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The Effects of Velocity on Force Production of the Elbow Flexors during Eccentric Isokinetic Muscle Contraction

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THE EFFECTS OF VELOCITY ON FORCE PRODUCTION OF THE ELBOW FLEXORS DURING ECCENTRIC ISOKINETIC MUSCLE CONTRACTION

by

Tracie Hildre
Bachelor of Science in Physical Therapy
University of North Dakota, 1995

An Independent Study

Submitted to the Graduate Faculty of the

Department of Physical Therapy

School of Medicine

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in partial fulfillment of the requirements

for the degree of

Master of Physical Therapy

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1996

This Independent Study, submitted by Tracie Hildre in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)

PERMISSION

Title	The Effects of Velocity on Force Production of the Elbow Flexors during Eccentric Isokinetic Muscle Contraction
Department	Physical Therapy
Degree	Master of Physical Therapy

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Signature Tracie Hilde

Date 12/14/95

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ABSTRACT

The traditional eccentric force-velocity curve illustrates a continuous increase in muscle force production as velocity increases. Recently, this curve has been scrutinized by some researchers who have found a plateau or decline in eccentric force production at the higher velocities. The purpose of this study was to examine the eccentric isokinetic force-velocity curve of the elbow flexor muscles over a broad range of velocities to observe whether it follows the traditional force-velocity curve.

Fourteen healthy female and six healthy male volunteers were tested using the Kinetic Communicator Dynamometer at velocities of 30, 60, 90, 120, 150, 180, and 210 degrees per second. At each velocity, the subject performed three maximal voluntary eccentric contractions of the elbow flexors and the peak force measurement was used for statistical analysis. A repeated-measures analysis of variance found no significant difference in eccentric force production as test velocities increased for men or for women. A graphic display of the force-velocity relationship for each group did not demonstrate the characteristics of the traditional eccentric force-velocity curve. Therefore, this study does not support the traditional force-velocity relationship findings for elbow flexors under eccentric isokinetic conditions.

CHAPTER I

INTRODUCTION

Isokinetic testing is popular among physical therapists as a means of objectively assessing muscle performance in healthy and patient populations.[1] An isokinetic muscle contraction is defined as "contraction of a muscle where the speed is controlled and maximum exertion occurs through its full range of motion, whether eccentric or concentric."[2] The advantage of isokinetic exercise over any other mode of exercise is that isokinetic exercise accommodates for the changing torques produced throughout the muscle's full range of motion (ROM).[3] Therefore, the highest resistance is provided when the muscle has the largest mechanical advantage. This facilitates a maximal demand on the muscle's work capacity throughout its ROM. Isokinetic exercise provides a means of achieving greater muscle strength gains when compared to isometric and isotonic forms of exercise.[4-6] The new trend in isokinetics is to exercise muscle eccentrically because of the functional role this type of muscle contraction has in activities of daily living.[7] Examples of eccentric loading response are descending stairs or lowering an object.[8]

The two forms of muscle contraction performed during isokinetic exercise are concentric and eccentric contractions. The skeletal muscle's primary function is to exert a force through a joint.[3] A concentrically contracting muscle produces force by developing tension while shortening against an opposing force.[7] During the eccentric contraction of muscle, also referred to as negative work, the muscle produces force by developing tension and controlling its lengthening while resisting the opposing force.[7] There is some controversy over the word choice "eccentric contraction." The word "eccentric" refers to muscle ends moving apart while "contraction" literally means "to draw together." Cavanaugh[9] states that the more correct phrasing for this phenomenon is "eccentric muscle action." However, modern nomenclature uses the term contraction to illustrate all active states of muscle instead of just those active states that result in shortening.[10] Therefore, this paper will use the widely accepted phrase "eccentric muscle contraction" so as not to conflict with other literature referenced in this paper.

A force-velocity curve describes the relationship between the velocity of a muscle contraction and the force produced by that muscle. In 1952, Abbott[8] reported that a concentric contraction will produce less force as the velocity of contraction increases. Conversely, Abbott claims that an eccentric contraction will produce more force as velocity increases. Thus, at a given velocity, an eccentric contraction is capable of producing more force than a concentric muscle contraction. Abbott's findings, along with several other studies, have helped formulate the traditional force-velocity curves for both concentric and eccentric muscle contractions.[11-14] (See Figure 1.)

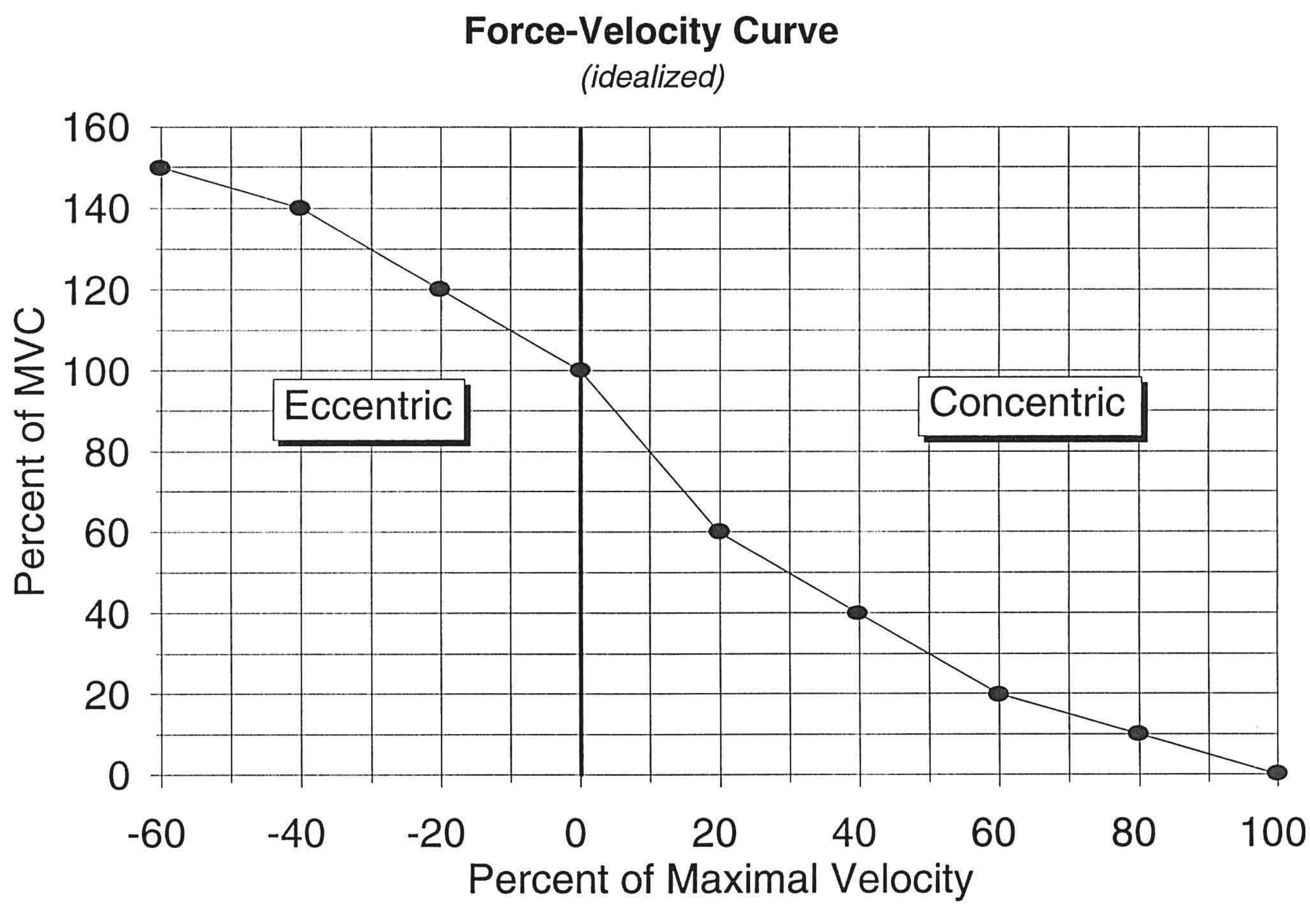

Figure 1. Idealized force-velocity curve for both concentric and eccentric contractions

Recent studies, however, with regard to eccentric isokinetic activity, have shown that the traditional force-velocity curve may not continue to increase linearly as once believed. Instead, the eccentric force production of muscle may tend to plateau when performed at higher velocities.[1,15-19] With the growing emphasis on eccentric isokinetic strengthening programs in combination with velocity spectrum training, a clear understanding of the eccentric force-velocity relationship is vital for correct interpretation of isokinetic testing results. Velocity spectrum training exercises muscle over a broad range of speeds. The intent of this type of training is to train muscle relative to the dynamic conditions that occur during functional activity.[8,20] Therefore, if an eccentric muscle contraction cannot physiologically produce more force at high velocities, clinicians would be in error to expect the patient or athlete's eccentric isokinetic testing results to reflect increased tension under such conditions. The purpose of this study is to examine the eccentric isokinetic force-velocity curve of the elbow flexor muscles over a broad range of velocities to observe whether it follows the traditional eccentric force-velocity curve.

CHAPTER II

LITERATURE REVIEW

The study of eccentrics began over a century ago with experiments observing man descending stairs.[20-22] Since then, research has concentrated on the biomechanical principles of an eccentric muscle contraction. However, the concept of eccentric isokinetics is relatively new and limited research in this area has been performed on commercial isokinetic dynamometers.[15,23,24] An understanding of the biomechanical principles and theories of dynamic eccentric muscle activity is imperative to the development of accurate eccentric isokinetic research.

There are many benefits to using eccentric muscle activity for exercise. It is well documented that the force generated during eccentric contractions exceeds the force generated during concentric and isometric contractions. The Elftman proposal[10] states that force production by muscle is strongest during an eccentric contraction, second strongest during an isometric contraction, and least strong during a concentric contraction. Doss and Karpovich[24] found that eccentric force was 13.5% greater than isometric force and 39.7% greater than concentric force when performed isotonically at similar angles of elbow flexion. Singh and Karpovich[25] likewise reported that eccentric forearm flexors produce

32.65% greater force than concentric forces when performed under isotonic conditions. Komi and Buskirk[26] found that eccentric training increased both eccentric and concentric force values more than concentric training alone. Therefore, exercise incorporating eccentric muscle activity is beneficial for patient populations and healthy individuals desiring maximal strength gains.

Investigators in the early 1900s found that positive work (concentric activity) required twice as much oxygen consumption when compared to negative work.[21] Asmussen[21] expanded upon these experiments and found that as speed increased, oxygen uptake during concentric activity was 125% of that required during eccentric activity. Research also provides evidence of other benefits with eccentric exercise including lower metabolic cost, lower energy consumption, and greater endurance capacity than concentric activity.[8,20] These benefits increase tolerance to eccentric exercise while the muscle is able to produce high levels of tension.

In the past, electromyography (EMG) has been used to compare concentric muscle fiber activity with eccentric muscle fiber activity. The results found that an eccentric muscle contraction exhibits less EMG activity when compared to a concentric muscle contraction under identical situations.[21,27] Komi and Buskirk[26] investigated whether eccentric or concentric strength training would affect EMG activity. After seven weeks of training, no significant differences in EMG activity were reported between pre-training and post-training results. The study by Rodgers and Berger[17] failed to show any differences in motor unit involvement between maximal eccentric and concentric contractions which is contrary to most published research. The differing EMG activity of concentric and eccentric muscle contractions is important to exercise prescription. If an eccentric strengthening exercise is performed, the individual's muscle is capable of high force output with possible support from only a few muscle fibers which could lead to increased stress to the muscle.

A negative aspect of eccentric exercise is the development of delayed onset of muscle soreness (DOMS). This muscle soreness is experienced 24 to 48 hours following exercise and poses a problem when the athlete needs to improve physical fitness in a short amount of time.[28,29] Literature provides four theories for DOMS including 1) lactic acid theory, 2) muscle spasm theory, 3) torn muscle tissue theory, and 4) torn connective tissue theory.

Briefly, the lactic acid theory suggests that high levels of lactic acid accumulation cause DOMS. This theory was disproved by studies conducted by Waltrous et al[30] and Schwane et al[31] which found decreased levels of lactic acid during and after eccentric exercise. The spasm theory, described by DeVries[32] in 1961, suggests that the accumulation of substance "p," which occurs during ischemic conditions, facilitates DOMS. In 1977, Abraham[33] reproduced DeVries' study but used bipolar EMG electrodes and found conflicting results. Armstrong[34] and Asmussen[35] believe there is more risk of DOMS to noncontractile connective tissue during an eccentric muscle contraction when compared to a concentric muscle contraction because less muscle tissue is contracting to produce the same amount of force. This research and the previously mentioned EMG studies support the connective tissue and muscle tissue tearing theories. The Fitzgerald et al[28] study, however, indicates that the intensity of muscle contraction may produce DOMS rather than the type of contraction performed by the muscle. Delayed onset of muscle soreness, regardless of cause, has been shown to be a serious consequence associated with eccentric training.

Lastly, new research findings raise questions regarding the traditional force-velocity curve of an eccentric muscle contraction. The traditional force-velocity curve for an eccentric and concentric muscle contraction has been shown to have inverse properties; meaning, as the velocity of a muscle contraction increases, the force produced concentrically will decrease while the eccentric force will increase.[15,21,26,36,37] Recent research has found that the eccentric force-velocity curve may not linearly continue to increase as was once believed. Walmsley et al[15] reported a general trend of increased torque as the velocity of eccentric contraction increased for wrist extensors. However, this same study was unable to find significant differences in torque production between all the different velocities tested. Griffin[1] reports that mean eccentric peak torque of elbow flexors increased between 30 and 120 degrees per second but then declined at 210 degrees per second. This study did not determine if the increase between 30 to 120 degrees per second was statistically significant but merely found that the mean peak torque increased between the two speeds.

Hageman et al[18] tested both male and female subjects and found that torque output did not significantly change as velocity increased during eccentric contraction for both the quadriceps and hamstrings muscle groups. Several other studies support this idea that eccentric force production may plateau or decline at higher velocities.[16,17,19]

A review of the research regarding dynamic eccentric muscle activity reveals differing opinions regarding the force-velocity curve of an eccentric muscle contraction. Few of these studies actually incorporated a wide spectrum of velocities in small increments to determine the force-velocity curve of an eccentric muscle contraction under isokinetic conditions. Therefore, further investigation in this area is warranted to define the specific path taken by the eccentric isokinetic force-velocity curve.

CHAPTER III

METHODOLOGY

Subjects

Twenty healthy University of North Dakota students, including 6 males and 14 females, volunteered for this study. The mean age of the male subjects was 28.3 years with a standard deviation of 2.7 years, and the mean age of the female subjects was 24.3 years with a standard deviation of 2.7 years. None of the subjects had any known cervical, shoulder, elbow, or wrist dysfunction on their dominant side (hand used for writing) as determined by responses to a medical questionnaire (see Appendix). Each volunteer reviewed and signed an informed consent form approved by the University of North Dakota's Institutional Review Board (see Appendix).

Instrumentation

The Kinetic Communicator 125AP Dynamometer (KINCOM) (Chattexc Corp, 101 Memorial Dr., Chattanooga, TN 37405) is a hydraulically driven, microcomputer-controlled device used to assess and treat human joint function. The KINCOM was used in this study to measure maximum voluntary eccentric peak force of the elbow flexor muscles at test velocities of 30, 60, 90, 120, 150, 180, and 210 degrees per second. The highest peak force measured in pounds (lbs) from three maximal efforts was obtained from the system's computer printout (software version 4.06). The dynamometer was calibrated electronically at the beginning of each test day according to the manufacturer's guidelines. Various functions of the KINCOM have been previously tested for reliability and validity of results. Functions pertinent to this study include lever arm position, lever arm velocity, and the force measuring system. The KINCOM was found to be reliable and valid in these three areas.[38-40]

Procedure

This study collected data regarding the elbow joint. The elbow complex is composed of three joints (humeroulnar, humeroradial, and superior radioulnar joints) which are formed by the distal end of the humerus and the proximal ends of the ulna and radius.[3] The elbow is classified as a diarthrodial, ginglymus (hinge) joint, with one degree of freedom of motion. These motions are flexion and extension occurring in the sagittal plane around a coronal axis. The elbow joint axis runs through the lateral distal epicondyle and the medial distal epicondyle, perpendicular to the long axis of the humerus. The lateral and medial distal epicondyles of the humerus were used as surface landmarks to determine elbow joint axis of rotation for this study. The elbow joint ROM for passive flexion is 0 to 160 degrees when in anatomical position. The three joints of the elbow complex are enclosed in a single joint capsule which is weak anteriorly and posteriorly. The sides of the elbow are more secure due to reinforcement by both the medial and lateral collateral ligaments.

The prime movers of elbow flexion are the biceps brachii, brachialis, and brachioradialis.[3] Accessory flexor muscles include the pronator teres, flexor carpi ulnaris, flexor carpi radialis, flexor digitorum superficialis, and palmaris longus. The brachialis shows EMG muscle activity during all muscle contractions (isometric, concentric, eccentric) and during all positions of the forearm (pronation, neutral, supination). The biceps brachii is active during all muscle contractions and when the forearm is neutral or supinated. No EMG activity is present in the biceps when the forearm is pronated. The brachioradialis has been shown to produce no muscle activity during an eccentric form of contraction. Therefore, the force-producing musculature in this study for eccentric isokinetic elbow flexion are primarily the biceps brachii and the brachialis.

Prior to the testing sessions, subjects attended two 30-minute practice sessions on consecutive days. Previous studies have found unreliability of testing results attributed to possible subject unfamiliarity of testing procedures.[1,20] Therefore, these practice sessions were incorporated to familiarize the subjects with the KINCOM device and testing procedure.

During the first practice session, positional adjustments were made and entered into the computer's database along with the subject's name and testing side. The standard KINCOM position for elbow flexion was used with minor adjustments made to compensate for varying body sizes (Fig 2). The seat was reclined at 60 degrees from the horizontal and seat depth was adjusted to leave

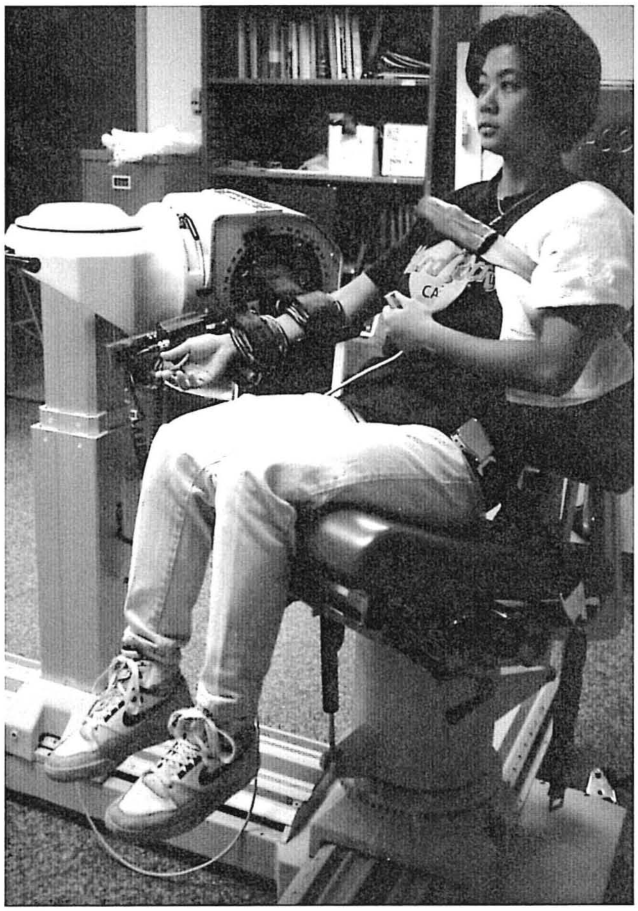

Fig 2--Testing position

a two-finger width space between the front of the seat and the popliteal space of the knee to prevent pressure to the posterior knee, thus promoting subject comfort. The subjects were positioned sitting because this provides the best stability for the body during testing.[1] The forearm was secured in a supinated position on the elbow flexion/extension force pad by two Velcro straps, one proximal to the wrist and one just distal to the elbow joint. Supination of the forearm was used to isolate biceps brachii and brachialis muscle activity.[3] A thin towel was placed between the Velcro straps and the forearm to provide more padding for comfort. The elbow joint was aligned with the axis of rotation of the dynamometer lever arm and elbow ROM was set for 30 to 120 degrees of flexion. The shoulder was positioned in approximately 20 degrees of abduction. Goniometric measurements were used for both elbow and shoulder ROM. Range of motion settings were verified at the beginning of all four sessions. Any positional adjustments that were needed, such as the elbow joint being realigned with the dynamometer axis, were made at the beginning of each session also. A strap was secured around the subject's upper chest and over the anterior surface of the shoulder to hold the upper body against the seat back in an attempt to prevent upper body substitution and minimize shoulder girdle motion. The subjects wore the KINCOM seat belt and held a safety button that, if activated, would immediately stop the machine. Verbal encouragement was given during testing.

During the first two practice sessions, the subject performed a pretest which involved three repetitions of eccentric elbow flexion contractions at submaximal effort for each of the seven speeds. A repetition consisted of an eccentric voluntary contraction from 120 degrees to 30 degrees of elbow flexion by the subject. Then the subject was asked to rest while the investigator returned the lever arm back to the original 120 degree elbow flexion position. This procedure was repeated until three repetitions were completed. This set-up was designed to prevent any concentric contraction of the muscle, which has been suggested to enhance eccentric force production when performed just prior to an eccentric contraction.[1] Between each speed a 30-second rest period was given. During the second day of practice, the subject performed another pretest in the same manner as the first day of practice.

The final two days of research consisted of experimental testing with data collection. Again, positional adjustments were made before testing to ensure proper ROM and dynamometer axis location. The first four velocities, in ascending order, were tested the first day and the last three velocities, in ascending order, were tested two days later. This testing arrangement was used to eliminate the effect of fatigue on test results and prevent DOMS. Three warm-up contractions preceded each data collection set with two warm-up repetitions performed at submaximal effort and the third at the subject's maximum voluntary effort. A two-minute rest period occurred between the warm-up sequence and testing. The repetitions used for testing were performed in the same manner as those performed during the practice sessions. Each repetition was initiated by the subject with no more than one minute elapsing between each repetition. After each testing set, a three-minute rest period was given before the next velocity's warm-up repetitions began.

Statistical Analysis

At each velocity, the maximum peak force produced during three eccentric isokinetic muscle contractions was used for statistical analysis. A two-way analysis-of-variance (ANOVA) was conducted to determine if the force produced was affected by a velocity and gender interaction, velocity alone, or gender alone. Because the interaction and velocity effects were not significant, and because the gender effect was significant, an ANOVA was performed to determine if the effect of gender remained significant at each velocity. Finally, a repeated measure ANOVA was utilized to further clarify if the mean force production was significantly different between velocities for men or for women. For all tests, significance was determined using an alpha level of .05.

CHAPTER IV

RESULTS

Various statistical procedures, a two-way ANOVA, one-way ANOVA, and a repeated-measures ANOVA were used to analyze results obtained in this study. The two-way ANOVA using all subjects ($N = 20$) found no significance between the force produced relative to a velocity and gender interaction ($p = .654$) and the velocity of muscle contraction ($p = .770$) (Table 1). However, gender did have a significant effect on the force produced by the subjects ($p < .001$). The one-way ANOVA found that the effect of gender remained significant at each velocity ($p < .001$) (Table 2). Finally, for each gender, the repeated-measures ANOVA found that mean force production was not significantly different between any of the seven velocities (males: $p = .658$; females: $p = .249$) (Table 3). The mean peak force produced at any given velocity was 115.98 ± 24.18 lbs for males and 59.12 ± 14.90 lbs for females.

A force-velocity graph was constructed to provide a visual interpretation of each gender's test results (fig. 3). Overall, the descriptive statistics and graph presentation of the eccentric isokinetic force-velocity relationship revealed a variable pattern of force production among the seven velocities.

Table 1.—Two-Way ANOVA

Source	df	SS	MS	F	P
Velocity	1	44.10	44.10	.087	.770
Gender	1	28817.14	28817.14	56.53	.000
Gender x Velocity	1	104.31	104.31	.205	.654

Table 2.—One-Way ANOVA Force and Gender Relationship

Source	df	SS	MS	F	P
Gender					
Between groups	1	59031.03	95031.03	288.29	0.000
Within groups	138	45489.51	329.63		
TOTAL	139	14052.54			

Table 3.—Repeated-Measures ANOVA: Elbow Flexion Force Scores by Gender

Elbow Flexion	30°/sec	60°/sec	90°/sec	120°/sec	150°/sec	180°/sec	210°/sec	df	ratio	p
Males	117.83 ±31.06	120.67 ±36.48	112.50 ±18.99	112.50 ±19.96	110.00 ±39.90	122.83 ±19.02	115.50 ±18.00	6.35	.692	.658
Females	62.79 ±18.72	58.57 ±13.35	57.00 ±12.67	57.00 ±11.55	59.43 ±15.03	59.71 ±17.86	59.36 ±16.21	6.91	1.34	.249

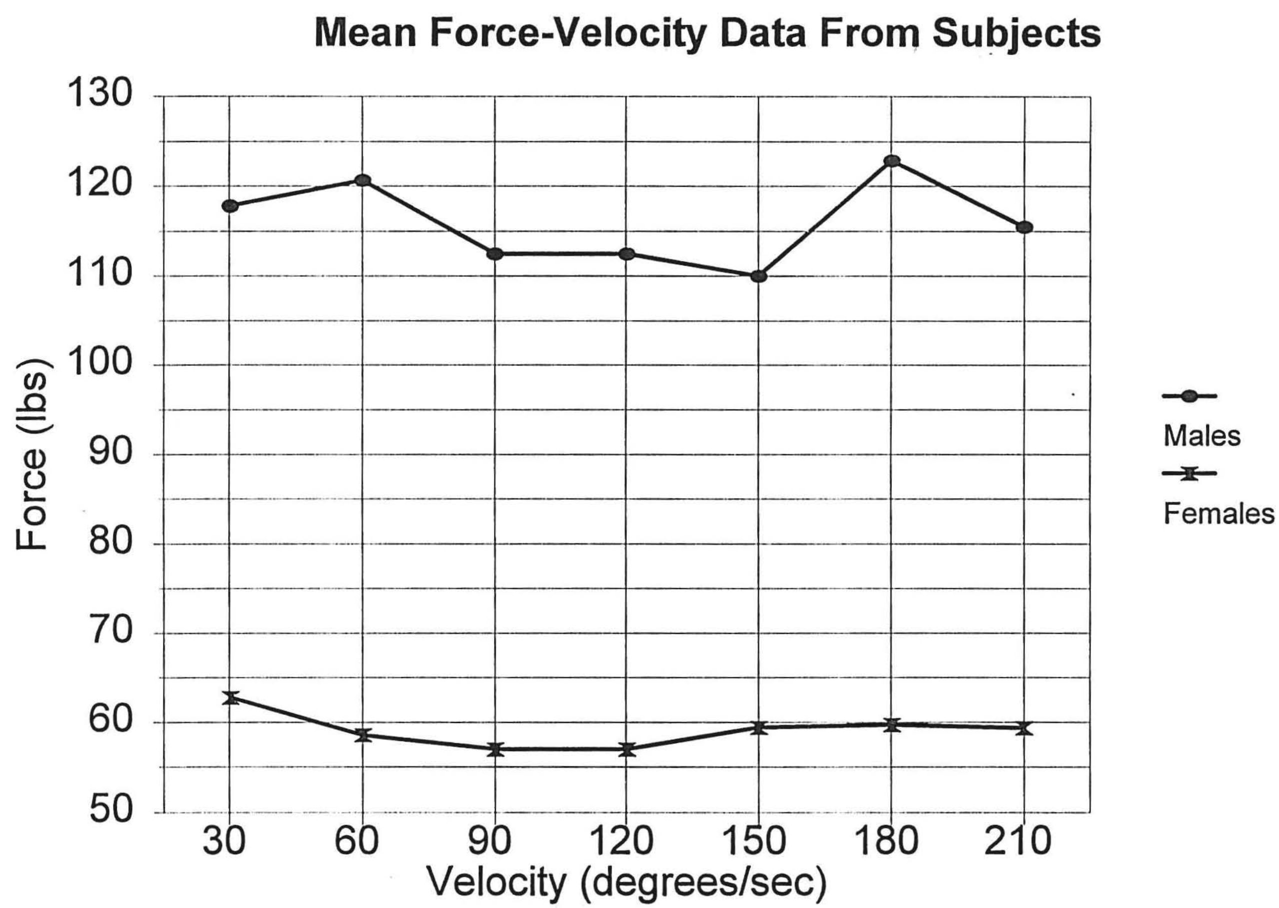

Figure 3. Force vs Velocity for Males and Females

This study found that velocity was not related to forces produced by eccentric isokinetic elbow flexor muscle contractions.

CHAPTER V

DISCUSSION

This study was undertaken to compare the eccentric isokinetic force-velocity curve of elbow flexor muscles to the traditional eccentric force-velocity curve. Unlike the heavily published traditional force-velocity curve, this study found that the eccentric isokinetic force-velocity relationship is not a continuously increasing curve, but instead presents as a relatively stable line without significant increases occurring between the seven velocities.

As previously stated, the traditional eccentric force-velocity curve demonstrates a continual increase in force production with increases in velocity.[8,11-14] In this study, the male subject's force-velocity graph fluctuates with an initial increase in force between 30 and 60 degrees per second. Next, a continual decrease in force occurred between 60 and 150 degrees per second. At 150 degrees per second, force again increased. The female subject's eccentric force-velocity relationship follows a slightly different path than the male curve. Initially, the force decreases between 30 and 120 degrees per second. At 120 degrees per second, the force increases with a slight decline again between 180 and 210 degrees per second. The male and female force-velocity relationships have two similar characteristics: 1) the mean peak force at 90 and

120 degrees per second remains constant and 2) after 150 degrees per second, force increased for both groups. The results obtained in this study for both genders, therefore, do not demonstrate the traditional force-velocity relationship.

Several recent studies challenged the traditional eccentric force-velocity curve characteristics.[1,15,17-19] Griffin[1] and Rodgers and Berger[17] focus specifically on the eccentric force-velocity curve of the elbow flexors. These two studies are similar to this study in that they challenge the traditional force-velocity curve; however, they are dissimilar from this study in many ways. The Griffin study was conducted on the KINCOM using four speeds to determine the eccentric isokinetic force-velocity relationship. Her study found an increase in torque production by female elbow flexors between 0 and 120 degrees per second. From 120 to 210 degrees per second, there was a decrease in force production. The initial increase found in Griffin's study was not represented in this study. However, Griffin reported her results without determining if the increases in force were statistically significant, only that the force increased between 0 and 120 degrees per second.

The second elbow flexion study was conducted by Rodgers and Berger[17] using 12 males on an independently assembled machine. Their findings were that torque increased up to a point and then fell off at the higher velocities. Significance was determined for the initial increase in torque. Although their study disputes the traditional force-velocity curve, a comparison with this study would be difficult because the two testing devices are so different.

Three statistical tests were run to determine if this study supported the traditional eccentric force-velocity curve. The first statistical test, a two-way ANOVA, found that gender had a significant effect on the force produced by the subjects ($p < .001$). This meant that the 20 subjects needed to be separated into male and female groups. Once the data were separated, a one-way ANOVA was utilized to determine if the effect of gender remained significant at each velocity, and it did ($p < .001$).

Next, for each gender, a repeated-measures ANOVA was run to determine if the mean force produced was significantly different between the seven velocities. The repeated-measures ANOVA found no significant difference, positively or negatively, in this study (males: $p = .658$; females: $p = .249$). The force produced by an eccentrically contracting muscle does not appear to increase or decrease when performed at different velocities. Statistical analysis of the data did not support the traditional eccentric force-velocity curve.

There are many extraneous variables that could have affected the results obtained in this study. The sample size used may be inadequate when referring findings onto a population. This intent of this study was to use a sample of 20 subjects. However, the two-way ANOVA findings that gender had an effect on the force produced by the subjects resulted in a division of the subjects into groups by gender (males = 6, females = 14). By grouping the subjects, statistical analysis to determine the effect of velocity on eccentric isokinetic force production is more valid. Although the sample sizes were made smaller, gender then had no interaction effect on the analysis of velocity and force production of elbow flexor muscles. A larger gender specific sample would have provided more valid results that could be inferred to a population.

Although the KINCOM has been found valid and reliable, the ability of the machine to stabilize the elbow joint during elbow flexion appears inadequate. The subject's elbow tended to slip and move around in the force pad during the study. This movement caused the elbow joint to be malaligned with the dynamometer which may have promoted different ROM arcs. The elbow ROM was set for 120 degrees to 30 degrees of elbow flexion. If this arc changed between repetitions, the results would not be accurate.

The sequencing of test velocities may have attributed to subject fatigue. Testing sequence was 30, 60, 90, and 120 degrees per second in ascending order on the first test day, and 150, 180, and 210 degrees per second in ascending order on the second test day. Results showed that for each gender mean peak force values tended to decrease between 30 and 120 degrees per second. The two test days were separated by one full day in an attempt to minimize fatigue and prevent DOMS. When performing muscle contractions at the slow speeds, the time frame for producing one's maximal force is longer than at the higher speeds. This may have led to subject fatigue. The force increases produced on the second day of testing may not be due to the effect of velocity, but instead may be the result of the subject's muscles being rested. Research design incorporating a random assignment of velocities may produce different results. Both Griffin and Rodger's studies used random sequencing of test velocities.

Besides methodological variables, statistical procedures may attribute to this study's conclusion. The elbow flexor musculature consists of a relatively small amount of muscle fibers when compared with other body muscle groups; i.e., quadriceps. The force producing capabilities of the elbow flexors is limited, meaning large numerical increases in mean force values may not be achievable by this muscle group. Therefore, using rigorous statistical tests that look for large differences in values to conclude significance may not be appropriate for certain muscle groups.

CHAPTER VI

CONCLUSION

The increased use of isokinetics by the physical therapist has resulted in need for better understanding of dynamic responses of human muscle under isokinetic conditions. Such knowledge would provide useful information for developing safe rehabilitation protocols and promoting accurate use of isokinetic scores when determining a person's progress. Currently, the traditional eccentric force-velocity curve is believed to describe how human muscle reacts to eccentric isokinetic conditions.

The purpose of this study was to examine the eccentric isokinetic force-velocity curve of the elbow flexor muscles over a broad range of velocities to observe whether it follows the traditional force-velocity curve. Results from this study found no significant increases in force production between any of the seven velocities. The mean peak force values produced no specific pattern; instead, results increased and decreased several times among the seven selected velocities. The results from this study, therefore, do not support the traditional eccentric force-velocity curve.

Further research is needed in this area to determine if, under eccentric isokinetic conditions, other muscle groups as well produce results that oppose the traditional eccentric force-velocity curve. Another study, with a revised research design including a larger sample size and random sequencing of testing velocities, may be beneficial.

APPENDIX

UNIVERSITY OF NORTH DAKOTA'S
INSTITUTIONAL REVIEW BOARD

DATE: March 23, 1995 **PROJECT NUMBER** IRB-9503-234

NAME: Tracie Hildre **DEPARTMENT/COLLEGE** Physical Therapy

PROJECT TITLE: The Effect of Velocity on Force Production in Eccentric Contraction

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on March 24, 1995 and the following action was taken:

☑ Project approved. **EXPEDITED REVIEW** NO. 3.
Next scheduled review is on March 1996.

☐ Project approved. **EXEMPT CATEGORY** NO. ____. No periodic review scheduled unless so stated in REMARKS SECTION.

☐ Project approved **PENDING** receipt of corrections/additions in ORPD and approval by the IRB. **This study may NOT be started UNTIL IRB approval has been received.** (See REMARKS SECTION for further information.)

☐ Project approval **deferred. This study may not be started until IRB approval has been received.** (See REMARKS SECTION for further information.)

☐ Project **denied.**
(See REMARKS SECTION for further information.)

REMARKS: Any changes in protocol or adverse occurrences in the course of the research project must be reported immediately to the IRB Chairman or ORPD.

cc: M. Romanick, Adviser
Dean, Medical School

[signature] 3/24/95

Signature of ~~Chairperson~~ or designated IRB Member — Date
UND's Institutional Review Board

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 596 Form may be required. Contact ORPD to obtain the required documents. (7/93)

_x_EXPEDITED REVIEW REQUESTED UNDER ITEM 3_ (NUMBER[S]) OF HHS REGULATIONS
___EXEMPT REVIEW REQUESTED UNDER ITEM __ (NUMBER[S]) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA
HUMAN SUBJECTS REVIEW FORM
FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED PROJECTS INVOLVING HUMAN SUBJECTS

PRINCIPAL INVESTIGATOR: Tracie Hildre **TELEPHONE:** (701) 746-0644 **DATE:** 3/7/95

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: 1027 Campbell Drive, Apt. 5, Grand Forks, ND 58201

SCHOOL/COLLEGE: Medicine **DEPARTMENT:** Physical Therapy **PROPOSED PROJECT DATES:** 3/95-3/96

PROJECT TITLE: The effect of velocity on force production in eccentric contraction.

FUNDING AGENCIES (IF APPLICABLE): ____

TYPE OF PROJECT:
_X_ NEW PROJECT __ CONTINUATION __ RENEWAL __ DISSERTATION OR THESIS RESEARCH _X_ STUDENT RESEARCH PROJECT
___ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Mark Romanick

PROPOSED PROJECT: __INVOLVES NEW DRUGS(IND) __INVOLVES NON-APPROVED USE OF DRUG
__INVOLVES A COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATIONS, PLEASE INDICATE THE CLASSIFICATION(S):
___ MINORS (<18 YEARS) ___ PREGNANT WOMEN ___ MENTALLY DISABLED ___ FETUSES
___ MENTALLY RETARDED ___ PRISONERS ___ ABORTUSES _x_ UND STUDENTS (>18 YEARS)
IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE ____

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1. ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.

Isokinetic testing is popular among physical therapists as a means of objectively assessing muscle performance in healthy and patient populations. Research indicates that an eccentric contraction generates more force than either a concentric or isometric contraction. In addition, as the velocity at which the eccentric contraction is performed increases, the capability of the muscle to develop more force increases. However, recent studies have noted that the force-velocity curve of an eccentric contraction does not continually increase but instead may plateau somewhere along this curve. The purpose of this study is to assess eccentric force-velocity relationships and determine if there is a point at which an increase in velocity will no longer result in an increase in eccentric force. This knowledge will allow for more accurate protocol development and eccentric isokinetic use in the clinical setting. Research testing will be done on the KinCom AP dynamometer so results can be transferred to clinical practice. Because eccentric isokinetic testing is performed clinically on humans, it is necessary that this research study provide results collected from human subjects.

PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

SUBJECTS:

It is anticipated that a total of 30 to 40 male and female subjects from the University of North Dakota will be recruited as volunteers. It is anticipated that the ages of the subjects will range from 20 years to 35 years. These subjects must have no known cervical, shoulder, elbow or wrist dysfunction on the dominant side (hand used for writing). This will be determined from answers given on a medical questionnaire prior to any form of testing.

METHOD:

We will use the Kinetic Communicator (KinCom) AP dynamometer (Chattexc Corp, 101 Memorial Dr, Chattanooga, TN 37405) to measure maximum voluntary eccentric peak torque of the elbow flexor muscles at velocities of 30, 60, 90, 120, 150, 180, 210°/sec. The dynamometer will be calibrated electronically according to manufactures guidelines before testing each subject.

Prior to experimental testing, subjects will attend two practice sessions, approximately 30 minutes in length, in which the investigator will explain the testing procedure, familiarize subjects with the KINCOM device, answer subjects' questions, and begin the subject's KINCOM file by entering data on individual position settings, age, gender, weight, and height information. During both practice sessions a pre-test will be performed by each subject at a submaximal level. Previous studies have found unreliability of testing results attributed to possible subject unfamiliarity with testing procedures. The two pre-tests are designed to establish greater subject familiarity with the testing procedure for this study. Informed consent will be obtained from all subjects at the beginning of the first practice session.

Each subject will participate in the two practice sessions and two test sessions. The sessions will be scheduled so that the practice and test sessions are separated by at least one day, but the practice sessions may be performed on consecutive days. The two test sessions will also be separated by one day. All subjects will be asked to refrain from vigorous upper extremity exercise during the 5-6 day span of the practice and test sessions, so as not to influence the results of this research project.

The subjects will be in a sitting position on the KinCom table with the axis of rotation of the dynamometer lever arm aligned with the elbow joint.

Straps will be secured around the subject's upper chest and shoulders to hold the upper body against the seat back to prevent upper body substitution and minimize shoulder girdle motion. The forearm will be secured in a supinated position on the force pad by two Velcro straps, one proximal to the wrist and one just distal of the elbow joint.

Experimental testing will consist of three voluntary maximal eccentric contractions at each of the different velocities listed above. The force required to initiate and maintain movement of the dynamometer lever arm will be low so the subject can safely start and stop the lever arm if necessary. After each eccentric contraction the lever arm will be returned to the original starting position by the investigator. The velocity sequence will progress from slow to fast, with the first four velocities tested during the first test session and the remaining three velocities tested during the second test session. Three warm-up contractions will precede each velocity set with two repetitions performed at submaximal resistance and the third at maximum resistance. A two minute rest period will occur between the warm-up sequence and testing. A three minute rest period will occur between each testing set and the next warm-up sequence. Verbal encouragement will be given as is consistent with protocols established by dynamometer manufactures in obtaining a maximal voluntary contraction. Subjects will not be informed of test scores and the same examiner will perform all testing.

DATA:

An analysis of variance (ANOVA) test will be used to determine significant differences in force production between the different velocities.

3. BENEFITS: (Describe the benefits to the individual or society.)

This research project is designed to provide understanding of the dynamic response expected from muscle under eccentric isokinetic conditions. Results from this study will help physical therapists more accurately develop realistic testing and rehabilitation eccentric isokinetic protocols used with clientele.

4. RISKS: (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psycho-logical, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

The risks to the subjects in this experiment will be minimal. The possible risks include muscle strain, delayed onset of muscle soreness and muscle fatigue, all common occurrences with any form of muscle exertion. Steps have been taken to minimize these risks including: 1) providing practice sessions to familiarize subjects with testing procedure, 2) a warm-up period including submaximal and maximal efforts before each new velocity set to ensure that the subject knows what to expect from the resisting pattern of movement and to create a positive transfer of motor learning, 3) adequate rest intervals between each set, 4) the subject will be able to voluntarily stop the lever arm movement by bringing their exerted force below the threshold level set by the investigator, and 5) each subject will hold a safety button that if activated will immediately turn-off the machine.

5. **CONSENT FORM:** A copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur. Describe where signed consent forms will be kept and for what period of time.

The consent forms will be kept in the University of North Dakota Physical Therapy Department's confidential file for two years after the completion of the research project. Forms will then be shredded and disposed. A copy of the consent form is attached.

6. For **FULL IRB REVIEW** forward a signed original and thirteen (13) copies of this completed form, and where applicable, thirteen (13) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

Office of Research & Program Development
University of North Dakota
Box 8138, University Station
Grand Forks, North Dakota 58202

On campus, mail to: Office of Research & Program Development, Box 134, or drop it off at Room 101 Twamley Hall.

For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:

______________________________ **DATE:** ________________

Principal Investigator

______________________________ **DATE:** ________________

Project Director or Student Adviser

______________________________ **DATE:** ________________

Training or Center Grant Director

INFORMATION AND CONSENT FORM

TITLE: THE EFFECT OF VELOCITY ON FORCE PRODUCTION IN ECCENTRIC CONTRACTION

You are being invited to participate in a study conducted by Tracie Hildre, a Physical Therapy student attending the University of North Dakota. The purpose of this study is to determine if there is a point at which an increase in velocity will no longer result in an increase of eccentric force. Information gained from this study will improve understanding of the dynamic response expected from human muscle during eccentric muscle contraction.

You will be asked to participate in two practice sessions and two testing session, each lasting approximately thirty minutes. You will be asked to report to the Physical Therapy Department at the University of North Dakota (Room 140 Medical Science North Unit) at an assigned time. You will be asked to wear a short sleeve shirt for the experiment. During the first practice session your age, gender, weight, and height will be recorded and you will be asked to fill out a medical questionnaire.

The sessions will be scheduled so that the practice and test sessions will be separated by at least one day, but the practice sessions may be performed on consecutive days. The two test sessions will also be separated by one day. You will be asked to refrain from any vigorous upper extremity exercise during the approximate five to six day span of the practice and test sessions, so as not to influence the results of this research project.

Experimental testing will consist of three voluntary eccentric maximal contractions by your dominant side elbow flexors. Each set of three contractions is performed at different velocities progressing from slow to faster speeds. The practice sessions are designed to answer your questions, familiarize you with the KinCom device and testing procedure, and properly position the machine for each subject. During the practice sessions you will perform a pre-test at submaximal level.

Although the process of physical performance testing always involves some degree of risk, steps have been taken to minimize the risk of injury or discomfort under the test parameters in this research project. However, muscle fatigue, delayed onset of muscle soreness, and muscle strain may occur from participating in this research project.

Your name will not be used in any reports of the results of this research project. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified by a number known only by the investigator. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigator involved is available to answer any questions you have concerning this research project, the procedures, and any risks or benefits that may arise from participating in this research study. In addition, you are encouraged to ask any question concerning this study that you may have in the future. Questions may be asked by calling Tracie Hildre at 701-746-0644. A copy of this consent form is available to all participants in the study.

In the event that this research activity results in a physical injury, medical treatment will be available, including first aid, emergency treatment, and follow-up care as it is to a member of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payor, if any. I will not hold the University of North Dakota, the UND Physical Therapy Department, or Tracie Hildre liable for any injury sustained during the course of this research project.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

____

Participant's Signature Date

____

Witness Signature Date

Questionnaire

Name________________________

Age______ Gender______ Weight______ Height______

Please check the box that applies to you. Leave no question blank. If at any time you decide you do not want to answer the questions posed on this questionnaire, please notify the investigator. To participate in this study this questionnaire must be completed and signed. Your signature verifies that you answered the questions honestly and to the best of your knowledge.

	YES	**NO**	
1.	_____	_____	Have you had a significant neck injury which may or may not have been treated medically. Examples: whiplash, fracture, sprain.
2.	_____	_____	Have you had a significant shoulder injury which may or may not have been treated medically. Examples: dislocation, instability, fracture, tendinitis.
3.	_____	_____	Have you had a significant elbow injury which may or may not have been treated medically. Examples: dislocation, fracture, sprain, bursitis, tendinitis.
4.	_____	_____	Have you had a significant wrist injury which may or may not have been treated medically. Examples: dislocation, fracture, sprain, carpal tunnel syndrome.
5.	_____	_____	I have never had a significant neck, shoulder, elbow, or wrist injury.

If you checked **YES** to questions 1-4, please describe the injury and specify which side of the body the injury occurred to.

________________________________ ________________________

Signature Date

December 1, 1995

Ms. Donna Ho
421 Swanson Hall
Grand Forks, ND 58202

Dear Donna,

I am writing to request permission to include a copy of the photograph we took of you on the KINCOM machine. Please sign below to authorize use of this photograph in my independent study project. Thank you for your assistance.

Sincerely,

Tracie Hildre

Tracie Hildre

I, Donna Ho, hereby authorize Tracie Hildre to use a photograph of me in her independent study project.

Donna Ho — Signature

12/6/95 — Date

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