Relative Isometric and Dynamic Endurance Curves for Different Muscle Groups of the Upper Extremities.

Seung Ho Yoon
Louisiana State University and Agricultural & Mechanical College

Follow this and additional works at: https://digitalcommons.lsu.edu/gradschool_disstheses

Recommended Citation
https://digitalcommons.lsu.edu/gradschool_disstheses/4540

This Dissertation is brought to you for free and open access by the Graduate School at LSU Digital Commons. It has been accepted for inclusion in LSU Historical Dissertations and Theses by an authorized administrator of LSU Digital Commons. For more information, please contact gradetd@lsu.edu.
INFORMATION TO USERS

The most advanced technology has been used to photograph and reproduce this manuscript from the microfilm master. UMI films the original text directly from the copy submitted. Thus, some dissertation copies are in typewriter face, while others may be from a computer printer.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyrighted material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each oversize page is available as one exposure on a standard 35 mm slide or as a 17" × 23" black and white photographic print for an additional charge.

Photographs included in the original manuscript have been reproduced xerographically in this copy. 35 mm slides or 6" × 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.
Relative isometric and dynamic endurance curves for different muscle groups of the upper extremities

Yoon, Seung Ho, Ph.D.

The Louisiana State University and Agricultural and Mechanical Col., 1988
PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark √.

1. Glossy photographs or pages ______
2. Colored illustrations, paper or print ______
3. Photographs with dark background ___√___
4. Illustrations are poor copy ______
5. Pages with black marks, not original copy ___√___
6. Print shows through as there is text on both sides of page______
7. Indistinct, broken or small print on several pages __√__
8. Print exceeds margin requirements ______
9. Tightly bound copy with print lost in spine ______
10. Computer printout pages with indistinct print ______
11. Page(s) _________ lacking when material received, and not available from school or author.
12. Page(s) _________ seem to be missing in numbering only as text follows.
13. Two pages numbered ______. Text follows.
14. Curling and wrinkled pages ______
15. Dissertation contains pages with print at a slant, filmed as received ___√___
16. Other__________________________________________________________  
   ________________________________________________________________
   ________________________________________________________________

UMI
Relative Isometric and Dynamic Endurance Curves
for Different Muscle Groups of the
Upper Extremities

A Dissertation
Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in
The School of Health, Physical Education,
Recreation and Dance

by
Seung Ho Yoon
B.P.E. Sung Kyun Kwan University, Seoul, Korea 1982
M.S. Eastern Illinois University 1983
May, 1988
ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to Dr. Jack K. Nelson for his gentle support and encouragement throughout the course of study. Appreciation is also extended to Drs. Ron Byrd, Jerry Thomas, and Dennis Landin for their assistance as dissertation committee members.

I must wholeheartedly thank my wife, Jae Sook Lee for her patience and also my mother-in-law, Kyung Ok Paik for her support and concern.

Most of all, I thank my mother, Bok Yeon Hwang. Without her blood, sweat, and tears, how could I possibly be standing here.
Foreword

This manuscript has been written in the style adopted by the American Psychological Association for submission to scholarly journals. Pages 1-33 represent the body of the manuscript as prepared for journal submission. The remaining pages constitute the appendix, and consist of extended review of literature and additional tables and figures.
## TABLE OF CONTENTS

Acknowledgements ........................................ii  
Foreword ....................................................iii  
List of Tables ...........................................v  
List of Figures ........................................vii  
Abstract ...............................................viii  
Introduction ..............................................1  
Method ....................................................4  
Results ...................................................10  
Discussion ...............................................17  
References ...............................................23  
Tables ....................................................27  
Figures ..................................................32  
Appendix A ...............................................38  
Appendix B ...............................................49  
Appendix C ...............................................57  
Appendix D ...............................................59  
Appendix E ...............................................66  
Vita .....................................................72
LIST OF TABLES

1. Overall and Individual Means and Standard Deviations for Relative Total Contraction and Relative Final Contraction Values of Muscle Groups for Both Types of Contractions ... 27

2. Overall and Individual Means and Standard Deviations for Maximal Strength and Total Force Output Values of Muscle Groups for Both Types of Contractions ................. 28

3. Pearson r Correlation Coefficients for Strength and Endurance Variables for Each Exercise Performing Isometric Contraction .................................................. 29

4. Pearson r Correlation Coefficients for Strength and Endurance Variables for Each Exercise Performing Dynamic Contraction .............................................. 30

5. Parameter Estimates of Exponential Regression of Each Exercise Performing Isometric and Dynamic Contractions ...................... 31

B-1. Exercises, Primary Muscle Groups, Tasks and Dependent Variables .................. 50

B-2. Randomized Testing Order of Exercises for Each Subject .......................... 52

D-1. ANOVA Summary Tables with Reliability
Estimates for the Relative Total Contraction Scores of Isometric Contractions ....... 60

D-2. ANOVA Summary Tables with Reliability
Estimates for the Relative Total Contraction Scores of Dynamic Contractions ........ 61

D-3. ANOVA Summary Tables with Reliability
Estimates for the Relative Final Contraction Scores of Isometric Contractions ........ 62

D-4. ANOVA Summary Tables with Reliability
Estimates for the Relative Final Contraction Scores of Dynamic Contractions ........ 63

D-5. Univariate ANOVA Summary Table for Relative Total Contraction ...................... 64

D-6. Univariate ANOVA Summary Table for Relative Final Contraction ...................... 65
LIST OF FIGURES

Figure 1. Endurance Curves for Isometric and Dynamic Contractions during Bench Press Exercise .............................................33

2. Endurance Curves for Isometric and Dynamic Contractions during Arm Curls Exercise .............................................34

3. Endurance Curves for Isometric and Dynamic Contractions during Shoulder Internal Rotation Exercise .........................35

4. Endurance Curves for Isometric and Dynamic Contractions during Wrist Flexion Exercise .............................................36

B-1. Picture of a Subject Performing Bench Press Exercise .............................................53

B-2. Picture of a Subject Performing Arm Curls Exercise .............................................54

B-3. Picture of a Subject Performing Shoulder Internal Rotation Exercise ..........55

B-4. Picture of a Subject Performing Wrist Flexion Exercise .............................................56
Abstract

This study analyzed the characteristics of both dynamic and isometric relative endurance curves for four different muscle groups of the upper extremities. College males (N=56) were tested on the Cybex Isokinetic Dynamometer both isometrically and dynamically on four exercises: bench press, arm curls, shoulder internal rotation and wrist flexion. In all, eight separate exercises were examined. Each dynamic and isometric exercise bout was for 80 and 60 s, respectively and data were recorded every 4 s. Parameters examined were Maximal Strength, Total Force Output, Relative Total (RT, TFO divided by 80s or 60s x peak force), and Relative Final (RF, the area produced during the last 12 s divided by 12s x peak force). A 4(exercises) X 2(dynamic, isometric) MANOVA with repeated measures was computed to determine if there were significant differences in RT and RF across repeated contractions for each task and each muscle group. The stability reliability coefficients for eight exercise bouts ranged from .84 to .98. Relative endurance scores of muscle groups were generally independent of one another, as were the relative endurance measures for dynamic and isometric contractions. Relative endurance depends on the kind of exercise being performed, that is, the type of exercise...
contraction, and the size of muscle group. The results of this study support the contention that relative endurance scores of muscle groups of the upper extremities are independent of one another and are specific to the type of contraction.
Relative Isometric and Dynamic Endurance Curves for Different Muscle Groups of the Upper Extremities

A number of techniques for assessing muscle performance have been developed, ranging from the measured movement of a known weight to chemical analysis of muscle tissue. Moreover, numerous factors are known to affect muscle performance, such as the size of muscle involved, the capacity for supplying blood to the active muscle, the arrangement of muscle fibers, number of motor units, ability to recover from fatigue, state of training, emotional state, familiarity with the test, and skill in the movement.

A great deal of research has been done on both strength and endurance and their relation to each other. This relation has been studied in regard to absolute and relative strength and endurance performances, types of muscular contraction for both strength and endurance, and the nature of the task. However, the diversity of the experimental arrangements and the variations in evaluative techniques have often produced conflicting results and confusion on the part of both the researcher and the practitioner.

Generally, muscular strength is accepted as positively related to absolute endurance (McGlynn, 1969;
Shaver, 1971; Start & Graham, 1964; Tuttle, Janney, & Salzano, 1955; Tuttle, Janney, & Thompson, 1950).

However, findings concerning the relation of muscular strength to relative endurance have not been consistent. Some researchers claim that relative endurance is not related to maximal strength (Carlson, 1969; Caldwell, 1963; Martens & Sharkey, 1966; Start & Graham, 1964), while others have reported a negative relation between strength and relative endurance (Berger, 1970; Carlson & McCraw, 1971; Heyward, 1975; McGlynn, 1969; Tuttle et al., 1955). Again, differences in testing methods, equipment, and experimental design may have been primarily responsible for the disagreement. Moreover, another possible explanation for the conflicting results may be traced to inconsistency in obtaining true maximum strength scores from the subjects (Byrd & Jenness, 1982).

There have been a number of methods for quantifying endurance including repetitions, time, average force, total integrated force, and force decrement. Martens and Sharkey (1966) operationally defined relative endurance as the number of times a subject could elevate 3/8 of his maximum dynamic strength in a flexion movement. Start and Graham (1964) considered isometric endurance as the time in seconds an individual load corresponding to 5/8
of each individual's maximum strength could be maintained in a flexed position. Total force output was used as the measure of relative endurance by Clarke and Gentry (1971) and Ordway, Kearney, and Stull (1977). Total force output can be calculated by integrating the area under the force-time curve. The terms Percent Final Contraction (%FC) and Percent Total Contraction (%TC) were introduced by Hoshizaki and Massey (1986). The %FC was the final 3 sec of impulse divided by the peak force multiplied by three, and the %TC was the total force output (Kg/sec) divided by peak force (Kg) times 63 sec.

Exponential analysis of fatigue curves has been used by researchers in studying muscle contractions over a period of time. The majority of experimenters have reported a linear or quadratic equation for the endurance patterns (Clarke & Gentry, 1971; Clarke & Stull, 1970; Hoshizaki & Massey, 1986; Kroll, 1966, 1974; Ordway et al., 1977). There is, however, a lack of uniformity in findings regarding the fatigue patterns exhibited by different muscle groups. For example, Karpovich, Cohen, and Ikai (1964) reported similarities between leg extensors and forearm flexors, and between hand grip and leg extensors, whereas Ordway et al. (1977) found that the fatigue pattern for forearm flexors and leg extensors was significantly different.
This study analyzed the characteristics of both dynamic and isometric relative endurance curves for four different muscle groups of the upper extremities. Specifically, these four exercises and the primary muscle groups were the bench press (triceps brachii and pectoralis major), arm curls (biceps brachii, brachialis, and brachioradialis), shoulder internal rotation (anterior deltoids and pectoralis major), and wrist flexion (palmaris longus, flexor carpi radialis, flexor carpi ulnaris, flexor digitorum superficialis, and flexor digitorum profundis).

The research questions addressed were
1. Are there significant differences in relative endurance for different muscle groups and different types of contractions?
2. Are there similarities among different muscle groups of the upper extremities in terms of the point of divergence (the point where the isometric endurance curve starts to diverge from the dynamic curve)?

Method

Subjects

The subjects were 56 undergraduate male students at Louisiana State University. The subjects were volunteers, although over half of the subjects from physical education activity classes received extra course
credit for participating in the study. The average height and weight of the subjects were 178.13 cm (SD=6.43) and 73.21 kg (SD=8.20), respectively.

Testing Apparatus

A Cybex Isokinetic Dynamometer was interfaced with an IBM Personal Computer. In the dynamic exercise, the computer was programmed to provide an audio cue every 4 s to prompt the subject to perform each repetition. The computer also measured the greatest force exerted during each repetition. During the isometric exercise bouts, the maximal force scores were automatically recorded every 4 s. The computer program converted the maximal force exerted during the 4-s period into voltage for comparison purposes. The speed selector of the Cybex dynamometer was set at 45° per s for the dynamic exercises and 0° for the isometric exercises.

Testing Procedures

Subjects were given practice to become familiar with the testing instrument and the exercise bouts. Subjects were thoroughly briefed on the purpose of the study and informed consent was obtained. The importance of serious, concentrated effort was stressed and the subjects were asked to exert as hard as possible during the testing. Testing was standardized in that no feedback was given during the testing and no external
motivational strategies were employed. Testing consisted of eight exercise bouts (four muscle groups x two types of contractions) and was administered by the author. The order of the four exercises was randomized before the experiment began (24 different combinations) and the order of types of contraction was decided by coin toss during the testing session. The order of the exercise bouts was randomly determined as each subject reported to the laboratory. Four of the eight bouts were completed on 1 day and the other four a week later. Subjects were asked to perform a minimum of 20 repetitions for the dynamic bouts and a minimum of 60 s sustenance for the isometric bouts.

**Bench Press.** The subject was positioned on his back on the Cybex Upper Body Exercise and Testing (UBXT) table. The bar, which was attached to the isokinetic dynamometer, was placed above his chest. The subject was instructed to grip the bar with the hands approximately shoulder width apart. During the dynamic exercise, upon hearing the audio cue, the subject exerted a maximal press. The subject passively allowed the bar to return to his chest after each press. The isometric bench press was performed with the bar resting approximately 5 cm from the subject's chest. The subject was directed to exert as hard as possible until told to stop.
Arm Curls. The subject was seated on the UBXT table facing the isokinetic dynamometer. The subject grasped the bar with palms up and hands placed approximately shoulder width apart. During the dynamic bout, the subject began with the bar 5 cm from his thighs, and pulled upward as hard as possible until the bar was approximately at shoulder height. The bar automatically returned to the starting position after each repetition. For the isometric bout, the bar was placed approximately 5 cm from the subject's thighs. The subject then performed a maximal exertion against the immovable bar. The subject was told to keep the upper torso erect during the contractions.

Shoulder Internal Rotation. The subject was seated on a chair which was 30 cm from the floor. The dynamometer was positioned so that the subject's shoulder was aligned with the locking collar of the dynamometer. During the dynamic bout, the subject executed an internal rotation movement (similar to arm wrestling) as hard as possible, starting with the forearm perpendicular to the floor and ending with the forearm in a neutral position parallel with the floor. The isometric performance was done with the hand grip resting at the starting position. Only the dominant hand was tested. The performing upper arm was stabilized with the Cybex V-pad and strap.
**Wrist Flexion.** The subject was seated on the backrest of the UBXT table with his shoulder aligned to the locking collar of the dynamometer. The dominant hand grasped the handle with the palm up. The forearm was stabilized with the V-pad and strap. A maximal force was exerted to flex the wrist starting from the neutral position with the back of the hand parallel with the floor and ending in a position of full flexion. During the isometric bout, maximum effort was exerted in the neutral position.

**Reliability Estimation**

Twenty subjects were randomly selected and retested on all exercise bouts to determine stability reliability for relative endurance measures of different muscle groups performing dynamic and isometric contractions. A minimum of 1 week was allowed between the test and retest.

**Analysis**

For one analysis, only the scores for the first 20 repetitions during the dynamic exercise bouts and the first 15 scores registered during the isometric bouts were used as data. The average of the three highest scores reflected maximal strength, and absolute endurance was considered to be the Total Force Output (TFO). Relative endurance was represented by Relative Total
Contraction (RT) and Relative Final Contraction (RF). RT was computed by dividing the obtained TFO by the TFO a subject would have obtained if he had held his peak force (the highest force exerted in a maximal force production effort) for the whole period, that is, 80 s for the dynamic bouts and 60 s for the isometric bouts. RF was the output a subject would have obtained during the last 12 s if no fatigue had occurred. The mathematical equations were:

\[
\begin{align*}
TFO &= \int_{0}^{60} F(x) \, dx \text{ for the isometric} \\
&\quad \int_{0}^{80} F(x) \, dx \text{ for the dynamic} \\
RT &= \left( \frac{TFO}{\text{peak force} \times 60} \right) \times 100 \text{ for the isometric} \\
&\quad \left( \frac{TFO}{\text{peak force} \times 80} \right) \times 100 \text{ for the dynamic} \\
RF &= \left\{ \\
&\quad \int_{48}^{60} \frac{F(x) \, dx}{\text{peak force} \times 12} \times 100 \text{ for the isometric} \\
&\quad \int_{80}^{68} \frac{F(x) \, dx}{\text{peak force} \times 12} \times 100 \text{ for the dynamic} \\
\right\}
\end{align*}
\]

where \( F(x) \) = endurance curve equation function and \( dx = \text{derivative x} \).

Intraclass correlation (R) was used to determine reliability for strength, absolute endurance (TFO), and relative endurance measures (RT and RF) of the eight exercise bouts. Pearson r was calculated to determine the relation between strength and absolute endurance and
between strength and relative endurance variables.

A simple linear or quadratic equation was established for each of the eight exercise bouts to investigate the shapes of endurance curves and to determine the similarity in fatigue patterns among the different muscle groups. The point of divergence, which was determined as the point where the dynamic and the isometric patterns began to separate, was arbitrarily detected by visual inspection.

A multivariate mixed model analysis (4 muscle groups x 2 tasks) was applied to determine if significant differences in RT and RF existed across repeated contractions for each exercise and each muscle group.

**Results**

**Reliability of the Data**

Reliability of maximal strength, Total Force Output (TFO), Relative Total Contraction (RT), and Relative Final Contraction (RF) was assessed using the test-retest data completed on approximately 36% of the subjects (n=20). Intraclass correlation was used to determine the stability reliability.

**Reliability of Maximal Strength.** Reliability coefficients for maximal strength for each exercise performing isometric and dynamic contractions were as follows: $R = .84$ and $.97$ for the isometric and dynamic
Bench Press; \( R = 0.87 \) and \( 0.92 \) for the isometric and dynamic
Arm Curls; \( R = 0.83 \) and \( 0.89 \) for the isometric and dynamic
Shoulder Internal Rotation; and \( R = 0.78 \) and \( 0.81 \) for the
isometric and dynamic Wrist Flexion. These results
were consistent with the reliability coefficients
reported in other studies regarding muscular strength.
Ordway, Kearney, and Stull (1977) reported a reliability
coefficient of \( r = 0.71 \) for intermittent isometric elbow
flexion and \( r = 0.82 \) for knee extension. Clarke and Gentry
(1971) reported reliability coefficients for isometric
grip contraction, \( r = 0.79 \); isotonic grip contraction,
\( r = 0.72 \); isometric elbow flexion, \( r = 0.79 \); and isotonic elbow
flexion, \( r = 0.70 \). Other researchers who have analyzed day-
to-day correlation coefficients for isometric strength
have reported coefficients as follows: \( r = 0.83 \) for leg
extension (Ebel, 1949); \( r = 0.94 \) for forearm flexion
(Carlson & McCraw, 1971); and \( r = 0.92 \) for handgrip (Heyward

**Reliability of TFO.** The force exerted over the
time of a maximal contraction performance was used as an
estimate of the total force output capability of a muscle
group. The reliability coefficient for total integrated
force for all muscle groups performing both the isometric
and dynamic tasks, respectively, were as follows: \( R = 0.84 \)
and \( 0.92 \) for Bench Press; \( R = 0.85 \) and \( 0.86 \) for Arm Curls;
$R = .79$ and $.81$ for Shoulder Internal Rotation; and $R = .62$ and $.75$ for Wrist Flexion. This was also in agreement with reported reliability coefficients for isometric and dynamic contractions of the forearm flexor muscles which have ranged from $r = .48$ to $r = .91$ (Carlson & McCraw, 1971; Clarke & Gentry, 1971; Karpovich, et al., 1964). Reliability coefficients reported for isometric grip endurance have ranged from $r = .75$ to $.88$ (Clarke & Gentry, 1971; Heyward & Massey, 1977; Karpovich, et al., 1964). Ebel (1949) reported a reliability coefficient of $.68$ for isometric leg extension endurance, while Karpovich, et al. (1964) reported $r = .75$ for the same muscle group performing work.

Reliability of RT and RF. Reliability coefficients for these two measures ranged from moderate to high. RF of the dynamic bench press had the highest reliability coefficient of $R = .96$ with the RF of dynamic shoulder internal rotation being the lowest $R = .75$. Hoshizaki and Massey (1986) reported reliability coefficients of $r = .56$ to $r = .79$ for intermittent and continuous grip contractions and forearm extension.

Relation Between Strength and Endurance.

The relation between strength and endurance variables was determined by computing Pearson $r$ between maximal strength, TFO, RT, and RF in all eight exercise
bouts. Overall and individual means and standard deviations for RT and RF are provided in Table 1 and for maximal strength and TFO in Table 2.

The correlation coefficients between strength and TFO were from moderate to high ranging between .72 and .86. This was expected because TFO was considered an indication of absolute endurance, as it was measured as the total integrated force over 80 s for the dynamic and 60 s of contraction for the isometric bouts. Hence the stronger individual can produce more force in a given time period (Burke, Tuttle, Thompson, Janney & Weber, 1953; Tuttle, et al., 1950). The coefficients between maximal strength and relative endurance variables (RT and RF) were mostly negative and low. The coefficients ranged from -.51 to .03 with only three out of 16 coefficients being positive. This result was also in accord with the values reported in the literature (Carlson, 1969; Carlson & McCraw, 1971; Heyward, 1975; Nwuga, 1975; Tuttle, et al., 1950; Tuttle, et al., 1955). Correlation coefficients between RT and RF reflected high relationships (r=.67 to .94), which was expected since both variables were somewhat similar. Table 3 and 4
contains Pearson r correlation coefficients for strength and endurance variables for each exercise performing isometric and dynamic contractions.

Insert Table 3 and 4 about here

-----------------------------------------------

Relation between strength and endurance was similar across muscle groups and tasks. For the relation between the isometric RT and RF, however, the bigger muscle groups had much higher correlation coefficients than the smaller muscle groups.

Analysis of Endurance Curves

The configuration of endurance curves for each muscle group performing dynamic and isometric exercise was described by an exponential analysis. Force values of each 4-s contraction for 80 s for the dynamic and 60 s for the isometric bouts were analyzed. Table 5 contains the parameter estimates of exponential regression of each exercise performing isometric and dynamic contractions.

Insert Table 5 about here

-----------------------------------------------

Endurance curves reflecting mean values for each muscle group for each task are provided in Figure 1 through 4.
Three out of four isometric endurance curves exhibited significant quadratic factors. The exception was wrist flexion. All dynamic endurance patterns exhibited a single exponent. The first exponent of all endurance curves was negative with the isometric bench press having the largest (standardized $b_1=-1.71$) and dynamic wrist flexion the smallest value (standardized $b_1=-.14$). Coefficients of the exponent in single exponent regression ranged from $-.02$ to $-1.41$ (standardized $b_1=-.64$ to $-.99$). In two-exponent endurance curves, a significant increase in variance accounted for by quadratic fit over linear fit was observed, although they had very small coefficients for the second exponents. Isometric bench press had a 21% increase, isometric arm curls 19%, and isometric shoulder internal rotation 24%. Figures 1 through 4 reveal that all 4-s force values were sustained at a higher level for the dynamic contraction compared to the isometric contraction in all muscle groups. The point at which the endurance curves for dynamic contractions began to diverge from isometric contractions was 12 s for bench press, 24 s for arm curls, 32 s for wrist flexion, and 16
Exponential analysis demonstrated a predominance of single-exponent regression. All dynamic curves demonstrated similar patterns, as did all isometric curves, except for wrist flexion. However, the curves differed between dynamic and isometric exercises for the same muscle group.

Relative Endurance

A multivariate mixed model analysis (Schutz & Gessaroli, 1987) was computed to evaluate the differences between the relative endurance performances of the four muscle groups for the two tasks. Relative endurance, as represented by RT and RF, was analyzed using 4 x 2 MANOVA with repeated measures. The analysis of multivariate mixed model revealed significant differences among muscle groups, $F(6,328)=86.22$, $p<.01$, and between tasks, $F(2,219)=721.94$, $p<.01$, with a non-significant interaction between the two factors, $F(6,438)=2.08$, $p>.05$. The order of both RT and RF mean values for the exercises was the same, and from the highest to the lowest was as follows: wrist flexion, shoulder internal rotation, arm curls, and bench press (see Table 1). Separate analysis of variance tests were performed for each RT and RF dependent measure of relative endurance. The $F$'s were 12.88, $p<.01$ for RT, and 23.74, $p<.01$ for
RF. In RT, the main effects were $F=6.80$, $p<.01$ for subject, $F=240.30$, $p<.01$ for muscle group, and $F=1150.98$, $p<.01$ for task (types of contraction). The interaction between muscle group and task was nonsignificant, $F=2.50$, $p>.05$. Similarly, in RF, the main effects were $F=6.13$, $p<.01$ for subject, $F=1032.09$, $p<.01$ for muscle group, and $F=1217.27$, $p<.01$ for task. The interaction between muscle group and task showed a nonsignificant $F$ of $.12$ ($p>.05$).

The comparison of means revealed significant differences between Bench Press and Arm Curls, Bench Press and Shoulder Internal Rotation, Bench Press and Wrist Flexion, Arm Curls and Shoulder Internal Rotation, Arm Curls and Wrist Flexion, and Shoulder Internal Rotation and Wrist Flexion. Wrist Flexion had the highest mean value, while Bench Press the lowest. Shoulder Internal Rotation was higher than Arm Curls (see Table 1). The dynamic contractions had greater RT and RF with means ranging from $55.89\%$ ($SD=7.46$) to $88.50\%$ ($SD=4.15$) than the isometric contraction means which ranged from $43.92\%$ ($SD=6.76$) to $80.60\%$ ($SD=4.81$).

Discussion

The reliability coefficients of relative endurance in this study were relatively high with only four of 16 being below .80. High correlations were found between
Total Force Output and maximal strength which supported the postulation that TFO measures are dependent upon the strength of the muscle group. Low and negative correlations between maximal strength and Relative Total Contraction, and maximal strength and Relative Final Contraction are consistent with previous studies on the relation between muscular strength and endurance. In the earlier studies, endurance was measured in terms of the length of time a muscle could retain a force determined as a percent of maximal strength. Corroboration of previous results implies that the method of measuring relative endurance in this study is valid and, moreover, RT and RF can be used as predictor variables for relative endurance. Low to medium correlations were obtained between measures of TFO and the two relative endurance measures, suggesting a limited relation between them.

A primary focus of this study was to determine if there were significant differences in relative endurance across different muscle groups of the upper extremities and between the two types of contraction. Relative endurance of muscle groups were generally independent of one another, as were the relative endurance measures for dynamic and isometric contractions. Wrist flexion was found to have the greatest relative endurance scores for both dynamic and isometric exercise bouts, and the bench
press showed the smallest. These results demonstrate that relative endurance depends on the kind of exercise being performed and the type of contraction.

The results also indicate that the size of the muscle group is related to the magnitude of relative endurance values. In this study, the biggest difference found in relative endurance values was between the bench press and wrist flexion, which were the largest and smallest muscle groups tested. This conforms to the results of Karpovich, et al. (1964) who observed lower relative endurance scores for gripping compared to forearm flexion and leg extension in performing an intermittent exercise. Hoshizaki and Massey (1986) reported significantly lower relative endurance scores for handgrip when compared to the dorsiflexors and to the forearm extensors and flexors. A factor recognized as essential to muscular endurance and possibly affected by musculature is the blood supply to the active muscle mass. Blood supply is important in providing oxygen and nutrients to muscle tissue and in the removal of metabolic wastes. The accumulation of muscle metabolites is known to be one possible cause of muscular fatigue (Funderburk, Karlsson, & Lind, 1972). Kroll (1966) compared the static, intermittent fatigue curves of high, middle, and low strength groups, and suggested that the
low strength group always demonstrated better endurance, compared to high and middle strength groups. Heyward (1975) mentioned that the negative relation between strength and relative endurance may be a function of differences in the muscle mass involvement and degree of intramuscular occlusion produced by the contracting muscle mass. The data in this study support the contention that stronger muscle groups fatigue faster than weaker muscle groups, and this suggests that differences in local circulatory efficiency and use of aerobic and anaerobic energy reserves may be responsible for the observed differences in fatigue patterns among different muscle groups. Heyward (1975) noted that the blood flow response to sustained static contraction is influenced by two opposing factors; vasodilatation of the blood vessels in the active muscle mass, and mechanical compression of the blood vessels by the contracting muscle mass. These inhibitory factors could explain the lower relative endurance performance of the isometric contraction exercises in this study. Obviously, the dynamic exercises permit greater blood supply to the muscles than the sustained static contraction of the isometric bouts.

Single-exponent regressions demonstrated dominance in the dynamic exercises, while most of the isometric
exercises reflected two-exponent curves. Two-exponent endurance curves for dynamic or intermittent exercise have been reported by Clarke and Gentry (1971), Clarke and Stull (1970), Hoshizaki and Massey (1986), and Kroll (1974). Hoshizaki and Massey (1986) and Kroll (1974) also reported single-exponent curves for intermittent exercises as did Clarke (1962) and Ordway, et al. (1977). For isometric or continuous muscle contraction, researchers have reported from one to four exponents for endurance curves (Clarke, 1962; Clarke & Gentry, 1971; Clarke & Stull, 1969; Hoshizaki & Massey, 1986; Royce, 1958). Dominance of single-exponent for the dynamic exercises indicates that fatigue from endurance exercises of the upper extremities increases at a relatively consistent rate across the 80 s period of dynamic contractions. The variation in the points of divergence of the endurance curves may be the results of differences in blood flow to the muscle groups, variations in neural stimulation of muscle fibers during contraction, and availability of energy substrates for metabolism.

Results comparing relative endurance measures for each of the four muscle groups performing dynamic and isometric contraction supported the contention that relative endurance is not generalizable across muscle groups. This suggests that the differences in relative
endurance across different muscle groups may be influenced by the physiological specificity to muscle groups such as blood supply (Heyward, 1975), energy substrates (Karlson, Funderburk, Essen, & Lind, 1975), fiber ratio (Hulton, Thorstensson, Sjodin, & Karlsson, 1975), skeletal leverage, ability to recover from work, and familiarity with the test.

In summary, quantification of relative endurance in terms of Relative Total Contraction and Relative Final Contraction seems to be effective in distinguishing differences in endurance among muscle groups performing isometric and dynamic contractions. This study also demonstrated the effectiveness of one- and two-exponent regression equations in describing relative endurance for isometric and dynamic contractions with all muscle groups. The results of this study definitely support the contention that relative endurance performances of muscle groups of the upper extremities are independent of one another and are specific to the type of contraction.
References


differences in handgrips and elbow-flexion fatigue. 

*Journal of Motor Behavior, 3*, 225-234.


Hulton, B., Thorstensson, A., Sjodin, B., and Karlsson,


Table 1

Overall and Individual Means and Standard Deviations for Relative Total Contraction and Relative Final Contraction Values of Muscle Groups for Both Types of Contractions

<table>
<thead>
<tr>
<th>Exercise X Task</th>
<th>RT</th>
<th>RF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Means(%)</td>
<td>SD</td>
</tr>
<tr>
<td>BP Isometric</td>
<td>65.13</td>
<td>6.12</td>
</tr>
<tr>
<td>Dynamic</td>
<td>77.18</td>
<td>7.32</td>
</tr>
<tr>
<td>AC Isometric</td>
<td>67.94</td>
<td>7.76</td>
</tr>
<tr>
<td>Dynamic</td>
<td>79.96</td>
<td>6.57</td>
</tr>
<tr>
<td>SIR Isometric</td>
<td>72.80</td>
<td>5.35</td>
</tr>
<tr>
<td>Dynamic</td>
<td>82.70</td>
<td>4.70</td>
</tr>
<tr>
<td>WF Isometric</td>
<td>77.50</td>
<td>4.39</td>
</tr>
<tr>
<td>Dynamic</td>
<td>88.50</td>
<td>4.15</td>
</tr>
</tbody>
</table>

Exercise

| BP | 71.15 | 3.51 | 49.91 | 4.87 |
| AC | 73.95 | 6.62 | 52.58 | 4.08 |
| SIR| 77.77 | 7.30 | 63.46 | 5.79 |
| WF | 83.00 | 5.93 | 74.53 | 6.84 |

Task

| Isometric | 70.86 | 6.65 | 54.01 | 4.43 |
| Dynamic   | 82.08 | 5.57 | 66.23 | 3.96 |
Table 2

Overall and Individual Means and Standard Deviations for Maximal Strength and Total Force Output Values of Muscle Groups for Both Types of Contractions

<table>
<thead>
<tr>
<th>Exercise X Task</th>
<th>MS</th>
<th>TFO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Means</td>
<td>SD</td>
</tr>
<tr>
<td>BP Isometric</td>
<td>198.11</td>
<td>38.47</td>
</tr>
<tr>
<td>Dynamic</td>
<td>209.55</td>
<td>33.94</td>
</tr>
<tr>
<td>AC Isometric</td>
<td>145.26</td>
<td>26.86</td>
</tr>
<tr>
<td>Dynamic</td>
<td>149.30</td>
<td>30.92</td>
</tr>
<tr>
<td>SIR Isometric</td>
<td>25.90</td>
<td>10.08</td>
</tr>
<tr>
<td>Dynamic</td>
<td>27.64</td>
<td>8.94</td>
</tr>
<tr>
<td>WF Isometric</td>
<td>5.72</td>
<td>1.26</td>
</tr>
<tr>
<td>Dynamic</td>
<td>5.79</td>
<td>1.84</td>
</tr>
</tbody>
</table>

Exercise

<table>
<thead>
<tr>
<th>Exercise</th>
<th>MS</th>
<th>TFO</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP</td>
<td>203.83</td>
<td>26.84</td>
</tr>
<tr>
<td>AC</td>
<td>147.28</td>
<td>24.53</td>
</tr>
<tr>
<td>SIR</td>
<td>26.77</td>
<td>6.80</td>
</tr>
<tr>
<td>WF</td>
<td>5.76</td>
<td>1.14</td>
</tr>
</tbody>
</table>
Table 3
Pearson r Correlation Coefficients for Strength and
Endurance Variables for Each Exercise Performing
Isometric Contraction

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Strength</th>
<th>TFO</th>
<th>RT</th>
<th>RF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench Press Strength</td>
<td></td>
<td>.79**</td>
<td>-.17</td>
<td>-.04</td>
</tr>
<tr>
<td></td>
<td>TFO</td>
<td>.31*</td>
<td></td>
<td>.21</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td></td>
<td>.92**</td>
<td></td>
</tr>
<tr>
<td>Arm Curls Strength</td>
<td></td>
<td>.86**</td>
<td>.03</td>
<td>-.18</td>
</tr>
<tr>
<td></td>
<td>TFO</td>
<td>.37**</td>
<td></td>
<td>.29*</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td></td>
<td>.94**</td>
<td></td>
</tr>
<tr>
<td>Shoulder Strength</td>
<td></td>
<td>.81**</td>
<td>-.45**</td>
<td>-.48**</td>
</tr>
<tr>
<td>Internal Rotation</td>
<td>TFO</td>
<td>.22</td>
<td></td>
<td>.13</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td></td>
<td>.70**</td>
<td></td>
</tr>
<tr>
<td>Wrist Flexion Strength</td>
<td></td>
<td>.72**</td>
<td>-.18</td>
<td>-.09</td>
</tr>
<tr>
<td></td>
<td>TFO</td>
<td>-.20</td>
<td></td>
<td>.05</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td></td>
<td>.76**</td>
<td></td>
</tr>
</tbody>
</table>

* p<.05    ** p<.01
Table 4

**Pearson r Correlation Coefficients for Strength and Endurance Variables for Each Exercise Performing Dynamic Contraction**

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Bench Press Strength</th>
<th>TFO</th>
<th>RT</th>
<th>RF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>.86**</td>
<td>.09</td>
<td>-.12</td>
</tr>
<tr>
<td></td>
<td>TFO</td>
<td>.40**</td>
<td>.14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td></td>
<td>.67**</td>
<td></td>
</tr>
<tr>
<td>Arm Curls Strength</td>
<td></td>
<td>.79**</td>
<td>-.51**</td>
<td>-.28*</td>
</tr>
<tr>
<td></td>
<td>TFO</td>
<td>.15</td>
<td></td>
<td>-.20</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td></td>
<td>.73**</td>
<td></td>
</tr>
<tr>
<td>Shoulder Strength</td>
<td></td>
<td>.85**</td>
<td>.18</td>
<td>-.37**</td>
</tr>
<tr>
<td>Internal Rotation TFO</td>
<td></td>
<td>.30*</td>
<td>.21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rotation RT</td>
<td></td>
<td>.78**</td>
<td></td>
</tr>
<tr>
<td>Wrist Flexion Strength</td>
<td></td>
<td>.77**</td>
<td>-.33**</td>
<td>-.28*</td>
</tr>
<tr>
<td></td>
<td>TFO</td>
<td>.19</td>
<td>.32*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td></td>
<td>.73**</td>
<td></td>
</tr>
</tbody>
</table>

* p < .05  ** p < .01
Table 5

Parameter Estimates of Exponential Regression of Each Exercise Performing Isometric and Dynamic Contractions

(Model: \( Y' = b_0 + b_1X + b_2X^2 \))

<table>
<thead>
<tr>
<th>Exercise Bout</th>
<th>( b_0 )</th>
<th>SE</th>
<th>( b_1 )</th>
<th>SE</th>
<th>( b_2 )</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP(^1) Isometric</td>
<td>231.39</td>
<td>4.35</td>
<td>-4.35</td>
<td>.31</td>
<td>.03</td>
<td>.005</td>
</tr>
<tr>
<td>Dynamic</td>
<td>222.56</td>
<td>.87</td>
<td>-1.41</td>
<td>.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC(^2) Isometric</td>
<td>163.11</td>
<td>3.46</td>
<td>-2.16</td>
<td>.25</td>
<td>.09</td>
<td>.00</td>
</tr>
<tr>
<td>Dynamic</td>
<td>155.99</td>
<td>.72</td>
<td>-.88</td>
<td>.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIR(^3) Isometric</td>
<td>28.69</td>
<td>.27</td>
<td>-.38</td>
<td>.02</td>
<td>.02</td>
<td>.00</td>
</tr>
<tr>
<td>Dynamic</td>
<td>28.60</td>
<td>.13</td>
<td>-.12</td>
<td>.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WF(^4) Isometric</td>
<td>6.06</td>
<td>.07</td>
<td>-.03</td>
<td>.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic</td>
<td>5.97</td>
<td>.05</td>
<td>-.02</td>
<td>.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

1 Bench Press
2 Arm Curls
3 Shoulder Internal Rotation
4 Wrist Flexion
Figure Captions

Figure 1. Endurance Curves for Isometric and Dynamic Contractions During Bench Press Exercise.

Figure 2. Endurance Curves for Isometric and Dynamic Contractions during Arm Curls Exercise.

Figure 3. Endurance Curves for Isometric and Dynamic Contractions during Shoulder Internal Rotation Exercise.

Figure 4. Endurance Curves for Isometric and Dynamic Contractions during Wrist Flexion.
Figure 1
Figure 3
Figure 4

- Dynamic
- Isometric

Time in sec

Force
Appendices
Appendix A

Extended Review of the Literature
Many studies have indicated that individuals with greatest muscular strength have greatest absolute muscular endurance, but the stronger individuals generally exhibit poorer muscular endurance relative to maximum strength than individuals of less strength. Tuttle, Janney, and Thompson (1950), using the grip dynamometer, found significant correlations ranging from .66 to .91 between maximum static strength and maximum load held for a 1-minute period. To overcome the limitations of the dynamometer available at that time, Tuttle, Janney, and Salzano (1955) constructed the Back and Leg Dynamometer designed for measuring and recording both maximum strength and strength endurance. Data collected by this instrument showed that individuals with the greater maximum strength have a greater absolute strength endurance index, stronger individuals maintain a smaller proportion of their maximum back and leg strength than those with less initial strength, and the development of strength endurance is not directly proportional to the development of maximum strength.

Start and Graham (1964) found similar results between maximum isometric strength and absolute isometric endurance ($r=.75$), which was measured by the time a common load representing 5/8 of the group's mean maximum strength could be maintained. In this experiment, the
Cable Tensiometer and the Modified Kelso-Hellebrandt ergograph were used for testing strength and endurance, respectively. They found a negative but nonsignificant correlation ($r=-.36$) between maximum isometric strength and relative isometric endurance as measured with individual loads corresponding to 5/8 maximum strength. Similar results were found in a number of studies (Berger, 1970; Irish, 1958; McGlynn, 1969; Tuttle et al., 1955).

In an attempt to determine the relation between isometric strength and relative isometric endurance of the right forearm flexor muscles, Carlson and McCraw (1971) noted the weak subjects performed significantly better than the strong subjects on the light weight loads, with no difference existing between the endurance performances on the heavy loads. The percentages of maximum isometric strength used for the endurance tests in the study were 30, 45, 60, and 75%. Similar results were observed by Heyward (1975) who indicated that low strength individuals tend to be able to maintain submaximal tension levels for longer periods of time than can high strength individuals.

Shaver (1971) tested 40 college male students on the bench press lift and found a strong correlation between maximum dynamic strength and absolute dynamic endurance.
There was no relation with maximum dynamic strength when subjects were required to lift a load equivalent to 75% of their maximum strength as many times as possible. In another study (1972), Shaver tested 120 male college athletes who were divided into three equal groups based on the sums of their maximum isometric strength scores. Individuals with the highest maximal isometric strength level had higher relative isotonic endurance when using 35, 40, and 45% of their maximum isometric strength than those of middle and low maximal strength. Shaver further noted that individuals with the highest maximal isometric strength level could maintain a higher percentage of that strength during a relative isotonic endurance bout (using 35, 40, and 45% of maximum strength) than those of middle and low maximal strength. A similar study by Carlson (1969) revealed no significant differences in relative isometric endurance at any of 50, 60, 70, and 80% weight loads of maximum strength among groups of three different levels of athletic achievement (high, middle, and low).

Kroll (1968) postulated that stronger muscles may fatigue faster than weaker muscles, but only under certain conditions and at specific strength levels. He reported that low level strength groups demonstrated significant linear fatigue patterns under 5 and 10 s recuperation period conditions, indicating the absence of
a steady state. At the same time, subjects with high and middle levels of strength were able to demonstrate quadratic curve components associated with a steady state while operating at higher levels of absolute strength. Even though high and middle levels of strength differed with regard to absolute amounts, their fatigue patterns were similar. He further suggested that perhaps low levels of strength operate primarily on aerobic energy reserves while higher levels seem to draw largely anaerobic reserves.

The analysis of results by Tuttle (1950, 1955) for the grip and back muscle indicates that maximum contraction could be maintained only for an instant and then the force immediately started to decline. Royce (1958), however, reported that there was no appreciable drop in the maximal force of a hand grip during the first 15 s. Hettinger (1961) concluded that the duration for the maximum force of forearm flexors was under 10 sec. Rohmert (1960) observed that the duration of the maximum isometric force exerted by arms extended straight forward was between 5.4 and 7.8 s, and Cotten (1967) reported the duration of sustained isometric contractions of the forearm flexors ranged between 3.0 and 9.8 s (M=5.6 sec). In Moudgil and Karpovich's study (1969), the maximum force, exerted by forearm flexors during isometric
contraction at 60°, 100°, and 120° at the elbow joint, was reached on the average in 2.6 s and lasted .67 s.

The relationships of endurance performances among different muscle groups have not been extensively investigated. Karpovich, Cohan, and Ikai (1964) studied dynamic contraction endurance the three muscle groups and found a definite relationship between leg and arm endurance, while the endurance of hand grip and elbow flexor muscle groups were not related. The subjects studied were 20 male prison inmates and 10 college students.

In the studies by Clarke and Gentry (1971), differences in strength and endurance parameters for two muscle groups (handgrip and elbow flexors), and two types of exercise (isotonic and isometric) were analyzed. Four measures were determined: initial strength, final strength, total work, and fatigable work. Total work was computed by the addition of intermittent contraction force values, obtained every 30 s, and sustained contraction force values obtained every 5 s. Fatigable work was computed by subtracting the force value of the final contraction from the force values of each of the preceding contraction differences. The correlation coefficients were moderately high for initial strength ($r = .70$ to $r = .82$) and total work ($r = .61$ to $r = .82$), but low
for final strength (r = .30 to r = .63) and fatigable work (r = .10 to r = .55). It was concluded that endurance measures of performance for handgrip and forearm flexion reflected more specificity than generality for both dynamic and isometric muscle contractions.

Ordway, et al. (1977) investigated strength and endurance of the elbow flexors and knee extensors. Twenty-seven male subjects performed two 5-minute bouts of rhythmic and isometric muscle contractions with each muscle group at a rate of 30 maximal contractions per minute. An exponential analysis was used to analyze the endurance curves. Strength decrement for the elbow flexors was 48% and 59% for the knee extensors, but the rate of fatigue was faster for elbow flexors. The results of their study agreed with Clarke and Gentry (1971) in concluding that individual muscle groups tend to fatigue at different rates.

Hoshizaki and Massey (1986) investigated the static contraction endurance characteristics of five muscle groups, finger flexors, forearm extensors, forearm flexors, plantar flexors and dorsal flexors on thirty-eight college males and found endurance to be specific to both the muscle groups and tasks (continuous and isometric). They concluded that continuous contraction resulted in significantly greater fatigue than did
intermittent contraction and that polynomial regression curves can effectively describe fatigue curves.
References


Appendix B
Summary of Exercises, Primary Muscle Groups, Tasks and Dependent Variables; Randomized Testing Order Table; and Pictures of a Subject Performing Each Exercise
Table B-1

**Exercises, Primary Muscle Groups, Tasks and Dependent Variables**

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Muscle Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench Press</td>
<td>Triceps Brachii &amp; Pectoralis Major</td>
</tr>
<tr>
<td>Arm Curls</td>
<td>Biceps Brachii, Brachialis, &amp; Brachioradialis</td>
</tr>
<tr>
<td>Shoulder Internal Rotation</td>
<td>Anterior Deltoids &amp; Pectoralis Major</td>
</tr>
<tr>
<td>Wrist Flexion</td>
<td>Palmaris Longus, Flexorcarpi Radialis, Flexorcarpi Ulnaris, Flexordigitorum Superficialis, &amp; Flexordigitorum Profundis</td>
</tr>
</tbody>
</table>

**Tasks**

1. Isometric maximal contraction for 60 sec.

2. Dynamic maximal contraction for 80 sec (each repetition every 4-sec).

**Dependent Variables**

Maximal Strength: The average of three highest force productions across contractions.

Total Force Output (TFO):

\[
\int_{0}^{60} F(x) \, dx \quad \text{for isometric contractions} \\
\int_{0}^{80} F(x) \, dx \quad \text{for dynamic contractions}
\]

Relative Total Contraction (RT):

\[
\left\{ \frac{TFO}{(\text{peak force} \times 60)} \right\} \times 100 \quad \text{for isometric} \\
\left\{ \frac{TFO}{(\text{peak force} \times 80)} \right\} \times 100 \quad \text{for dynamic}
\]
Relative Final Contraction (RF):

\[
\int_{48}^{60} \frac{F(x) \, dx}{\text{(peak force x 12)}} \times 100 \text{ for isometric}
\]

\[
\int_{68}^{80} \frac{F(x) \, dx}{\text{(peak force x 12)}} \times 100 \text{ for dynamic,}
\]

where \( F(x) \) = regression function, and \( dx = \text{derivative}\ x. \)
<table>
<thead>
<tr>
<th>Order</th>
<th>Subject ID</th>
<th>Order Subject ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. B</td>
<td>W C S B</td>
<td>1, 25, 49</td>
</tr>
<tr>
<td>2. C</td>
<td>S W B C</td>
<td>2, 26, 50</td>
</tr>
<tr>
<td>3. S</td>
<td>W S B C</td>
<td>3, 27, 51</td>
</tr>
<tr>
<td>4. W</td>
<td>C S B W</td>
<td>4, 28, 52</td>
</tr>
<tr>
<td>5. C</td>
<td>B W S C</td>
<td>5, 29, 53</td>
</tr>
<tr>
<td>6. B</td>
<td>C W S B</td>
<td>6, 30, 54</td>
</tr>
<tr>
<td>7. S</td>
<td>B C W S</td>
<td>7, 31, 55</td>
</tr>
<tr>
<td>8. W</td>
<td>S C B W</td>
<td>8, 32, 56</td>
</tr>
<tr>
<td>9. B</td>
<td>W S C B</td>
<td>9, 33</td>
</tr>
<tr>
<td>10. S</td>
<td>B C W S</td>
<td>10, 34</td>
</tr>
<tr>
<td>11. W</td>
<td>B S C W</td>
<td>11, 35</td>
</tr>
<tr>
<td>12. C</td>
<td>S B W C</td>
<td>12, 36</td>
</tr>
<tr>
<td>13. S</td>
<td>C W B S</td>
<td>13, 37</td>
</tr>
<tr>
<td>14. C</td>
<td>W B S C</td>
<td>14, 38</td>
</tr>
<tr>
<td>15. B</td>
<td>S W C S</td>
<td>15, 39</td>
</tr>
<tr>
<td>16. W</td>
<td>S B C W</td>
<td>16, 40</td>
</tr>
<tr>
<td>17. B</td>
<td>C S W B</td>
<td>17, 41</td>
</tr>
<tr>
<td>18. W</td>
<td>C B S W</td>
<td>18, 42</td>
</tr>
<tr>
<td>19. S</td>
<td>C B W S</td>
<td>19, 43</td>
</tr>
<tr>
<td>20. C</td>
<td>B S W C</td>
<td>20, 44</td>
</tr>
<tr>
<td>21. B</td>
<td>S C W B</td>
<td>21, 45</td>
</tr>
<tr>
<td>22. S</td>
<td>W C B S</td>
<td>22, 46</td>
</tr>
<tr>
<td>23. C</td>
<td>W S B C</td>
<td>23, 47</td>
</tr>
<tr>
<td>24. W</td>
<td>B C S W</td>
<td>24, 48</td>
</tr>
</tbody>
</table>

*B* Bench Press  
*W* Wrist Flexion  
*C* Arm Curls  
*S* Shoulder Internal Rotation
Figure B-2
Figure B-4
Appendix C

Subjects' Consent Form
EXPERIMENT SIGN-UP FORM

My signature, on this sheet, by which I volunteer to participate in the experiment on Relative dynamic and isometric endurance curves for different muscle groups of the upper extremities conducted by Seung Ho Yoon indicates that I understand that all subjects in the project are volunteers, that I can withdraw at any time from the experiment, that I have been or will be informed as to the nature of the experiment, that the data I provide will be anonymous and my identity will not be revealed without my permission, and that my performance in this experiment may be used for additional approved projects. Finally, I shall be given an opportunity to ask questions prior to the start of the experiment and after my participation in complete.

Subject's signature
Appendix D

Reliability of Relative Endurance Measures
Table D-1

ANOVA Summary Tables with Reliability Estimates for the Relative Total Contraction scores of Isometric Contractions

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>1257.48</td>
<td>66.18</td>
<td>20.86**</td>
<td>.91</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>55.22</td>
<td>55.22</td>
<td>17.41**</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>60.28</td>
<td>3.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>1372.97</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>1573.16</td>
<td>82.80</td>
<td>5.74**</td>
<td>.82</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>27.59</td>
<td>27.59</td>
<td>1.91</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>274.06</td>
<td>14.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>1874.81</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>1356.33</td>
<td>71.39</td>
<td>6.96**</td>
<td>.86</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>12.26</td>
<td>12.26</td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>194.82</td>
<td>10.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>1563.41</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>1173.88</td>
<td>61.78</td>
<td>7.70**</td>
<td>.86</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>16.27</td>
<td>16.27</td>
<td>2.03</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>152.47</td>
<td>8.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>1342.62</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p<.05 ** p<.01
Table D-2

ANOVA Summary Tables with Reliability Estimates for the Relative Total Contraction scores of Dynamic Contractions

**Bench Press**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>1829.28</td>
<td>96.28</td>
<td>3.99**</td>
<td>.75</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>15.63</td>
<td>15.63</td>
<td>.65</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>458.88</td>
<td>24.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>2303.79</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Arm Curls**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>2258.33</td>
<td>118.86</td>
<td>5.95**</td>
<td>.83</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>31.49</td>
<td>31.49</td>
<td>1.58</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>379.25</td>
<td>19.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>2669.07</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Shoulder Internal Rotation**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>2031.65</td>
<td>106.93</td>
<td>4.91**</td>
<td>7.7</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>82.92</td>
<td>82.92</td>
<td>3.81**</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>414.03</td>
<td>21.79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>2528.60</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Wrist Flexion**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>571.90</td>
<td>30.10</td>
<td>6.47**</td>
<td>.85</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>1.60</td>
<td>1.60</td>
<td>.34</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>88.40</td>
<td>4.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>661.90</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p<.05    ** p<.01
### Table D-3

**ANOVA Summary Tables with Reliability Estimates for the Relative Final Contraction Scores of Isometric Contractions**

#### Bench Press

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>1249.40</td>
<td>65.76</td>
<td>23.09**</td>
<td>.96</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>4.90</td>
<td>4.90</td>
<td>1.72</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>54.10</td>
<td>2.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>1308.40</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Arm Curls

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>842.55</td>
<td>44.34</td>
<td>8.45**</td>
<td>.87</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>12.21</td>
<td>12.21</td>
<td>2.33*</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>99.70</td>
<td>5.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>954.46</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Shoulder Internal Rotation

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>1167.55</td>
<td>61.45</td>
<td>15.48**</td>
<td>.93</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>6.48</td>
<td>6.48</td>
<td>1.63</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>75.39</td>
<td>3.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>1249.42</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Wrist Flexion

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>915.48</td>
<td>48.18</td>
<td>16.85**</td>
<td>.94</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>7.07</td>
<td>7.07</td>
<td>2.47*</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>54.38</td>
<td>2.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>976.93</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p<.05 ** p<.01
Table D-4

ANOVA Summary Tables with Reliability Estimates for the Relative Final Contraction Scores of Dynamic Contractions

**Bench Press**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>1769.27</td>
<td>93.12</td>
<td>23.01**</td>
<td>.94</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>30.63</td>
<td>30.63</td>
<td>7.57**</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>76.88</td>
<td>4.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>1876.78</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Arm Curls**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>1442.31</td>
<td>75.91</td>
<td>11.15**</td>
<td>.90</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>23.97</td>
<td>23.97</td>
<td>3.52**</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>129.38</td>
<td>6.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>1595.66</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Shoulder Internal Rotation**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>1483.01</td>
<td>78.05</td>
<td>12.73**</td>
<td>.92</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>12.20</td>
<td>12.20</td>
<td>1.99</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>116.53</td>
<td>6.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>1611.74</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Wrist Flexion**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>19</td>
<td>1302.75</td>
<td>68.57</td>
<td>10.05**</td>
<td>.89</td>
</tr>
<tr>
<td>Trials</td>
<td>1</td>
<td>17.49</td>
<td>17.49</td>
<td>2.56*</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>19</td>
<td>129.58</td>
<td>6.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>1449.82</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < .05    ** p < .01
Table D-5

Univariate ANOVA Summary Table for Relative Total Contraction

Dependent Variable: RT

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>PR&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODEL</td>
<td>227</td>
<td>35852.94</td>
<td>157.94</td>
<td>12.88</td>
<td>.0001</td>
</tr>
<tr>
<td>ERROR</td>
<td>220</td>
<td>2698.69</td>
<td>12.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>447</td>
<td>38551.62</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>ANOVA SS</th>
<th>F</th>
<th>PR&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub</td>
<td>55</td>
<td>4585.00</td>
<td>6.80</td>
<td>.0001</td>
</tr>
<tr>
<td>Exer</td>
<td>3</td>
<td>8843.01</td>
<td>240.30</td>
<td>.0001</td>
</tr>
<tr>
<td>Sub*Exer</td>
<td>165</td>
<td>8214.12</td>
<td>4.06</td>
<td>.0001</td>
</tr>
<tr>
<td>Task</td>
<td>1</td>
<td>14118.81</td>
<td>1150.98</td>
<td>.0001</td>
</tr>
<tr>
<td>Exer*Task</td>
<td>3</td>
<td>92.01</td>
<td>2.50</td>
<td>.0604</td>
</tr>
</tbody>
</table>
Table D-6

Univariate ANOVA Summary Table for Relative Final Contraction

Dependent Variable: RF

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>PR&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODEL</td>
<td>227</td>
<td>74026.65</td>
<td>326.11</td>
<td>23.74</td>
<td>.0001</td>
</tr>
<tr>
<td>ERROR</td>
<td>220</td>
<td>3022.08</td>
<td>13.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>447</td>
<td>77048.73</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>ANOVA SS</th>
<th>F</th>
<th>PR&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub</td>
<td>55</td>
<td>4634.10</td>
<td>6.13</td>
<td>.0001</td>
</tr>
<tr>
<td>Exer</td>
<td>3</td>
<td>42532.65</td>
<td>1032.09</td>
<td>.0001</td>
</tr>
<tr>
<td>Sub*Exer</td>
<td>165</td>
<td>10133.48</td>
<td>4.47</td>
<td>.0001</td>
</tr>
<tr>
<td>Task</td>
<td>1</td>
<td>16721.36</td>
<td>1217.27</td>
<td>.0001</td>
</tr>
<tr>
<td>Exer*Task</td>
<td>3</td>
<td>5.06</td>
<td>.12</td>
<td>.9466</td>
</tr>
</tbody>
</table>
Appendix E

Computer Program for the Cybex Instrumentation
P=768: ' CH 0 = TORQUE  CH 1 = ANGLE
20 DIM X%(100),TMR%(5),SC(5):GOSUB 7000 : 'GET TIMING
PARAMETERS
30 CLS:PRINT:PRINT:PRINT
40 PRINT""
43 PRINT"
50 PRINT"
60 PRINT"
63 PRINT"
65 PRINT" FILES "
66 PRINT"
70 PRINT" Q ----- QUIT
73 PRINT"
90 PRINT"
93 PRINT
100 INPUT" CH$"
105 IF CH$="Q" OR CH$="q" THEN 9000
110 IF CH$="C" OR CH$="c" THEN 8000
120 IF CH$="1" THEN 900
130 IF CH$="2" THEN 4000
140 GOTO 30
900 CLS
910 PRINT:PRINT:PRINT
920 PRINT"
925 PRINT"
930 PRINT"
935 PRINT"
940 PRINT"
942 PRINT" SHOULDER "
943 PRINT"
945 PRINT"
950 PRINT"

1 ----- REPETITIONS
2 ----- ISOMETRIC
C ----- CLEAN OUT
Q ----- QUIT

ENTER CHOICE
1 ----- BENCH
2 ----- CURLS
3 ----- FOREARM
4 ----- LEG
Q ----- QUIT
955 PRINT"

" 960 PRINT"
965 PRINT
970 INPUT" ENTER CHOICE ";CH$
975 IF CH$="Q" OR CH$="q" THEN 30
978 E=VAL(CH$)
980 IF CH$="1" THEN F$="BENCH.REP":GOTO 1020
985 IF CH$="2" THEN F$="CURLS.REP":GOTO 1020
990 IF CH$="3" THEN F$="FOREARM.REP":GOTO 1020
993 IF CH$="4" THEN F$="SHOULDER.REP":GOTO 1020
994 IF CH$="5" THEN F$="LEG.REP":GOTO 1020
995 GOTO 900
1020 OPEN F$ FOR APPEND AS #1
1030 C=0 : CLS
1040 INPUT "ENTER NAME OR Q TO QUIT ";NM$
1050 IF NM$="Q" OR NM$="q" THEN 1290
1060 INPUT "ENTER ID # ";ID$
1070 PRINT
1080 INPUT "PRESS ENTER WHEN READY ........ ";ZZ$
1090 PRINT:PRINT:PRINT "PRESS SPACE BAR TO STOP EXERCISE."
1100 C=0
1110 MAX=0:C=C+1:BEEP
1120 FOR I=1 TO TMR%(E)
1130 IF INKEY$=CHR$(32) THEN 1210
1140 OUT P,0:Q=INP(P)
1150 IF Q>MAX THEN MAX=Q
1160 NEXT
1170 MAX=INT(MAX*SC(E))
1180 X%(C)=MAX
1190 PRINT "MAX FOR REP ";C;" --> ";MAX
1200 GOTO 1110
1210 INPUT "DO YOU WANT TO SAVE THIS DATA (Y/N) ";SV$
1220 IF SV$="N" OR SV$="n" THEN 1030
1230 PP$=""
1240 FOR I=1 TO C
1250 PP$=PP$+STR$(X%(I))
1260 NEXT I
1270 PRINT #1,NM$;" ";ID$;" ";PP$
1280 GOTO 1030
1290 CLOSE:GOTO 900
4000 CLS
4010 PRINT:PRINT:PRINT
4020 PRINT"
4025 PRINT"
1       BENCH
2       CURLS
3       FOREARM
4       SHOULDER
5       LEG

Q       QUIT

ENTER CHOICE

;CH$
4075  IF CH$="Q" OR CH$="q" THEN 30
4078  E=VAL(CH$)
4080  IF CH$="1" THEN F$="BENCH.ISO":GOTO 5010
4085  IF CH$="2" THEN F$="CURLS.ISO":GOTO 5010
4090  IF CH$="3" THEN F$="FOREARM.ISO":GOTO 5010
4092  IF CH$="4" THEN F$="SHOULDER.ISO":GOTO 5010
4093  IF CH$="5" THEN F$="LEG.ISO":GOTO 5010
4095  GOTO 4000
5010  TK=1
5020  OPEN F$ FOR APPEND AS #1
5030  C=0 : CLS
5040  INPUT "ENTER NAME OR Q TO QUIT ";NM$
5050  IF NM$="Q" OR NM$="q" THEN 5260
5060  INPUT "ENTER ID # ";ID$
5070  INPUT "PRESS ENTER WHEN READY .............";ZZ$
5077  PRINT:PRINT
5080  PRINT "PRESS SPACE BAR TO STOP EXERCIS ..."
5100  GOSUB 5200
5110  FOR I=1 TO ISOTIME : NEXT I
5115  IF INKEY$=CHR$(32) THEN 5130 ELSE 5100
5130  INPUT"DO YOU WANT TO SAVE THIS DATA (Y/N) ";SV$
5140  IF SV$="n" OR SV$="N" THEN 5030
5150  PP$=""
5160  FOR I=1 TO C
5170    PP$=PP$+STR$(X%(I))
5180  NEXT
5190 PRINT #1,NM$;" ";ID$ ";" ;PP$ :GOTO 5030
5200 MAX=0 : C=C+1
5210 FOR I=1 TO 10 : OUT P,0;K=INP(P)
5220 IF K>MAX THEN MAX=K : NEXT
5230 MAX=INT(MAX*SC(E)):X%(C)=MAX
5240 PRINT "MAX FORCE ---> ">;MAX
5250 RETURN
5260 CLOSE : GOTO 4000
7000 OPEN "PARAM" FOR INPUT AS #2
7005 LINE INPUT #2,DUMB$
7 0 1 0 I N P U T
#2,TMR%(1),TMR%(2),TMR%(3),TMR%(4),TMR%(5),ISOTIME
7012 LINE INPUT #2,DUMB$
7013 INPUT #2,SC%(1),SC%(2),SC%(3),SC%(4),SC%(5)
7020 CLOSE #2
7030 RETURN
8000 CLS
8010 PRINT:PRINT
8020 PRINT" 
8025 PRINT" REP FILES . . .
8030 PRINT" 1 - BENCH
8040 PRINT" 2 - CURLS
8050 PRINT" 3 - FOREARM
8052 PRINT" 4 - SHOULDER
8053 PRINT" 5 - LEG
8055 PRINT" 
8060 PRINT" SO FILES . . .
8070 PRINT" 
8080 PRINT" 6 - BENCH
8090 PRINT" 7 - CURLS
8100 PRINT" 8 - FOREARM
8105 PRINT" 9 - SHOULDER
8107 PRINT" 10 - LEG
8110 PRINT"
"
8125 PRINT"
"
8127 PRINT"
"
99 - ALL FILES

Q - QUIT
Vita

Seung Ho Yoon was born on March 13, 1959 in Seoul, Korea where he grew up attending elementary, junior high, high school, and college. He majored in Physical Education at Sung Kyun Kwan University. Upon graduation with Bachelor's degree in August of 1982, he came to the United States to continue his study and received Master of Science from Eastern Illinois University, Charleston, Illinois in December, 1983.

In January, 1984 Yoon entered the doctoral program at Louisiana State University, Baton Rouge. While pursuing a Doctor of Philosophy in Professional Preparation with a specialization in Measurement and Evaluation and a minor in Experimental Statistics, he was a teaching and research assistant in the School of Health, Physical Education, Recreation, and Dance.

After completing the requirements for the Ph. D. degree, Yoon will work for the Seoul Olympic Organizing Committee.
DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Seung Ho Yoon

Major Field: Physical Education (Measurement)

Title of Dissertation: Relative Isometric and Dynamic Endurance Curves for Different Muscle Groups of the Upper Extremities

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

April 28, 1988