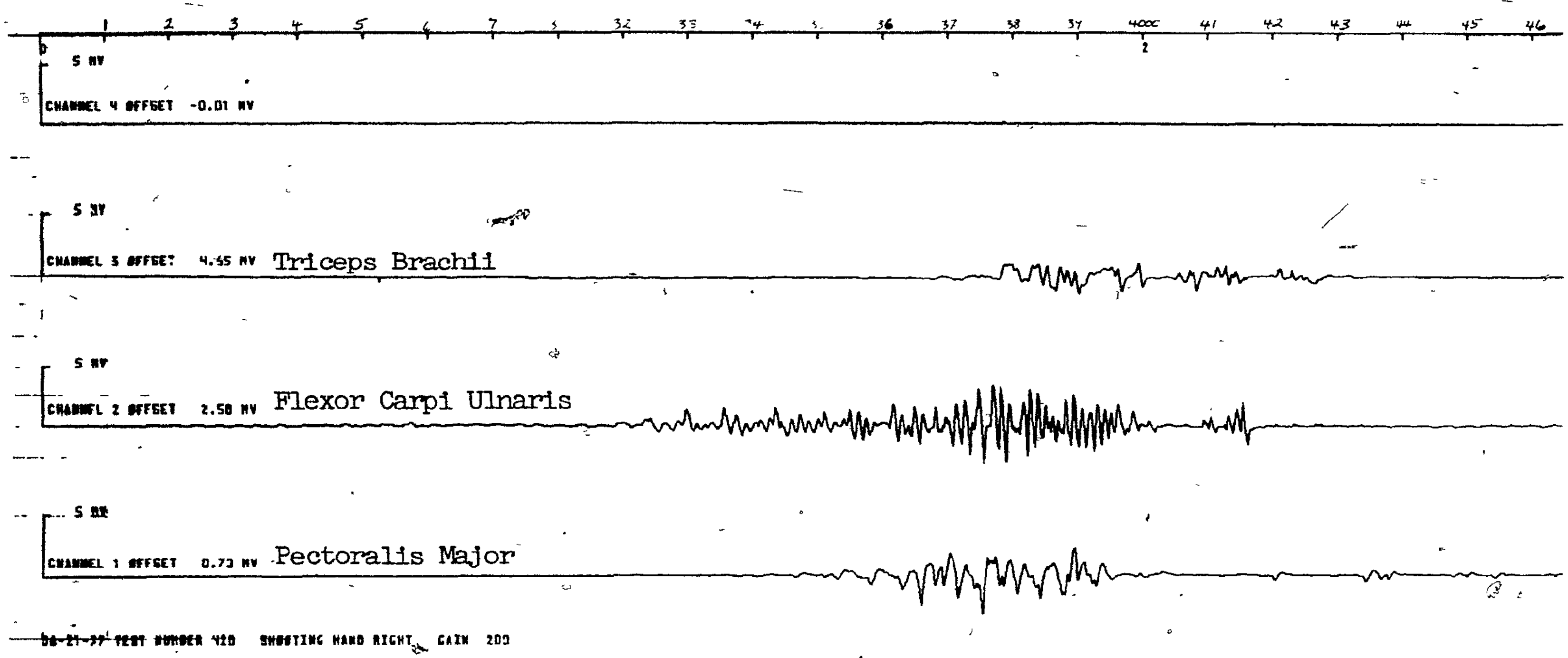
START= 2827 END= 3100 DURATION= 273 UNITS
START= 1. 41 END= 1. 55 DURATION= 0. 14 SECS.

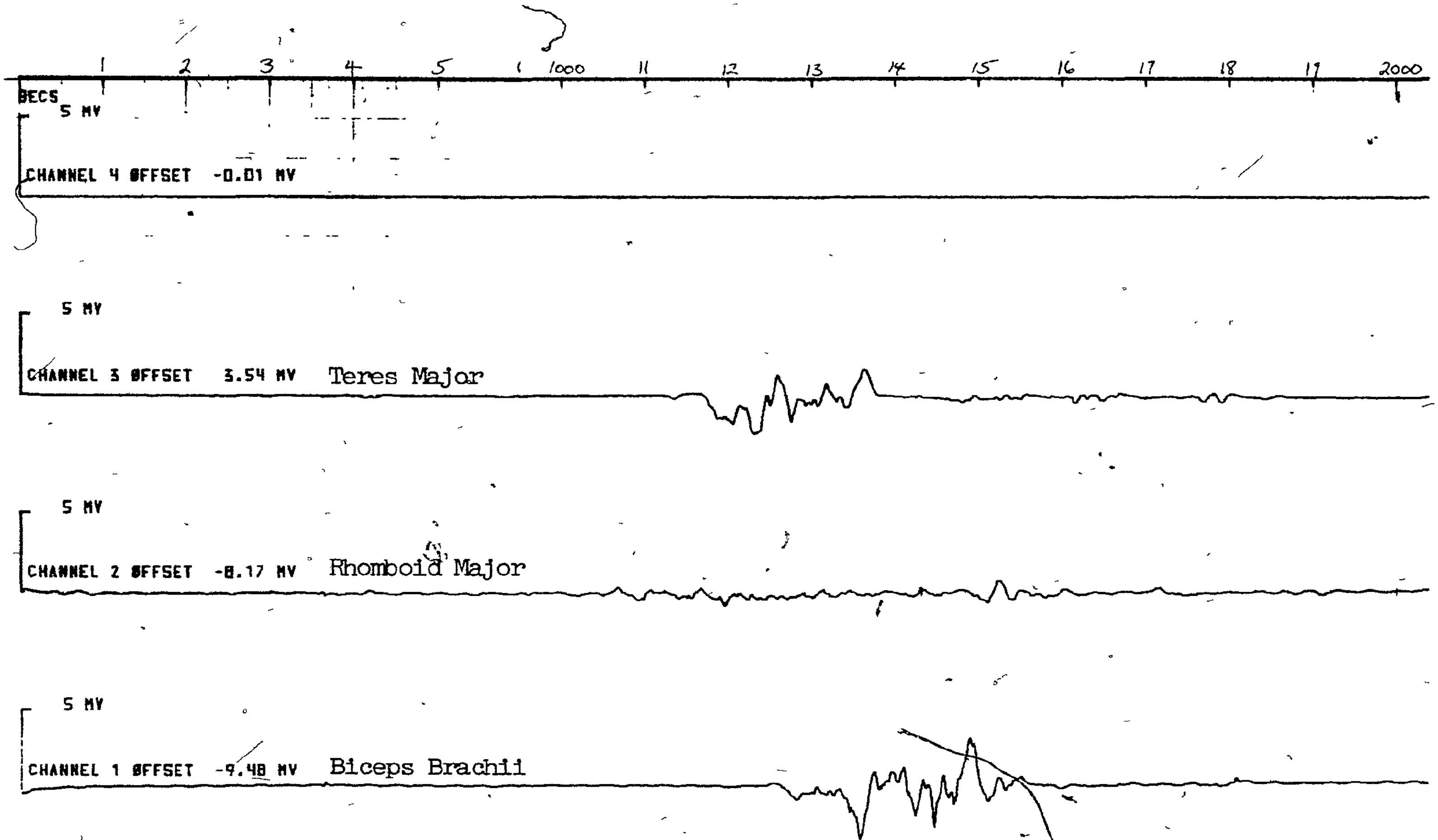
AVERAGE SUM= -97. 75
RECTIFIED SUM= 220. 14
INTEGRATED SUM= 220. 40

AVERAGE= -0 36
RECTIFIED= 0. 80
RMS= 127. 67
INTEGRAL= 0. 11

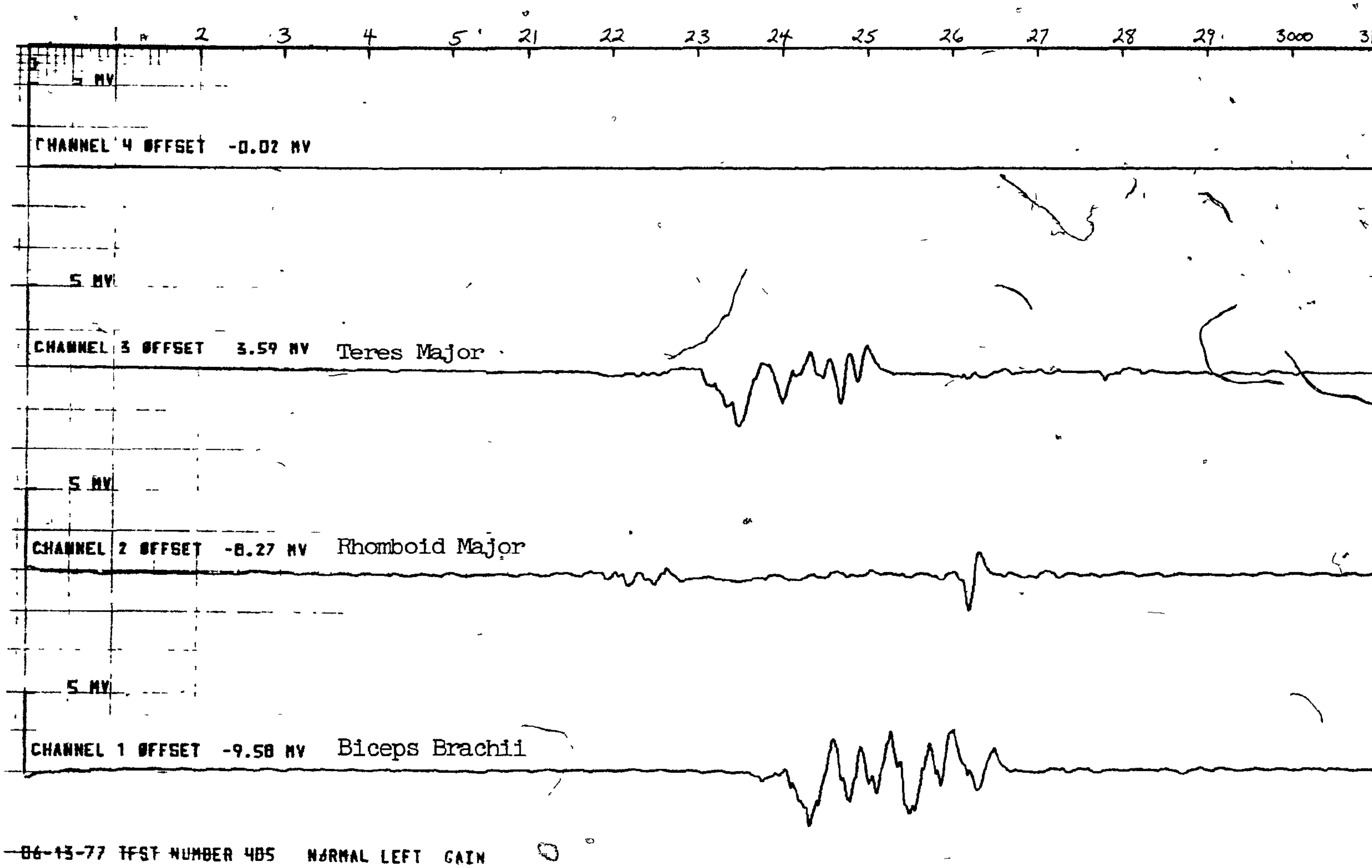

Triceps Brachii
Flexor Carpi Ulnaris
Pectoralis Major

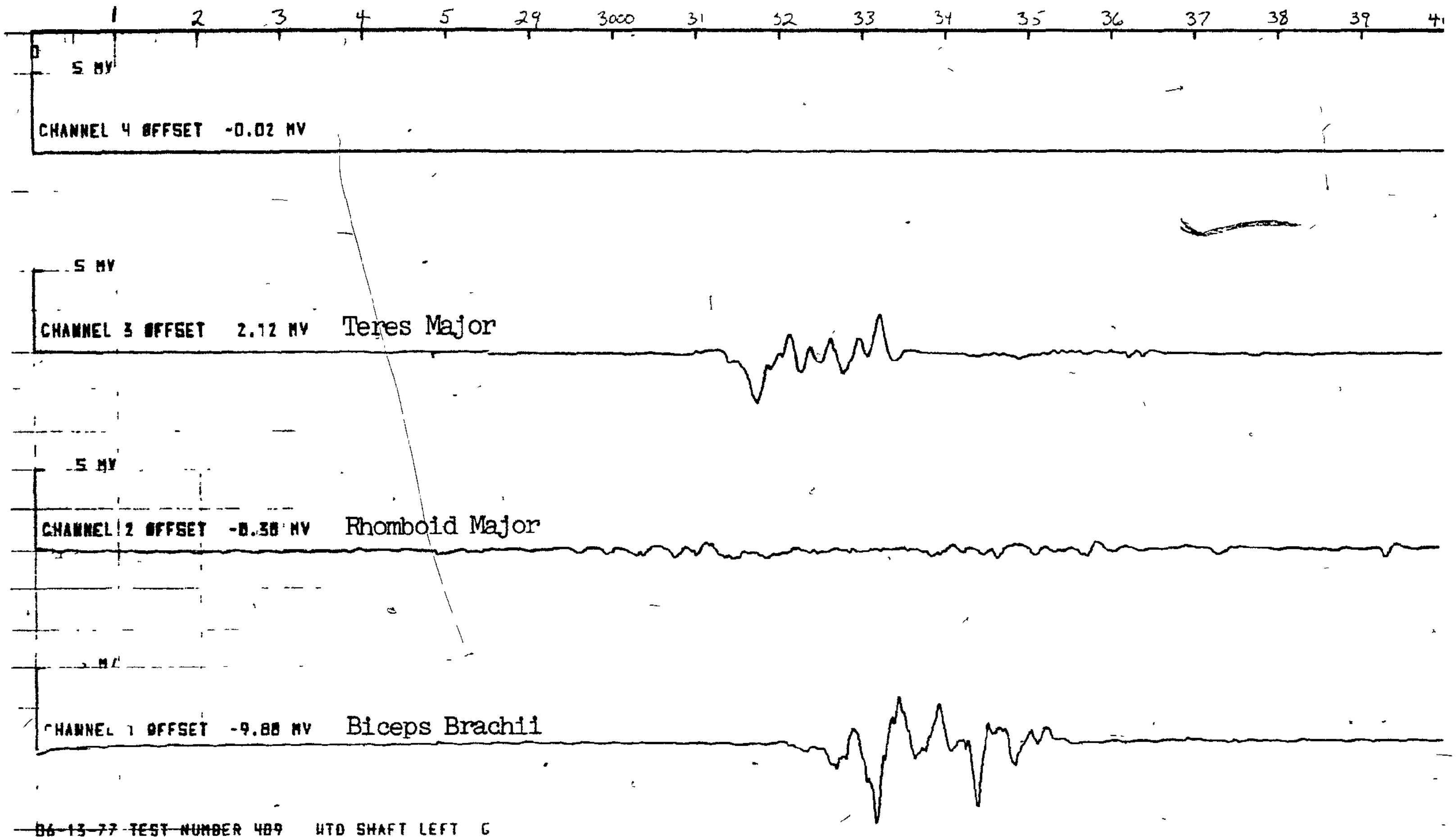

CHANNEL 4 OFFSET -0.01 MV
5 MV
CHANNEL 3 OFFSET 3.66 MV
Triceps Brachii
5 MV
CHANNEL 2 OFFSET 3.56 MV
Flexor Carpi Ulnaris
5 MV
CHANNEL 1 OFFSET 0.46 MV
Pectoralis Major


5 MV
CHANNEL 4 OFFSET -0.01 MV
5 MV
CHANNEL 3 OFFSET 4.55 MV Triceps Brachii
5 MV
CHANNEL 2 OFFSET 2.50 MV Flexor Carpi Ulnaris
5 MV
CHANNEL 1 OFFSET 0.73 MV Pectoralis Major
08-21-77 TEST NUMBER 420 SHOOTING HAND RIGHT GAIN 200

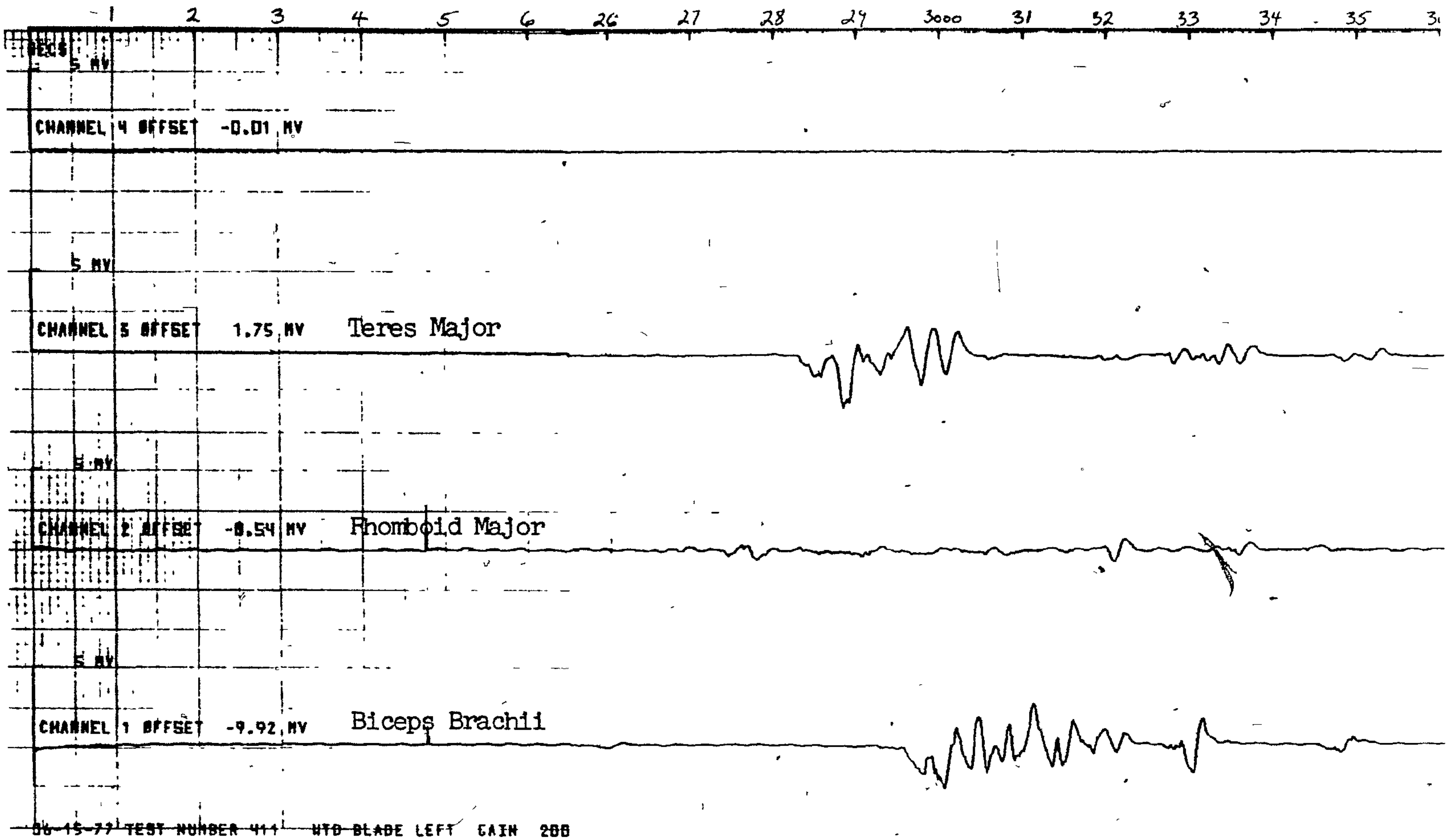


06-13-77 TEST NUMBER 402 SHØØTING HAND LEFT GA


1 2 3 4 5 21 22 23 24 25 26 27 28 29 3000 31
5 MV
CHANNEL 4 OFFSET -0.02 MV
5 MV
CHANNEL 3 OFFSET 3.59 MV Teres Major
5 MV
CHANNEL 2 OFFSET -8.27 MV Rhomboid Major
5 MV
CHANNEL 1 OFFSET -9.58 MV Biceps Brachii
06-13-77 TEST NUMBER 405 NORMAL LEFT GAIN



1 2 3 4 5 29 3000 31 32 33 34 35 36 37 38 39 40
5 MV
CHANNEL 4 OFFSET -0.02 MV
5 MV
CHANNEL 3 OFFSET 2.12 MV
Teres Major
5 MV
CHANNEL 2 OFFSET -0.38 MV
Rhomboid Major
CHANNEL 1 OFFSET -9.88 MV
Biceps Brachii
06-13-77 TEST NUMBER 409 HTO SHAFT LEFT G



1 2 3 4 5 6 26 27 28 29 3000 31 32 33 34 35
SECS
5 MV
CHANNEL 4 OFFSET -0.01 MV
5 MV
CHANNEL 5 OFFSET 1.75 MV
Teres Major
5 MV
CHANNEL 2 OFFSET -8.54 MV
Rhomboid Major
5 MV
CHANNEL 1 OFFSET -9.92 MV
Biceps Brachii
06-15-77 TEST NUMBER 411 WTD BLADE LEFT GAIN 200