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John J. Conzemius
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Electromyographic and Force Analysis

of a Shotokan Karate

Punching Technique

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John J. Conzemius
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Electromyographic and Force Analysis of a Shotokan Karate Punching Technique

Approved by:

Thesis Advisor: *Marcus Webster*

Dr. Marcus Webster,   Associate Professor of Biology

Department Reader: *Charles Rodell*

Dr. Charles Rodell,   Chair, Department of Biology

Department Reader: *Cheryl Knox*

Dr. Cheryl Knox,   Associate Professor of Biology

Department Chair: *Charles Rodell*

Dr. Charles Rodell,   Chair, Department of Biology

Margaret Cook

Dr. Margaret Cook,
Director of the Honors Thesis Program

Mark Thamert, OSB

Fr. Mark Thamert
Director of the Honors Program

Electromyographic and Force Analysis
of a Shotokan Karate
Punching Technique

Abstract:

Electromyographic and force analysis of *Pectoralis major* and *Latissimus dorsi* muscles during a reverse punch demonstrated a significant positive correlation between the average force of individuals and their rank (p<0.01; r-squared=0.73). Also demonstrated was a positive correlation between the amount of EMG activity in the muscles studied and the force (for *Pectoral:* r-squared=0.757, p<0.05; for *Latissimus:* r-squared= 0.733, p<0.1). The relationship between punch duration and rank yielded insignificant results (for *Pectoral:* r-squared= 0.222, p<0.240; for *Latissimus:* r-squared=0.461, p<0.065). Precontact EMG activity and rank regression analysis demonstrated a significant positive correlation for both muscles (for *Latissimus:* p<0.005, r-squared=0.752; for *Pectoral:* p<0.006, r-squared=0.735). Post contact EMG activity and rank regression analysis also demonstrated a significant positive correlation for both muscles (for *Latissimus:* p<0.004, r-squared=0.773; for *Pectoral:* p<0.005, r-squared=0.760). A negative correlation between precontact EMG activity and punch duration was shown for both muscles (for *Pectoral:* -0.568; for *Latissimus:* -0.626). A negative correlation was between punch duration and force was shown for both muscles (for *Pectoral:* -0.559; for *Latissimus:* -0.715). A positive correlation between force and precontact EMG activity was demonstrated (for *Pectoral:* 0.757; for *Latissimus:* 0.733).

Electromyographic and Force Analysis of a Shotokan Karate Punching Technique

Introduction:

Electromyography is the study of the electrical properties of muscles. Loeb and Gans describe the contraction of muscles as an electrical event (1986). Electric potentials propagate along the membranes of muscles from the innervation sites of motor nerves. These potentials cause the release of Calcium from the sarcoplasmic reticulum of muscle cells into the matrix surrounding the contractile filaments. Molecular reactions then take place resulting in the contraction of the muscle.

By placing probes on the surface of the skin or into the tissue, these potentials can be "recorded as the myoelectrical signal" (Gans, 1986). J.V. Basmajian, M.D. describes many techniques of measurement of the myoelectrical signal (1962). The most useful techniques for recording large muscle movements is the skin surface recording technique. Surface electrodes are placed on the skin covering a large muscle and the potentials are recorded during movement.

Karate is the art of controlled, refined muscle movement to maximize the forces generated by muscles. Karate students train to develop an awareness of specific muscle actions and a sense of how to manipulate these muscle actions. The

result of this awareness is the ability to produce a great deal of force from a particular move or technique.

Many factors are important in the execution of a correct technique. The fundamental part of any technique, especially in the Shotokan style of karate, is the placement of the legs and feet in a specific stance. Okacaki and Stricevic explain that the "stance provides stability, balance and strengthens techniques" (1984). Another important part of a technique is the speed of delivery.

"The speed of reaction and the speed of movement are of central importance in the correct execution of karate techniques. It is not physical strength, per se, that is of central importance in determining the power of a technique but the speed implicit in muscular expansion and contraction" (Layton, 1988).

Okacaki and Stricevic explain that movement originates from the large muscle groups of the body and is transferred to the extremities during a technique (1984). The large supporting muscles of the legs and trunk initiate movement and the added movement of the extremities coupled with this initiating movement result in very powerful techniques. In a punching technique, the momentum and energy created by the legs and trunk is transferred into the fists.

Another important aspect of a technique is the action of the drawing arm. In a punching technique, the drawing arm acts in opposition to the punching arm. As the punching arm is extended towards the target, the drawing arm is drawn towards

3

the body at the same speed as the punching arm. The action of the drawing arm "stabilizes, provides balance and increases the impact of the punch" (Okacaki, 1984).

Many punching techniques also involve the rotation of the fists at the end of the technique. Okacaki and Stricevic explain that this "adds 1cm of distance to the punch and allows the muscles of the forearm, elbow and upper arm to work with and be supported by the chest muscles. The result is that the trunk stands much more firmly behind the punching arm" (1984).

The final and perhaps most important element of a karate technique is the focus. Okacaki and Stricevic describe the focus as a "process of combining all the elements of a karate technique", and that "only at the instant of focusing can momentum and effect be maximized" (1984). The focus is characterized by the simultaneous contraction of major muscle groups and the rapid expulsion of air using the diaphragm at the end of a technique. "If air is forcefully exhaled and muscles are contracted at the same time, the full strength of the body will be realized" (Okacaki, 1984).

The skill level of a Karate student is determined by how well they are able to control their bodies in perform techniques with respect to the above aspects of a technique. The skill level and experience of a student is expressed as a rank (See Figure 1). Each rank is achieved through a testing procedure in which students must perform specific techniques demonstrating adequate physical skills as well as an understanding of the concepts behind the movements. The requirements are progressively more difficult for each rank.

Since electromyography is a measuring technique that demonstrates the activity of specific muscles, it can be a useful tool in describing the muscle activity taking place during activities such as karate. Electromyography offers a direct window into the movements and types of muscles used in a particular technique. By measuring the activity of a specific muscle or muscle group during a technique, the development of muscle control and activity of karate students can be determined.

Another means of analyzing a karate technique involves force output. The force of a technique is an indication of the effectiveness of that technique. A good technique combining all the necessary aspects will produce a high impact force while a bad technique will produce a low force level.

This project was designed to study the muscle activity of two muscles involved in a basic Karate technique and relate this to the force output of the technique. This relationship was then analyzed in terms of the training level of the individuals who participated. I hypothesized that as the rank of tested individuals increases with experience, the individuals will show an increase in the electromyographical activity of the muscles used in the technique. This increase in muscle usage should correlate with higher force output of the technique for the higher ranked individuals.

Okacaki and Stricevic explain that "Karate power is the result of momentum generated by body muscles acting in correct sequence and the tensing of these muscles at the instant of impact" (1984).

Zenkutsu-dachi (front stance) is a basic stance where

Methods:

Apparatus:

The equipment set-up for the electromyography portion of the experiment

consisted of attaching disposable silver/silver chloride surface electrodes to the

preselected sites on the *Pectoralis major* of the punching side and the *Latissimus*

dorsi of the opposite side for each subject (See Figure 2).

Wire leads from the electrodes on each muscle were then connected to two

Grass P15 A.C. Preamplifiers. For each muscle, the medial lead was connected to the

G1 terminal and the lateral lead was connected to the G2 terminal. The Hi band

Filter, Lo band Filter and Amplification settings for the preamplifiers were 1kHz,

3Hz and 100 respectively.

The output from the preamplifiers was fed into the input channels of the

MacLab/4 digital aquisition system (A.D.I. Inc, Australia), where the signals were

processed using the *Scope* program. The MacLab was operated in conjunction with a

Macintosh IIci microcomputer.

A force detection apparatus was used to record the force of each technique

(See Appendix A). Force sensor output was recorded concurrently with

electromyographical activity on the MacLab system.

I calibrated the force sensor with 100g and 2kg weights. The preamplifier was calibrated using the internal voltage standard. The system was calibrated during each recording session.

Experimental Technique:

The technique studied in the experiment was *gyaku choku-zuki* (reverse straight punch) at *chudan* (midsection) level. The testing procedure is similar to that of an experiment discussed by Dr. Clive Layton (1988). Each participant stood in front of the force detection apparatus in *zenkutsu-dachi* (front stance) such that the front foot was two hip width's in front of the other, the feet one hip width apart, 60% of the weight on the front foot and 40% on the back foot (Okacaki, 1984). Distance from the force detection apparatus was established such that the outstretched arm extended one inch past the pad of the apparatus. The *gyaku choku-zuki* technique involved punching with the arm opposite the leg which was in front. The beginning position was with the punching arm drawn back along the body in a cocked position with the palm of the fisted hand facing up and the drawing arm outstretched towards the target. The participants were instructed to limit as much as possible any extraneous movement of other muscle groups or rotation of the hips in order to concentrate the movement in the muscles being studied. Upon verbal signal, the participant executed several full, maximal techniques.

While the participant performed multiple punches, the computer recorded 12 500msec samples. Recording was performed until there were 6 recorded samples

where the force impulse was between 300msec and 500msec. This ensured that muscle activity leading up to and following impact was recorded in the sample.

Fourteen volunteers participated in the experiment. The folowing chart displays how the ranks were represented by the participants:

Rank:	# of Volunteers:
0	2
1	0
2	2
3	3
4	1
5	4
6	0
7	1
8	0
9	0
10	0
11	1
12	1

Recording and Analysis:

The EMG signal was analyzed by examining three characteristics of the wave form (See Figures 3-6). The first was the duration of the technique. The time from a recognizable change in the baseline of the EMG until the force of contact was first detected was measured using the marker and measurement function of *Scope*. This period of time was also examined in terms of overall EMG activity. I converted the wave forms to absolute values and then integrated them using *Scope's* mathematical functions. The resultant value is a measure of EMG activity in the muscle during the technique up to the point of contact. The same analysis was performed on the wave form from the point of contact with the force detector until

8

the deflection in the force spike returning back to the baseline. This corresponds to the focus point of the technique.

The force recordings were analyzed by determining the magnitude of the deflection of the initial force spike.

The data were analyzed using *CA-Cricket Graph III* . Regression and correlation analyses were performed using Minitab.

Results:

Actual recordings of the EMG signal and the force detector are shown in FIgures 3-6. Each EMG recording has two important regions, the pre-contact activity region and the post contact activity region. The force recording shows a large spike at the point where contact with the sensor was made.

Figures 3 and 4 are recordings from the *Pectoralis major* of a individuals ranking 0 and 12 respectively. The force spike is much greater in Figure 4 and the huge difference in the mV scales of the EMG show that there is a great deal more muscle activity in Figure 4.

Figures 5 and 6 show recordings from the *Latissimus dorsi* of the same two individuals as in Figures 3 and 4. The same results can be seen in Figures 5 and 6 as in 3 and 4.

The graph in Figure 7 shows the average force for each rank. A linear regression of the data results in a positive slope indicating that force increases with

rank. Regression analysis of the relationship between force and rank yielded a p value of 0.014, and an r-squared value of 73.3%.

The graphs in Figures 8 and 9 show the average punch duration times for each rank for the *Pectoralis major* and the *Latissimus dorsi* respectively. For both graphs, a linear regression demonstrates a negative slope. This means that the trend is for the length of time for the technique to decrease with increasing rank. Regression analysis of the relationship between punch duration for the *Pectoral* and rank yielded a p value of 0.239 and an r-squared value of 22.2%. The same analysis performed on values recorded from the latissimus yielded a p value of 0.064 and an R-squared value of 46.1%.

The graphs in Figures 10 and 11 show the average EMG activity values for each rank leading up to contact with the force detector. The units for EMG activity are the integration units (mVx ms). For the *Pectoral* muscle, the regression p value was 0.006 and the r-squared value was 73.5. For the *Latissimus* muscle, the p-value was 0.005 and the r-squared value was 75.2%.

The graphs in Figures 12 and 13 show the average EMG activty values for each rank after the contact with the forcr detector. The regression values for the *Pectoral* muscle yielded a p value of 0.005 and an r-squared value of 73.5%. The p value and r-squared value for the *Latissimus* were 0.005 and 75.2% respectively.

Correlational analysis of the relationship between the time of technique duration and pre-contact EMG activity for the pectoral for all ranks yielded a value of -0.568. This value for the latissimus was -0.626.

Correlational analysis was also performed to determine the relationship between the time duration of the technique and the force measured. The time determined from the pectoral recording yielded a value of -0.559. This relationship using the times from the pectoral yielded a value of -0.715.

The relationship between the force of the technique and the amount of EMG activity before contact was also examined through correlational analysis. The latissimus yielded a value of 0.733, and the pectoral yielded a value of 0.757.

Discussion:

The muscles chosen for the experiment were the *Pectoralis major* of the punching arm and the *Latissimus dorsi* of the drawing arm. The specific action of the *Pectoralis major* studied in this experiment is the "extension of the humerus when fully cocked" (Cody, 1990). This corresponds to the cocked, ready position of the technique. The Pectoralis major pulls the humerus anteriorly. The *Latissimus dorsi* opposes the action of the *Pectoralis* pulling the forward-extended humerus posteriorly (Cody, 1990). This corresponds to the drawing arm action of the technique.

The technique *gyaku choku-zuki* was chosen for the experiment because it is a basic technique, learned early in training. It is simple enough for individuals with no karate experience to perform, and yet is an extremely functional technique used extensively in higher levels. The *zenkutsu-dachi* stance is very basic also.

The EMG wave forms were analyzed on the basis of significant aspects of the technique. The first characteristic, the time from initiation to impact, was determined from the beginning of muscle activity until the time of contact with the force sensor at the end of the strike. Okacaki and Stricevic state that "speed is one of the essential factors of the technique" and that "the faster the technique, the more power the resultant technique will have" (Okacaki, 1984).

The second characteristic is the overall muscle activity of the technique. The amount of deflection in the EMG wave form during the technique is a measure of the activity of the muscle during the technique. By integrating the absolute value of all the points on the wave form, the overall activity of the muscle can be measured. The period of activity leading up to the point of contact is important in that this is the time where the momentum is generated to carry the force into the target. The period of time directly after contact is the focus point of the technique, which is characterized by brief and extremely powerful contractions of the major muscle groups.

The force wave form allows for the association of the exact time where contact takes place with the muscle activity. The force recording also shows the sustained force as a result of the focus of the technique. The force does not drop immediately back to zero, it plateaus during the time of muscle contraction, and then drops back to zero when the muscle activity has ended.

The points on the graph depicted in Figure 7 show a large variation in the levels of force. This fluctuation is most likely due to the inability of some of the

participants to punch the sensor naturally. Some of the participants were extremely hesitant about hitting the apparatus. In spite of the small sample size, there is a significant positive correlation between the average force of the six punches performed by an individual and his/her experience level ($p<0.01$, r-squared=0.73).

The time duration of the punch is important in that it is an indication of the speed of the punch. A faster moving object has more momentum than a slow moving object. Figures 8 and 9 show the relationships between punch duration and rank. The time duration of the technique should decrease as ranks get higher. Again the graphs show a great deal of fluctuation. The general trend for both graphs supports the hypothesis, as ranks get higher, the time for the technique decreases. The p value for the *Pectoral* muscle time duration was considerably higher than the limit to be considered statistically significant. The p value for the latissimus muscle was slightly above the statistical limit of 0.05. This does not discount the trend seen in the graph, however.

The times calculated from the EMG wave forms measured generally from 150 msec in the higher ranks to almost 250msec in the lower ranks. These numbers are much lower than those calculated in a previous experiment. The data from the previous experiment show times from 417msec for dan (black belt) levels to 450msec for lower level individuals (Layton, 1988). Layton explains that it is expected that higher ranks will have faster punches due mainly to practice and familiarity with the technique(1988).

The EMG activity was expected to increase progressing through the ranks. A higher degree of muscle activity would be needed to increase the speed of a technique. The results in Figures 10 - 13 show that the higher ranks show a great deal more muscle activity than the lower ranks. This is expected, but the dramatic difference raises questions about the validity of the data. The higher rank individuals show a disproportionately high level of muscle activity. This may be due to calculation error in the determination of the values of activity taken from the EMG wave form. The integration technique may have been uncontrollably inconsistent. The statistical analysis of the data yielded agreeable results however. The p values for the regression analysis of the pre-contact muscle activity values for the pectoral and latissimus were 0.006 and 0.005 respectively. This indicated that the relationship between the muscle activity and rank is statistically significant. Similar results were obtained for the analysis of post-contact muscle activity. P values were 0.004 and 0.005 for the latissimus and pectoral.

The post-contact muscle activity was higher than that of pre-contact muscle activity in every rank except for those individuals with no karate experience. This higher muscle activity is most likely the result of the focus of the technique. The *Latissimus dorsi* recorded activity level was the strongest for almost all of the Karate experienced individuals. This is due probably due to the action of the drawing arm which has been stated as being important in adding stability, strength and power to the technique. The drawing arm in a proper technique is a major component of the focus, which is supported by the data.

Correlational analysis of the relationship between technique duration and EMG activity showed a negative correlation which was not statistically significant for both muscles. The correlation trend is valid, as higher muscle activity (stronger contraction) should lead to a faster technique. The values of 0.568 and 0.626 are not very far off from the 0.754 significance limit. There is some significance to this even though it is not strictly significantly significant.

Speed and force of the technique were also negatively related indicating that as speed increased, force also increased. Correlation analysis, however, revealed that this trend was not significantthroughout the range of ranks studied. This is a weak support for resulting perhaps from greater muscle activity yields a higher force output than a slower punch.

The amount of EMG activity positively correlated with the force generated by the technique (r-squared =0.757 for *Pectoral*, $p<0.05$; r-squared = 0.733 fot *Latissimus*, $p<0.1$). These results further support the hypothesis that the amount of muscle activity affects the amount of force generated in a technique involving these muscles.

This project has found supporting data for the idea that high levels of activity in specific muscles associated with a particular technique will increase the speed and force generated by the technique. The longer an individual has trained in Karate the higher the effect will be. This trend is probably true for any such physical activity.

In a future study along the same lines, there should be a greater emphasis on a higher sample size. This was a major limiting factor in this study. Not all ranks were accounted for and in some cases, only one individual represented a particular rank. For the study to be completely accurate and comprehensive, more efforts would be needed to ensure a stratified sample of rank, body size, sex, and sufficient numbers to create sound averages.

A better technique or testing procedure could be selected also. In the testing procedure, the participants were asked to limit extraneous movement and hip rotation. Hip rotation is a major aspect of generating power and initiation of the technique. To try and limit that affects the technique making it a less accurate representation of the technique.

Acknowledgements:

Graph Rank #:	Shotokan Rank:	Belt Level:
0	No experience	None
1	9th kyu	White
2	8th kyu	1st Orange
3	7th kyu	2nd Orange
4	6th kyu	Green
5	5th kyu	1st Purple
6	4th kyu	2nd Purple
7	3rd kyu	1st Brown
8	2nd kyu	2nd Brown
9	1st kyu	3rd Brown
10	1st dan	1st Black
11	2nd dan	2nd Black
12	3rd dan	3rd Black

Figure 1. Comparative ranking scheme of experimental representation vs. official *Shotokan* rank vs. belt color rank.

Pectoralis   major   Latissimus dorsi
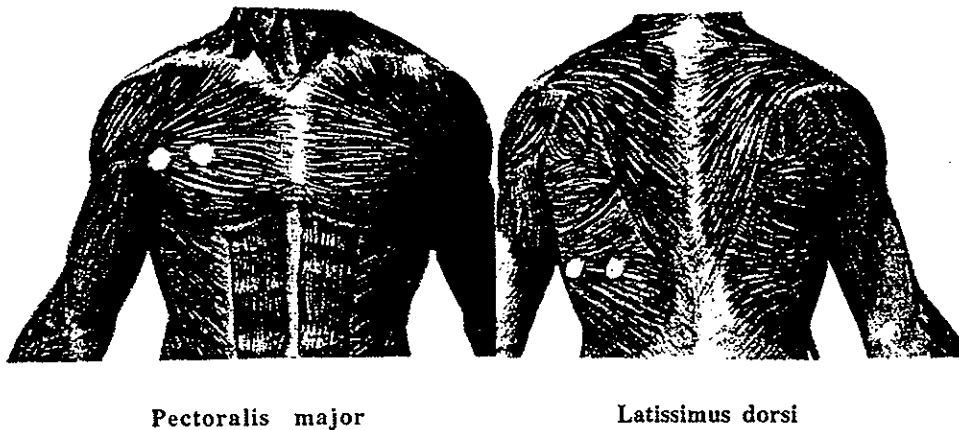
Figure 2. Electrode placement on *Pectoralis major* and *Latissimus dorsi*.
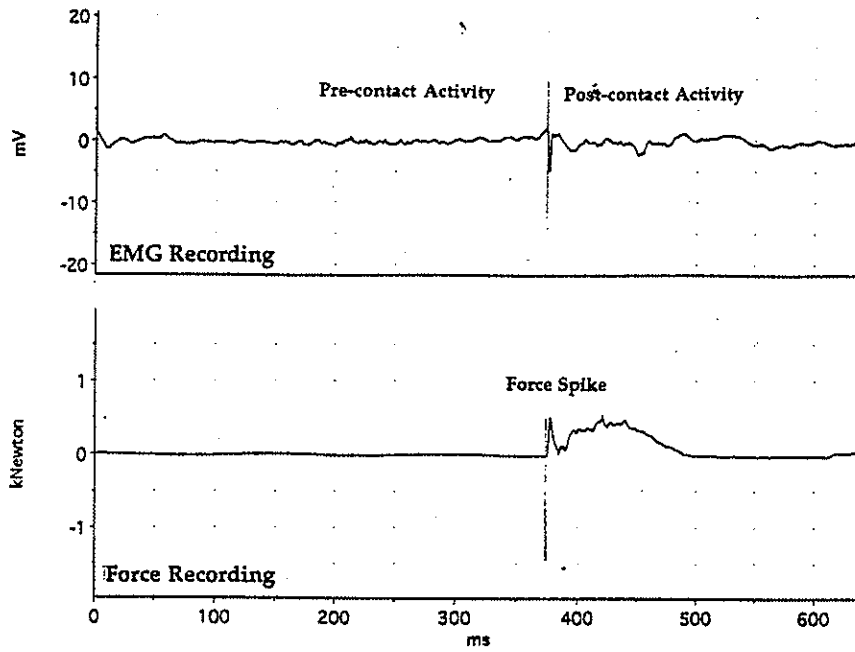
Figure 3. EMG and Force recording of *Pectoralis major* during reverse punch performed by individual of rank 0.
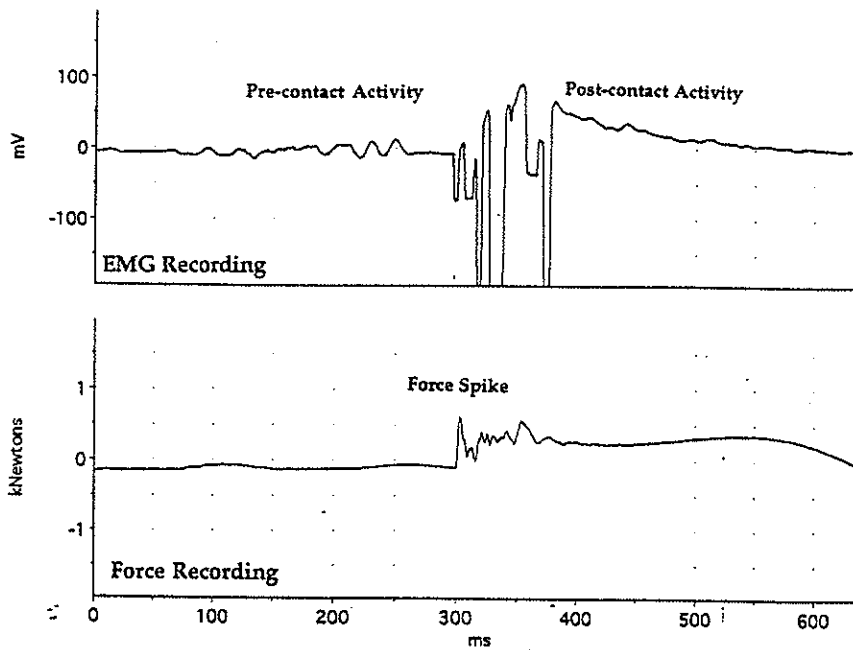
Figure 4. EMG and Force recording of *Pectoralis major* during reverse punch performed by individual of rank 12.
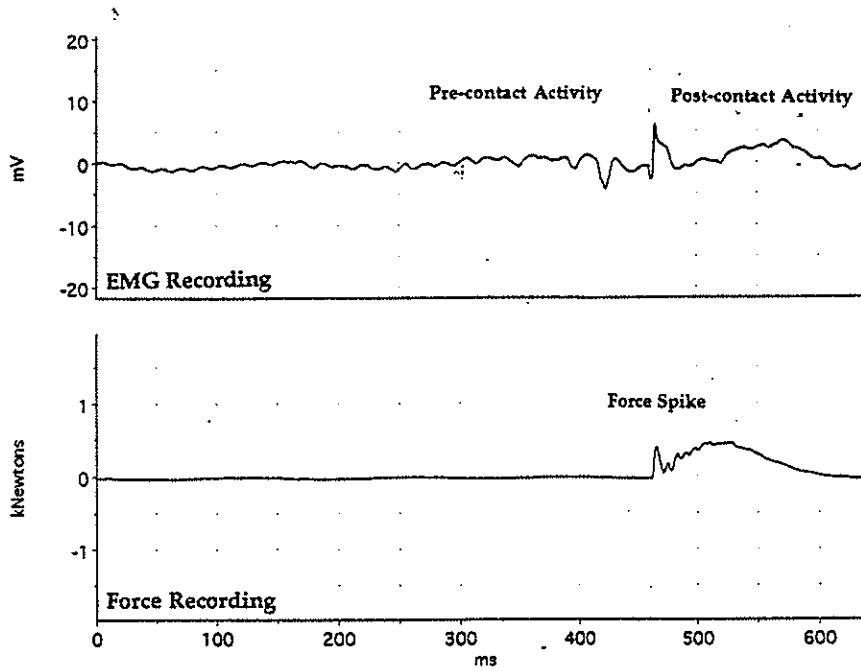
Figure 5. EMG and Force recording of *Latissimus dorsi* during reverse punch performed by individual of rank 0.
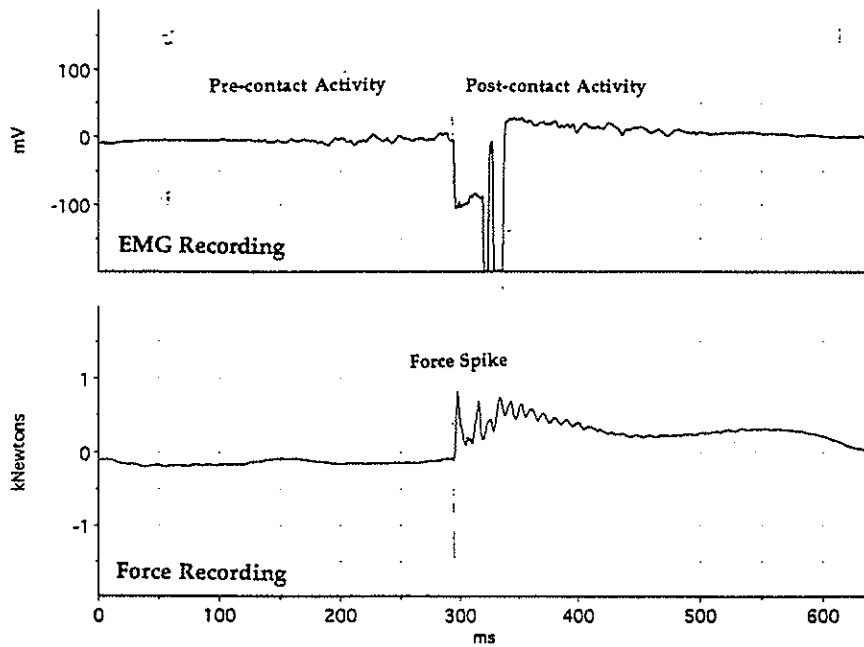

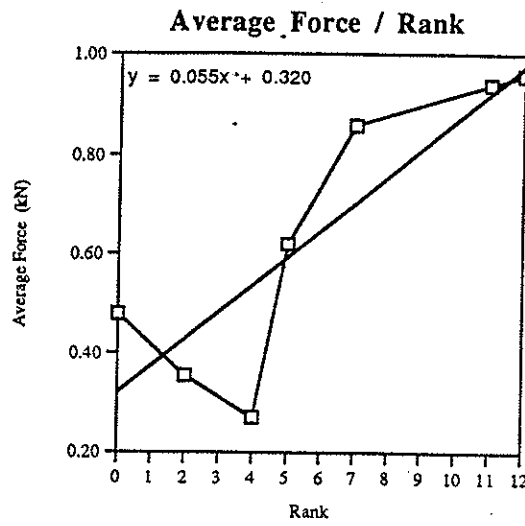Figure 6. EMG and Force recording of *Latissimus dorsi* during reverse punch performed by individual of rank 12.

19

Average Force / Rank

$y = 0.055x + 0.320$

Figure 7. Average Force of all individuals for each represented rank.

Average Punch Duration / Rank
Pectoral Test

$y = -3.504x + 241.178$

Figure 8.

Average Punch Duration / Rank
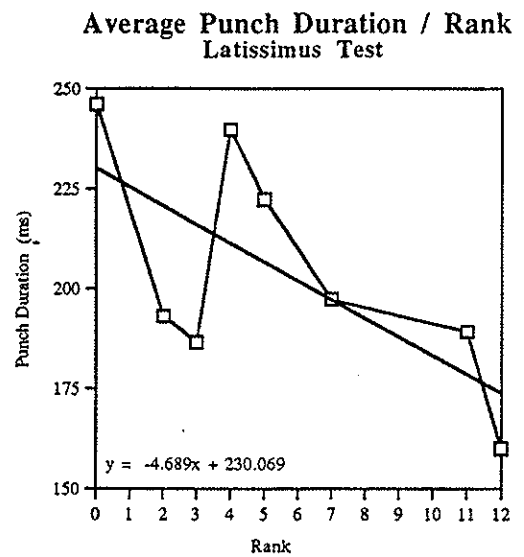### Latissimus Test

$y = -4.689x + 230.069$
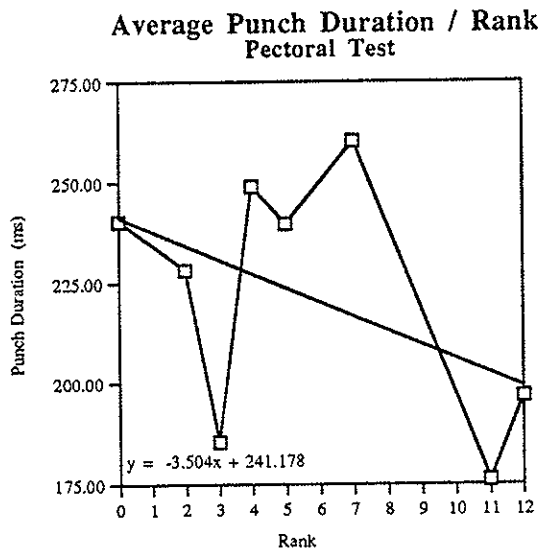
Figure 9.

Figures 8 & 9. Average Punch Duration of all individuals for each represented rank.

Figure 8. Measured from *Pectoralis* recordings.

Figure 9. Measured from *Latissimus* recordings.

20

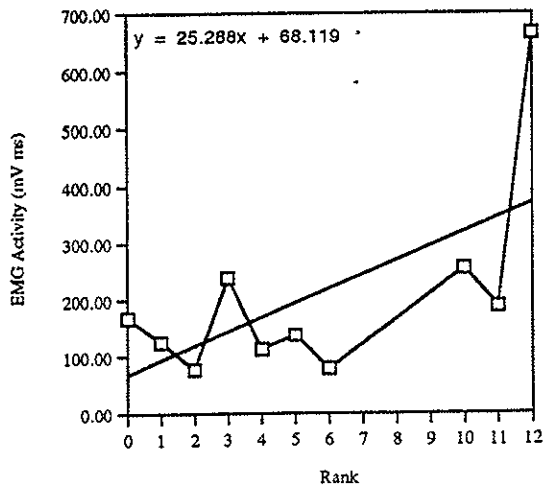**Average Pre-Contact EMG Activity / Rank**
Pectoral

y = 25.288x + 68.119

Average Pre-Contact EMG Activity / Rank
Latissimus

y = 56.753x - 81.178
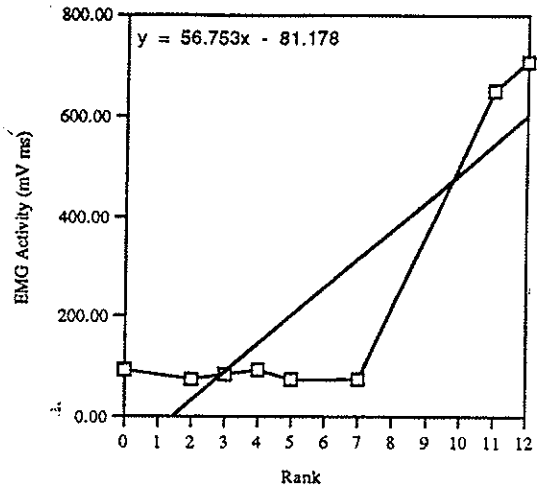
Figure 10.

Figure 11.

Average Post-Contact EMG Activity / Rank
Pectoral

y = 541.854x - 1356.763

Average Post-Contact EMG Activity / Rank
Latissimus

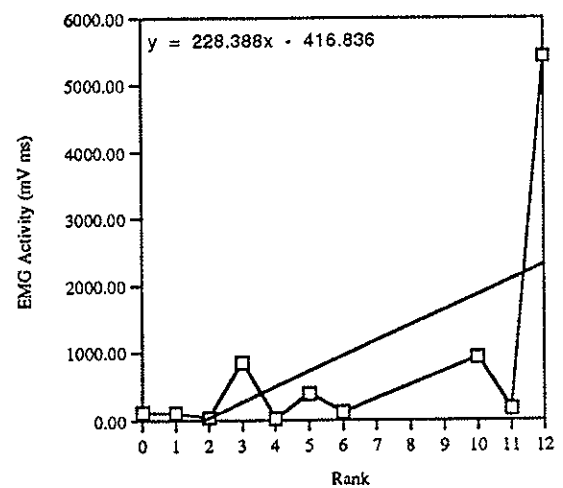y = 228.388x - 416.836
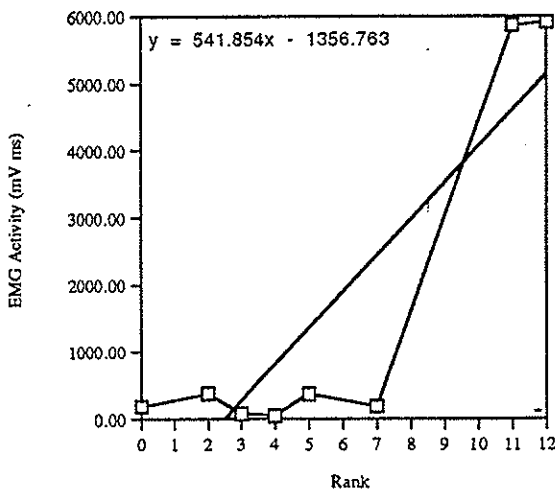
Figure 12.

Figure 13.

Figures 10 & 11. Average Pre-Contact EMG Activity of all individuals for each represented rank.

Figures 12 & 13. Average Post-Contact EMG Activity of all individuals for each represented rank.

Figures 10 & 12. Measured from *Pectoralis* recordings.

Figures 11 & 13. Measured from *Latissimus* recordings.
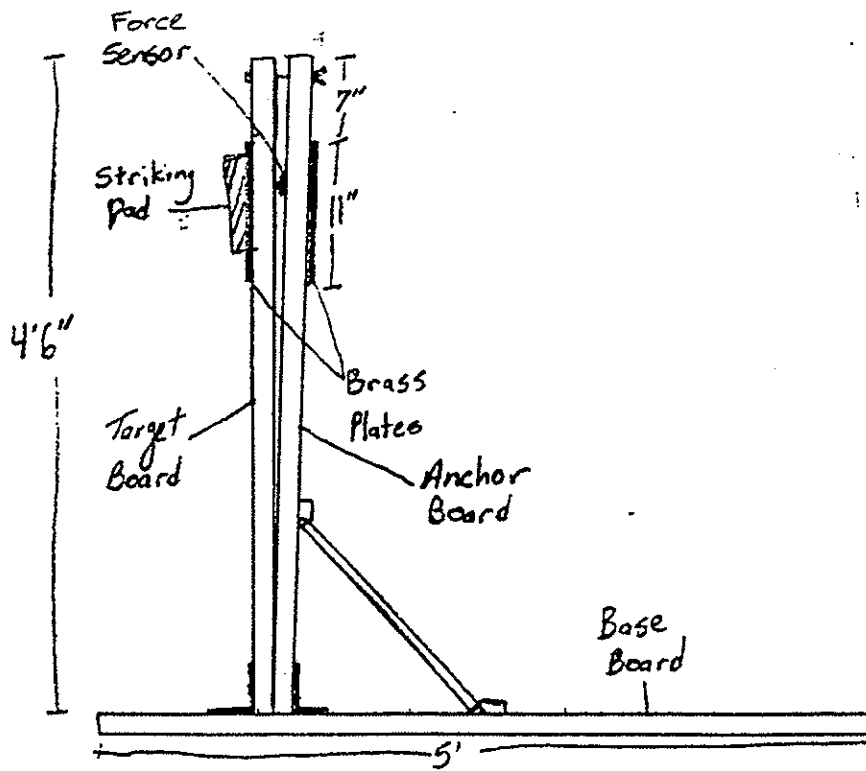
Units of EMG Activity are integrated units (mVx ms).

21

Figure 14. Force Detection Apparatus

APPENDIX

Force Detection Apparatus

The Force Detection Apparatus (See Figure 14) was designed to resemble a makiwara (striking post). A makiwara is a useful tool in Karate training (Layton, 1988). It enables the student to practice striking an object without inflicting harm on themselves or on another person. The makiwara is designed to absorb the force of a striking technique and provide enough resistance so the student can appreciate the impact.

The Force Detection Apparatus acts as a sandwich around the force sensor. The force sensor is fixed between two boards, when the target board is struck, it compresses the force sensor which is attached to the anchor board.

In constructing the force detection apparatus, two 4'6"X1"X6" boards were equipped with 11"X4" brass plates 7" from one end of the boards. Into the anchor board, a 1" wide space was removed from the center of the board along the length of the brass plate. Seven holes were drilled into the brass plate spaced 1.5" apart along the routed gap. Seven holes were also drilled into the target board spaced identically to the anchor board. The brass plate of the target board was placed to cover one side of the board making blind holes. When the two boards are placed against each other, the holes should line up.

The two boards were fastened to a 5'X2"X12" base board with 4 pieces of angle iron. The boards were flush with each other with the brass plates facing away from each other. A support brace was added between the base board and the anchor board.

The force sensor was then placed in the gap of the anchor board and secured to the brass plate. A rounded steel peg was placed into the hole in the target board opposite the hole now occupied by the force sensor. This serves as a single point of contact with the sensor which is recommended in the operator's manual to provide a more accurate measurement. With the sensor in place, the boards should be spaced at the top. This ensures that any force applied to the target board will be directly transferred to the sensor. A bolt was placed through the two boards at the top to provide lateral stability, keep the boards held tightly together, and prevent the board from sliding too far past each other when they bend absorbing the impact force. Finally, a large weight was placed on the front of the apparatus to prevent bouncing upon impact. A 1" thick foam rubber pad was placed on the brass plate of the target board as a striking surface.

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