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THE UNIVERSITY OF ALBERTA

TRAINABILITY AND GENERALITY/SPECIFICITY RATIOS OF THE

ABILITY OF GRADE FIVE BOYS TO DEVELOP TORQUE

by

(C) MELVIN ROSS HETHERINGTON

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Trainability and Generality/Specificity Ratios of the Ability of Grade Five Boys to Develop Torque" in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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Date .. May 3, 1971 ......

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External Examiner

ABSTRACT

The primary purpose of this investigation was to determine the effects of eight weeks isometric training on grade five boys. Secondary purposes were to determine the degree of retention of the training effect over a period of ten weeks; to determine if the effects of training were general or specific; and to determine if the capacity to exert muscular force is general or specific.

A specially desinged strain gauge instrument was employed to test the 96 grade five boys in the study before the training program was initiated, after an eight week training period, and after a ten week detraining period. For the training period, the subjects were randomly assigned to four groups. Group one performed nine maximal isometric contractions, held for six seconds each with the elbow at 90 degrees; group two was a treated control, and received a pseudo-ultrasound treatment; group three performed three maximal, six second isometric contractions with the elbow at 60 degrees, 90 degrees and 120 degrees; and group four was a non-treated control group that took the three tests, but did not participate in any training program. The training programs were held twice each week for a period of eight weeks.

Although the total group of subjects obtained significantly higher scores after the training program than before, the experimental groups did not score significantly higher than either the treated control group, or the non-treated control group. Similarly, the total group scored significantly higher after the ten week detraining period than on the pre-test, but the experimental groups did not score significantly higher than either the treated control group or the non-treated control group. The scores for the total group were not significantly different between the post-training and post-detraining tests.

The commonly used squared correlation method of estimating generality and specificity was compared with analysis of variance and principal components analysis techniques. On an analysis of the pre-test raw scores, generality was found to be 1.017 times larger than specificity when the 60 and 90 degree scores were compared, 1.034 times larger when the 60 and 120 degree scores were compared, 3.980 times larger when the 90 and 120 degree scores were compared, and 1.671 times larger when scores at all three angles were compared together using the squared correlation method. Larger figures of 2.286, 2.079, 7.521, and 2.843 respectively were obtained when analysis of variance techniques were utilized to partition the total variance. Principal components analysis further

indicated that the squared correlation underestimates the true generality factor. Analysis of the same data produced a first principal component or generality factor of 82.53 percent. The conclusion was drawn that the capacity to exert an elbow flexion muscular force is more general than specific between the 60, 90, and 120 degree angles, and for this example, the squared correlation method of calculating generality and specificity underestimated the generality/specificity ratio.

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INTRODUCTION

The Problem

Statement of the Problem. Investigations concerning
the development of the ability to exert muscular forces
have been conducted mostly with college-aged subjects.
With few exceptions (4, 6, 7), these studies have consis-
tently demonstrated that training of subjects of this age
group by isometric techniques will elicit a training
effect resulting in a greater ability to exert muscular
force after training than before. Because of these findings,
and because little empirical evidence is available, the
usual assumption is that younger children will respond
similarly to training. However, since young boys go through
marked changes at the time of puberty, which involve the
muscular system as well as other systems, there is a
possibility that the response to training before and after
this stage of maturation will not be identical. Since the
literature is almost void of information, which would shed
light on this question, the present study will investigate
the effects of eight weeks of isometric training on the
ability of grade five boys to develop torque.

Subproblems. Controversy has arisen in recent years concerning the specificity or generality of training effects from isometric exercises. Some investigators (3, 5) have found that isometric training causes positive effects only at the point at which the training was administered, whereas others (1, 2, 9, 10) have found that the training caused an effect which was general throughout the whole range of movement of the joint. Because this question is presently unresolved, the data from the present study will be analyzed to determine if any effects of training are specific or general.

The second subproblem is closely allied to the first. The pre-test data will be analyzed to determine if the scores at 60 degrees, 90 degrees and 120 degrees are related to each other, or if the scores from angle to angle tend to be specific.

The third subproblem of this study is concerned with the retention of the training effects from isometric exercises. Inclusion of training programs in the school physical education programs are of little value if the students regress immediately after the training ceases. Similarly, for athletes to involve themselves in programs for one or two months would be ineffective if the benefits to be derived were only of a short-term nature. On the

other hand, if the effects of training are retained, this may be a very worthwhile portion of the program both for athletes and for physical education classes. Since the length of the retention of a training effect after isometric training is not known, the effects of ten weeks detraining will be investigated in this study.

Hypotheses to be Tested. Four hypotheses will be tested in this study.

1. Isometric training practiced twice per week for eight weeks will not have a significant effect on the ability of grade five boys to develop torque.

2. Effects of training will be general throughout the range of movement, and not specific to the angle at which the training is administered.

3. The changes in ability to develop torque will not be different over a period of ten weeks for a group having just finished isometric training, and a control group.

4. The ability to develop torque is general throughout the range of motion, and not specific to any angle.

Definition

The ability to develop torque is composed of the sum of the perpendicular components of the forces exerted by all muscles assisting in the action being tested, multiplied

by the respective distance of each insertion from the
fulcrum.

The Concept of Strength

Much confusion exists concerning the meaning of the
work "strength." Strength has been defined as the force
which can be exerted by a muscle. On the other hand,
strength has been defined as the amount of force which may
be generated against a measuring instrument. Although
these sound very similar, the differences will be described
below. Together with these problems, we have also the
psychological implications. A person may have a difficult
time lifting a weight under ordinary circumstances, but
under the proper conditions of motivation, such as fear
for example, this person is in fact capable of lifting
a much larger weight. This does not mean that the person
has become stronger, but more motivated. Also, mere
practice of exerting force in a particular fashion may
result in a better performance. The person may not have
increased in strength, but only in skill.

An example will illustrate the differences between
the force generated by the muscle group, and the force
which would be exerted on a measuring instrument. Con-
sider the elbow flexion movement. Figure 1 is a dia-
grammatic representation of the torques acting about
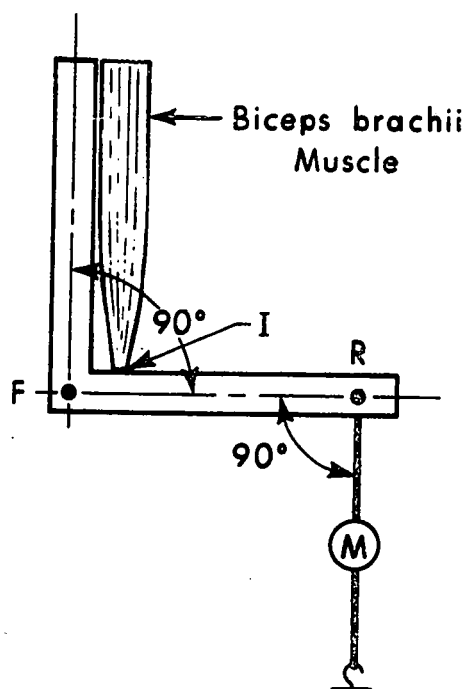
FIGURE 1. TORQUES ACTING ABOUT THE ELBOW JOINT

the elbow joint. For purposes of discussion, let us assume
that all of the force for elbow flexion comes from the bi-
ceps brachii muscle. F is the fulcrum of the system. I
is the insertion of the biceps brachii muscle, and R is
the position on the forearm, where the resistance is at-
tached. M is the measuring instrument. The force arm will
be the difference between I and F and the resistance arm
will be the difference between R and F. Let the force arm
equal one inch in length, and let the resistance arm equal
six inches in length, and assume a force of 50 pounds is re-
corded at M.

$$\text{Since } F \times FA = R \times RA \text{ (8; p. 126)}$$
$$F \times 1 \text{ inch} = 50 \times 6 \text{ inches}$$
$$\text{and } F = 300 \text{ pounds}$$

Therefore, in this example, although only 50 pounds
are recorded on the instrument, 300 pounds of force would
have to be supplied by the biceps brachii muscle. Quite
obviously, there is a large difference between the mus-
cular force exerted, and the force recorded. This example
is over simplified since all of the force for elbow flexion
does not come exclusively from the biceps brachii muscle.
The brachioradialis, brachialis, pronator teres, flexor
carpi radialis, and flexor carpi ulnaris all contribute,
and the contribution of these muscles is further compli-
cated by the fact that their angle of insertion is not at
a right angle. However, the simplified example does il-

Consider if one were to slide the point R toward the elbow one inch. If the force from the muscle was still 300 pounds, the recorded force would now be 60 pounds. Conversely, if the resistance was moved one inch towards the wrist, the recorded force would only be 42.86 pounds. The original score of 50 pounds then, is of very little meaning in relation to the force exerted by the muscle, unless the length of the resistance arm is known.

Changes in scores can occur in a similar fashion by changing the angle of the joint. Figure 2 is an example of exactly the same system as figure 1, except that the angle of the elbow is changed from 90 degrees to 120 degrees. Since the effective force cuasing rotation around the fulcrum is only the perpendicular component (8; p. 120), the force causing rotation would only be:

$$F_1 = 300 \times Cosine\ 120 = 300 \times 0.866 = 259.8$$
$$259.8 \times 1\ inch = 6\ inches \times R$$
$$R = 43.3$$

These examples make it very clear that the scores received on a measuring instrument in no way resemble the actual capacity of the muscle to exert a force against the bone to which it is inserted. The examples also indicate that the procedure employed to measure the forces has a great bearing on the scores received, and that scores are of very little value for comparison purposes,
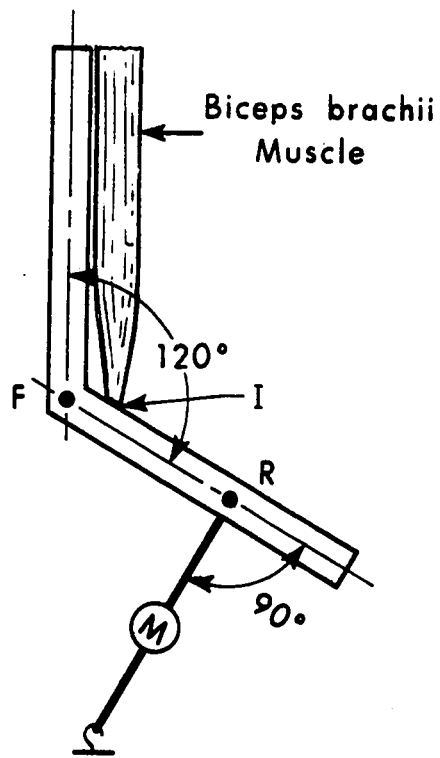
FIGURE 2. TORQUES ACTING ABOUT THE ELBOW JOINT
WITH THE ELBOW AT 120 DEGREES

except when compared with the scores collected in exactly the same fashion.

The scores received in the measurement of muscular force are resultants of five factors. These are the forces generated by the muscles, the angle of insertion of the muscles, the distance of the insertion of the muscles from the fulcrum, the length of the resistance arm, and the angle of the joint positioned for the test. The first three of these may be thought of as the ability the subject has as required for this test. The force generated by the muscle is based on how many muscular fibres are actually contracted, the nerve supply to the muscles, the capillary system, how motivated the subject is to score well, and other psychological and physiological factors. Some individuals may have muscles which insert more perpendicularly than others, and the distance between these insertions and the fulcrum may vary from individual to individual. However, to attempt to actually find the exact force generated by each muscle and the resultant contribution to the total torque would be impossible with the testing procedures presently available.

In view of the preceding discussion, no attempt will be made to define strength, or to measure strength. Instead, the ability to develop torque will be studied. Since F x FA = R x RA, the sum of the perpendicular

components of the forces times their respective force arms will be equal to the resistance measured multiplied by the length of the resistance arm. Since both the resistance and the resistance arm can be measured, a measure of ability to develop torque may be calculated. If a subject obtains a higher score on a post-test than on a pre-test, a greater ability to develop torque has been demonstrated. This definition avoids the necessity for stating that the person has become stronger, or has gained in strength.

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CHAPTER II

REVIEW OF RELATED LITERATURE

Strength has been the topic of many research investigations. Several excellent reviews of these investigations have already been compiled, and the results of these reviews are included rather than an exhaustive review of individual studies. The word "strength" will be used in this chapter as it has been used in the articles reviewed, bearing in mind the disparities of meaning associated with the word which were discussed in Chapter I.

The chapter is divided into six sections. Those sections are: muscular development by isometric techniques; muscular development in young boys; retention of training effects; specificity of muscular development; apparatus for measurement of muscular forces; and reliability of physical performance measurement.

Muscular Development by Isometric Techniques

Steinhaus (78) made an historical review of research training for the development of muscular strength in 1955. In the review, Steinhaus stated that as early as 1897, Morpurgo ran dogs, and measured 53 percent

and 55 percent increases in the cross-sectional area of
the sartorious muscle of two dogs. The increased cross-
sectional area was attributed to increased size of the
muscle fibers, and rot to the addition of more fibers.
Steinhaus credits Seibert with being the first to assert
the overload principle in 1925. The overload principle
states that strength is developed only by exerting forces
of high intensity, and that mere replication of an exer-
cise at a low resistance below a minimum threshold will
not elicit a training effect. After the work of Seibert,
most published research on strength made use of the over-
load principle, and isotonic training techniques were
used such as the progressive resistance exercises tested
and described by DeLorme and Watkins. It was not until
Muller started to publish his work in 1953, that attention
turned to isometric training.

Darcus (23) in 1956 evaluated the methods of in-
creasing muscle strength, and stated that there was no
generally accepted method of muscle training up to that
time. Darcus also stated that the size of muscle fibers
can be increased by appropriate exercises, but a corres-
ponding increase in strength is not guaranteed. There
are many other factors involved in muscle function such as
inhibition for example. It may be that training reduces
inhibitory impulses, and inhibition is just as much a part

of function as excitation. Darcus concludes that there is
no evidence which shows that isometrics are better than
isotonics, or that isotonics are better than isometrics in
the development of strength, and it is still only possible
to hypothesize as to the optimum method of improving mus-
cular strength.

In 1958, Lawther (53) summarized the research con-
ducted at Pennsylvania State University from 1952 to 1958
on the topic of strength development. Four different
methods of training were shown to produce significant
training effects, but no differences were found between
the methods. Isometric training when compared with iso-
tonic training was neither superior nor inferior, although
the isometric training was accomplished in a much shorter
amount of time per training session. Lawther stated that
although strength training produced many favourable
changes in group means, almost every group contained in-
dividuals in whom the reverse effect was found, and that
the advisability of prescribing any procedure for an in-
dividual is of doubtful merit except as a temporary mea-
sure. Lawther also cautions that strength research is
somewhat subjective by its nature since scores are depen-
dent upon the subject's degree of motivation, his back-
ground of punishing experience, and his willingness to en-
dure the pain of all-out effort.

In 1959, Clarke (16) reviewed the research that had been conducted on the development of volitional muscle strength. Clarke felt that since the majority of the studies had been conducted over periods of from five, six or eight weeks, very little had been learned that could differentiate a specific type of program as being superior to the others. The following conclusions were drawn:

(a) Both isometric and isotonic exercises develop strength. There is no evidence which shows that one is clearly better than the other.

(b) No study has verified that strength gains of five percent per week can be obtained as Hettinger and Muller had stated in their first publications. A more realistic figure is two percent per week.

(c) Isotonics are more favourable in the development of endurance, and in the retention of strength.

Hettinger (40), in 1961, reviewed 204 experiments conducted at the Max Plank Institute for Arbeitsphysiology in Dortmund, Germany by Hettinger and Muller. Some of the major conclusions were:

(a) Increase in muscle strength occurs only peripherally, does not involve a crossing phenomena in the cerebral center, and results only from a stimulus of sufficient degree of intensity.

(b) The maximum obtainable training effect is about

three to four per cent per week. The average gains of the elbow flexors were found to be between one and one half and two per cent per week.

(c) Maximum improvement in the strength of a muscle group being trained can be obtained by giving one maximum voluntary isometric muscle contraction against a resistance for from one to two seconds.

A review of the research on isotonic and isometric progressive resistance exercises was published by Rasch (69) in 1961. Rasch concluded from the review that strength can be developed by either isotonic or isometric exercises, but that the cause of the development was still in dispute. Tension appeared to stimulate strength development, and increasing tension more frequently during the training program increased the effect of training. Isometrics may be beneficial because tension is greater in zero velocity contractions.

Howell (43) reviewed 97 studies in 1962 on the topic of isometric strength and endurance, and drew the following conclusions concerning training:

(a) There is no basic agreement as to the number of contractions necessary to elicit a training effect. There is also no agreement that daily contractions of six seconds are best, or that contractions of two-thirds maximum are optimum for developing strength.

(b) There is little difference between isotonic and isometric programs in the development of strength.

(c) Past studies have not controlled variables adequately which would have contributed to experimental error.

Royce (73) in 1964 has made a plea for re-evaluation of isometric methods. After extensive testing, the figure of five per cent per week expected increase from isometric training has been considerably decreased. Hettinger lowered the figure to 3.3 per cent and later to 1.8 per cent. Royce discusses an experiment by Muller and Rohmert which was conducted in view of the conflicting results of improvement in strength reported. The authors stated that the rate of increase became smaller, the closer the subject came to the theoretical asymptote. This asymptote was called the "Endkraft" which is the potential maximal strength plateau related to the training period. Six conclusions were drawn:

(a) The larger the ratio between the static load and the initial maximal force, the greater the rate of increase of strength.

(b) The smaller the ration between initial maximal force and the estimated "Endkraft," the greater the rate of increase in strength.

(c) The "Endkraft" and the rate of strength increase

become larger when the duration of the maximal static contraction is changed from one to five seconds.

(d) Contractions below a certain force have no training effect.

(e) Repeating a short maximal contraction several times a day does not increase the training effect.

(f) A single maximal training contraction acts as a gradually diminishing stimulus for strength increase for a period of seven days. Royce suggests that since it is not possible to predict if athletes who are near this "Endkraft" can increase their static strength, or if an increase in static strength will improve athletic performance, that much is still to be learned, and that new design of experiments is necessary, instead of replication of older experiments.

Berger (8) has drawn conclusions from the results of extensive experimentation with isometric and isotonic training programs. These conclusions are:

(a) Submaximal training of two-thirds maximum twice weekly, and maximum loads once weekly will result in as much improvement as training maximally three times weekly.

(b) Submaximal training three times per week with loads less than two-thirds maximal will not increase strength.

(c) When training three times per week, the optimum

load lies between 3 R. M. and 9 R. M.

(d) Training once weekly with 1 R. M. for one set will increase strength significantly after the first week of training, and each week up to at least the sixth week.

(e) Weight training with the 10 R. M. for three sets, twice daily, is just as effective as training the same way three times weekly.

(f) The optimum number of training days per week is not known, but training four or five times per week may not be as effective as training two or three times per week.

(g) It is not known if the conclusions cited above can be applied to prepubescent subjects.

Ball et al. (4), Belka (7), Bergeron (10), Chui (12), Coleman (19), Cotton (20), Macintosh (58), McGlynn (59, 60), Mendryk (63), Meyers (64), Morehouse (66) and Whitley and Smith (85) in recent studies have all administered isometric training under experimental conditions. The number of training periods ranged from 18 to 40, and each utilized high school or college men as subjects. Twelve of these studies reported statistically significant increases in strength. Meyers (64) did not find significant improvement over the control group, and McGlynn (59) obtained an increase followed by a decrease with subsequent training.

Summary. Research on isometric training received
its major impetus after the Hettinger and Muller publica-
tions in 1953. Research has not shown that isometrics
are superior to isotonics, or that isotonics are superior
to isometrics in the development of strength. The optimum
number of contractions to employ when isometrically train-
ing is still unknown. Positive results have been achieved
with from one to two seconds to three contractions held
for six to ten seconds. The optimum number of training
programs per week is also unknown. Common practice is to
train daily for at least five days per week, but some
studies have shown that training four or five days per
week may not be as beneficial as training two or three.
Early studies reported gains in strength of five per cent
per week, but two per cent per week is a more realistic
figure, with some studies showing as low as one to one and
one-half per cent per week.

Research has tended to report the changes in group
means, and consequently disregard individual differences in
response to training. Individuals differ in their response
to training because of such factors as their present level
of strength as compared with their potential, and motiva-
tion. Inhibition may be a significant factor influencing
scores, so individuals may score higher after training be-
cause of decreased inhibitory impulses, and not because of

increased muscular capacity. However, regardless of the cause, significant increases in group means have been consistently shown with a variety of programs of isometric training, and with either high school or college men as subjects.

Muscular Development in Young Boys

The majority of the research which has been conducted on the topic of muscular development in young boys has been of the normative type, as opposed to training type studies. The Medford, Oregon boys growth study (17) is an example in which strength was measured along with maturity factors, physique type, body size measures, motor tests, scholastic aptitude and achievement, psycho-personal adjustment, and interests on a ten year longitudinal basis. Over 60 graduate research projects have used the data from this study, and over 30 of these utilize strength scores collected in this investigation. This research provides fundamental knowledge on the acquisition of strength from the ages of seven to eighteen, but was not designed to determine the effects of training.

Adamson (1) isometrically trained one group of boys whose average age was eleven and one-half years, five days per week for four weeks, and another group of

the same age isotonically for the same period of time.
Both groups gained significantly more than a control
group in back extension strength, but only the group
trained isometrically was superior to the control group in
elbow flexion after training. An eight week detraining
period resulted in the two experimental groups decreasing
somewhat in elbow flexion strength, whereas the control
group increased, with the result that the three groups
were approximately equated as they had been when the ex-
periment was begun. On the back extension test, the group
means for the experimental groups increased on each suc-
cessive test, but the differences between the control
group and the experimental groups were no longer signifi-
cant after the detraining period.

Bready (11) conducted a training program on
seventh grade boys. The boys exercised for six weeks
doing a phasic exercise with the right elbow flexors.
Significant increases were recorded in both strength and
endurance, and a six week detraining period did not pro-
duce any further change in either strength or endurance.

Fifth grade boys were given isometric training
by Hergert (39). The subjects trained each school day
for 30 days during the first five minutes of their phy-
sical education period. The experimental group scored

significantly higher on the post-test than did the control group.

Schweid et al. (76) used first grade and third grade boys as subjects. The training was composed of a combination of isometric and isotonic training. The subjects performed a knee extension exercise followed by holding the knee extended against the resistance for a period of five seconds. The experimental groups improved significantly more than their corresponding control groups when tested in a similar fashion to the training procedure. Schweid et al. did not state whether the significantly increased scores were attributed to increase in strength, or increase in endurance.

Hutinger (46) exercised third grade boys and girls ranging in age from eight years to ten years and eight months, on a horizontal ladder. Significant gains were made in push-ups, pull-ups, and pushing and pulling strength, but not in right and left grip strength. The failure to improve significantly in grip strength was attributed to the fact that these muscle groups were not actively exercised.

Hettinger (40) conducted a series of studies on subjects ranging in age from six to sixty-five years of age. Men were found to show the higher trainability be-

tween twenty and thirty years of age. Boys of ten years of age were found to have about 60 per cent as much trainability as men from twenty to thirty. Between ten and twenty years of age, the trainability was found to rise sharply.

Summary. Although many research workers have measured muscular forces of young boys, very few have conducted training type studies on boys of prepubetal age. Research that has been conducted on young boys has produced the following results.

1. Young boys do not respond to training to the same degree as men from twenty to thirty years of age.

2. Training effects that do occur are not sustained over a period of time.

3. Training programs designed to develop endurance have been more successful than those designed to develop the ability to exert maximum force.

Retention of Training Effects

Although numerous studies have demonstrated significant training effects, very few follow-up studies have been conducted to determine the degree of retention of the training effect. Hettinger (40) found that the training effect retention time was dependent upon the length of the training period. If the increase in strength had been acquired over a long period of time, the decrease in strength

was gradual. If the strength had been acquired quickly, decrease tended to be more rapid. The training effect could be completely retained by administering one training stimuli every two weeks after training, and the retention time could be doubled by giving one training stimuli every six weeks. Hettinger's results must be viewed with some caution, since the studies were conducted with very few subjects.

Hislop (41) studied the post-training responses of 19 of 91 subjects. Subjects were retested at intermittent periods for a period of up to one year. No significant drop-off in maximum strength was observed, and a decrease of one per cent was the greatest change observed. Retention of the training effect was attributed in part, to the functional organization of the muscular response, rather than to changes that are limited to the muscles. This functional organization was termed "motor learning."

Lyne (57) trained 46 subjects three times per week for eight weeks. After the training period, the subjects either desisted from training or trained once per week, once every two weeks, or once every three weeks. The group which desisted from training declined significantly in strength, those training once per week made significant increases, whereas those training only once every two or

three weeks did not either significantly improve or decline.

An eight week period to test strength maintenance was conducted by Morehouse (66) after nine weeks of training. Significant decreases in strength were found after a period of eight weeks, but the difference in the amount of loss between the first four weeks and the second four weeks was not significant. Those who trained at 50 per cent intensity during the maintenance phase incurred more loss than those who trained at 100 per cent intensity. However, varying the frequency of training from twice per week to only once every two weeks did not effect the amount of strength loss.

Adamson (1) trained one group of eleven year old boys isometrically, and another isotonically. Both of these training programs resulted in gains in strength that were significantly higher than a control group. However, a retest conducted eight weeks after the completion of the training program revealed that the groups were approximately equated, as they had been when the experiment was begun. Although the training had caused a temporary increase, the benefits were dissipated by the time eight weeks had elapsed.

Summary. Very few training studies have tested
the retention of the training effects. Of the studies
reviewed, only one study reported no decline in the
training effect when no post-training stimuli were admin-
istered (41). This retention was attributed, in part,
to motor learning. Two other studies (57, 1) reported
significant decreases in strength after the training pro-
gram, when no stimuli was administered during the detrain-
ing period. Groups which trained once every two weeks
after the training period were successful in retaining
the training effect (40, 57, 66), as were those which
trained only once every three weeks (57). Hettinger (40)
reported that the rate of strength loss was proportional
to the length of time the training program was in effect,
and also that the time taken to lose the training effect
can be doubled with one training stimuli every six weeks.

Specificity of Muscular Development

A theory of neuromotor specificity has been pro-
posed by Henry (29). A paper on coordination and motor
learning disturbed many who had traditionally believed
in a concept of general motor ability, general coordina-
tion, or general athletic ability. Henry (29) stated that
"coordinations are highly specific - it is largely a matter
of chance whether an individual who is highly coordinated

in one type of performance will be well or poorly coordinated in another." Since 1956, Henry and co-workers (18, 30, 32, 35, 36, 37, 38, 55, 56, 62, 63) have tested the relationship between a variety of performance variables, and shown that the relationship that does exist between two types of performance is very low. Reaction time has been compared to movement time, and one type of movement has been compared to another (62); the speed of one arm has been compared to the speed of another (55); static strength has been compared to speed of movement (18); and development of static strength has been compared to changes in speed of movement (63) to examine the degree of relationship between these variables. In all of these cases the correlations have been relatively low, and the majority of investigators have concluded that these performance variables are virtually uncorrelated. With regards to static strength and speed of movement, Henry (30) said that the relationship is "too small to be of practical importance."

Because such a high degree of specificity has been found in these variables, some investigators (7, 10, 25, 54, 74, 84) have hypothesized that the ability to exert a static force is not general throughout the entire range of movement, and that it may be specific to the joint angle at which the limb was exercised. Logan (54) applied resistance at different angles during knee extension iso-

tonic training. The results indicated that strength is gained at a point in the range of motion where the greatest resistance was applied.

Since Logan (54) used isotonic training methods, Gardner (25) elected to investigate the same problem with isometric training, because of the difficulty of drawing accurate conclusions relative to the specific nature of strength gains with isotonic methods. Gardner trained his subjects at only one angle, and then tested them at three angles. No significant improvements were acquired at angles other than the ones at which the subjects were trained, so the author concluded that strength changes from isometric training were quite specific.

Richardson (71) investigated Gardner's findings as a sub-problem in a study on high school students. The subjects were trained at 90 degrees, 135 degrees, and 165 degrees and took the tests at 115 degrees and 135 degrees. Although the isometric group did not train at 115 degrees, they showed significant improvement at this angle.

Belka (7) obtained results in agreement with Richardson. Specificity was not found to be as pronounced as reported by other investigators. Training isometrically at the testing angles for wrist flexion did not improve subjects more than groups trained dynamically.

The effects of static strength training at various positions was studied by Bergeron (10). One group of subjects trained isometrically in a supine press exercise with the arms in an extended position. The second group trained with their arms flexed, while a third group trained isotonically, doing a supine press exercise through a full range of movement from flexed to extended positions. All three groups gained significantly in strength when the arms were flexed, and when they were extended, and no differences were found between any of the experimental groups. The results did not show that isometric strength gains are specific to the angle at which the joint is exercised.

Whitley (84) studied a closely related problem by investigating to see if gains in strength would be equal throughout the range of movement. Subjects were trained in a horizontal arm movement, at angles of 0 degrees, 12 degrees, 24 degrees, 36 degrees, 48 degrees and 60 degrees statically, and another group dynamically through the same angles. Both groups gained significantly at all of the angles tested, with the one exception being that the group trained dynamically did not significantly improve at the 12 degree angle. Whitley concluded that strength gain is generally transferred from pre- to post-training performance.

Summary. Of the studies reviewed, only Logan (54), and Gardner (25) have shown that effects of training are specific to the angle at which the training actually occurred. Richardson (71), Belka (7), Bergeron (10), and Whitley (84) found that the training effect was not specific to a certain point within the range of motion. Because of these conflicting results, the question of the specificity of strength training is unresolved.

Apparatus for Measurement of Muscular Forces

Hunsicker and Donnelly (45) made an historical review of instrumentation which has been used to measure strength. They have reviewed the initial development of the spring steel dynamometer which was first built in 1807; a mercurial dynamometer developed by Kellogg which was capable of measuring 22 muscle groups; a pneumatic dynamometer for measuring grip strength; the ergograph originated by Mosso and improved by Kelso and Hellebrandt; the tensiometer introduced by Clarke; and the strain guages which have most recently been used in strength measurement. Hunsicker and Donnelly state that physical educators have generally used spring steel dynamometers of the type developed by Sargent. Psychologists have preferred the Smedley hand dynamometer, and orthopedists and physical therapists have most often used Martin's spring balance

apparatus which measures breaking strength. Breaking strength is the maximum force recorded in an instrument before the resistance offered by the subject is overcome. The Kellogg mercurial dynamometer, although versatile, was found to be too cumbersome and too expensive. The inadequacy of the pneumatic dynamometer was that it could be used only to measure grip strength. Strain guages have been introduced partly because they make it possible to record the force over a period of time, and not just the peak force.

Daniels, Williams, and Worthingham (21) reviewed muscle testing techniques used in connection with rehabilitation of paralyzed patients since 1900. Lovett first used gravity tests in his office gymnasium in 1912. Martin introduced his spring balance test in 1915 in collaboration with Lovett. A sling was fastened to the extremity with the pull at right angles to the long axis of the limb. The spring balance was held by an assistant. These authors summarized by stating that although modifications have been forthcoming, the use of gravity and resistance still remain the basis for manual muscle testing.

Studies Using Various Instruments

The universal dynamometer designed by Kellogg has been used by Wendler (83). Contrary to Hunsicker and

Donnelly (45), Wendler believed that the advantage of this instrument was its inexpensive nature. Wendler statistically analyzed a large battery of strength measurements in order to construct a short battery of tests for men and women that could all be measured with the same piece of apparatus.

Newman (67) descirbed a myometer used for measuring breaking strength. A small compact instrument that fits easily into the tester's hand was pushed against the limb of the subject. The subject resisted as strongly as possible, until the force was finally overcome by the tester pushing on the myometer. The instrument was hydraulic, and the pressure was indicated on a dial, with a pointer stopping at the maximum reading. Newman felt that the advantages of his myometer were compactness, a weight of less than one pound, and the requirement of no electrical or mechanical connections. A major limitation of the device was that it measured forces only up to 60 pounds, so had limited versatility. However, it was very suitable for measuring the strength of fingers, and the wrist.

Dynamometers for measuring finger strength have been described by Rudd (74), and by Tarbell (79). Tarbell fabricated his instrument out of a Sphygmomanometer. A lever pressed down on the inflated cuff which normally goes around the arm, and the pressure on the cuff caused

an increase in the column of mercury. The calibration proved to be linear, and Tarbell stated that patients were motivated, who were too weak after paralysis to use a regular hand dynamometer. Rudd's dynamometer was made from an obstetrical home baby scale. According to Rudd, the instrument was sufficiently accurate for practical measurement, and also could be used for providing a means of mild progressive resistance exercises to injured hands capable of little activity.

A manuometer push apparatus was described by Meyers and Piscopo (65). The subject stood facing this instrument which stood as high as his sternum and pushed against the apparatus with his arms in a horizontal position. The idea of this apparatus was to measure push-up strength, but had the disadvantage of having the subject in a very unstable position.

The tensiometer has been the most frequently used instrument for measuring strength during the past twenty-five years. The tensiometer was adapted for strength measurement by Clarke (13). When a cable which passes over a riser and under a sector on each side is pulled taut, the tension is recorded on a dial. The instrument is adaptable to almost any testing condition required for strength testing, and is used repeatedly in connection with the battery of test items which have also been developed

by Clarke (14). An example of the extensive use of this instrument was in the ten year longitudinal Medford Growth Study (17), in which thousands of strength measurements were taken.

There has been a recent trend towards the use of strain gauge instruments to measure muscular forces. Although the cable-tensiometer method remains very popular, Asa (3), Beasley (6), Belka (7), Darcus (22), Hansen (26), Hislop et al. (42), McGlynn (59, 60), C. Morehouse (66), Ralston et al. (68), Rasch and Morehouse (70), Richardson (71), Salter and Darcus (75), Singh and Karpovich (77), Tuttle et al. (80, 81) and Wakim et al. (82), have all employed strain gauge instruments.

Beasley (6) selected the strain gauge because it met his criteria of having a large range; fast response time; a graphic output; light in weight; and stable in calibration. A load cell was incorporated into a myodynagraph which also included the recording system.

Hislop et al. (42) described an instrument which was supported as a cantilever. The instrument was described as having the advantages of simplicity of operation and design; accuracy; durability; and inexpensiveness.

Singh and Karpovich (77) have designed a strain gauge dynamometer that will measure both isometric and iso-

tonic strength. The strain gauge instrument was found to be ideal for this purpose since it was possible to record forces for a period of time during the isotonic movement, instead of only the maximum force applied.

Description of instruments to measure grip strength, and back and leg strength and endurance have been presented by Tuttle (80,81). Tuttle explained that the principles of measurement used for grip strength, and back and leg strength could be applied to the testing of any muscle groups. Hansen (26) employed an adaptation of Tuttle's instrument in order to measure elbow strength.

<u>Comparison of Different Testing Instruments</u>. Wakim (82) evaluated different instruments of muscle testing in 1950. The weaknesses of the spring scale were said to be the high internal resistance, the changing sensitivity of spring systems, and the inability to record maximal contractions of the large muscle groups. The Newman myometer was found to have the value of being compact, but had the disadvantage of the force being applied by the investigator, while the subject merely tried to resist the force applied by the tester. The Clarke tensiometer was compared with Wakim's aluminum ring strain gauge instrument. Simultaneous readings were taken with the instruments, while measuring right forearm flexion. The average force recorded by the strain gauge instrument was 61.1 pounds, while the tensio-

meter recorded an average of 57.0 pounds. Both were calibrated identically before the experiment, so the differences in scores were attributed to friction within the tensiometer.

In 1954, Clarke (15) conducted a comparable experiment to Wakim in order to compare the objectivity of the spring scale, the Newman myometer, the Wakim-Porter strain gauge, and the Clarke tensiometer. Clarke found the tensiometer to have the greatest precision for all the strength tests, and was also the most stable and most generally useful. The strain gauge was generally more sensitive for the smaller muscle groups, but not as sensitive for the larger muscle groups. The objectivity coefficients of the strain gauge compared well with the tensiometer but the strain gauge was found to become distorted with use, was slow to return to its original shape, and was sensitive to changes in room temperature. The capacity of the spring scale was only 100 pounds, so the instrument could be used for only two of the six tests used in the study. The objectivity coefficients were .91 and .97 for these two tests, but the spring scale has the fault of having some movement under tension which causes the joint angles to change, and effect the magnitude of the scores. The Newman myometer was capable of recording scores only up to 60 pounds, required experienced testers, and mean scores were found to be lower than with the tensio-

meter.

Meyers and Piscopo (65) compared the manuometer
with the tensiometer. The reliability of the tensiometer
on the 12 subjects ranged from .96 to .98. For the eleven
subjects tested on the manuometer, the reliability coeffi-
cients ranged from .83 to .91. It was concluded that the
tensiometer was more reliable, and that there was a learning
factor with the manuometer due to the higher scores recorded
on the second and third days compared to the first. Another
reason for the superior reliability of the tensiometer was
attributed to the fact that it was possible to position the
subject in a more stable position.

Summary. Varieties of apparatus for muscle testing
have been in existence since at least the early 1800's.
Through the years, various investigators have utilized
spring steel dynamometers, mercurial dynamometers, pneuma-
tic dynamometers for measuring grip strength, Smedley hand
dynamometers, Martin's spring balances, Newman myometers,
and push manuometers. These have been generally replaced
in recent years by tensiometers and strain guage instruments.
The tensiometer has the advantage of being light in weight,
extremely versatile, simple to operate, and sufficiently
reliable and objective. The strain guage instruments have
the disadvantage of being somewhat more difficult to operate
since they require an electrical power supply, and an elec-

trical recorder, and also some of these instruments are not adaptable to a large variety of testing situations. They have the advantages of providing a permanent recording, of being linear in calibration, and of being satisfactorily reliable.

Reliability of Physical Performance Measurement

Research workers have published several informative articles on the subject of reliability of measurement since 1958 (2, 5, 24, 31, 32, 47, 48, 49, 50, 51, 52). These articles serve to point out the various sources of unreliability in measurement of performance variables in physical education research, and also to point out some of the shortcomings of methods which have been traditionally used to estimate reliability.

Feldt and McKee (24) have discussed the split-halves and test-retest techniques, and compared them with analysis of variance techniques. The true score is defined as the mean of an hypothetical infinite series of measurements on the subject. The obtained score is equal to the true score plus the error score, and the reliability is equal to the variance of the true scores divided by the variance of the obtained scores. The test-retest method assigns day-to-day fluctuations in scores to error variance. In the split-half method, all scores are obtained on the

same day, so these fluctuations in scores are assigned to the true score. Feldt and McKee state that the assignment of these score fluctuations is to either error variance or to true score variance without enough careful thought or understanding by many experimenters. Feldt and McKee therefore conclude that analysis of variance techniques are more efficient in the estimation of the ratio of true variance to obtained variance, for the following reasons:

1. Definition of error factors can be explicitly and unambiguously stated.

2. Estimations can be made as to the number of trials per period which are needed to bring the reliability up to a desired level.

3. Approximations may be made of the reliability of a few trials as compared to a larger number.

4. It is flexible in that it allows the experimenter to calculate the reliability with the error classified under different headings for comparative purposes.

Kroll has written extensively on the topic of reliability and specifically how reliability concepts can be applied to research involving isometric strength measurements (47, 48, 49, 50, 51, 52). While generally agreeing with Feldt and McKee (24) that the analysis of variance method, or intraclass method, is superior in most cases because it differentiates between possible sources of error,

Kroll has pointed out some characteristics which must be understood if analysis of variance is to be used to estimate reliability. These are:

1. The intraclass correlation method is sensitive to differences in means and variances. The product moment correlation is not.

2. The product moment correlation and intraclass correlation do not approximate equivalent things. Although both have the same denominator, the product moment correlation has an estimate of covariance in the numerator, while the intraclass correlation has an estimate of the variance among class means in the numerator. Therefore, the former is bivariate, the latter is univariate, and the two are not equivalent logically, although they may often be similar numerically.

3. The intraclass correlation is not normally distributed, but negatively skewed.

Use of the intraclass method was illustrated in an experiment by Kroll (47) on wrist flexor strength. The subject had five trials of testing on three consecutive days. The reliability was 0.93, but observation of the data indicated that there was both a day-to-day effect and a between trial effect, so Kroll decided that this was not an adequate measurement schedule for reliability. In another experiment conducted by Kroll (49), reliabilities of 0.91,

0.99 and 0.97 were found when subjects were pre-tested and
then post-tested three weeks later, and again after a period
of three months. Significant differences were found between
the pre-test and both retests, so test-retest reliability
was affected. The intraclass test-retest reliability coef-
ficient was 0.80, even with the high individual test relia-
bilities.

Because of the outcome of the above two experiments,
Kroll (50) conducted a study to examine the effects of
measurement schedules upon criterion strength scores. The
study was based on Hettinger's contention that a training
stimulus is completely dissipated in fourteen days, and that
several training stimuli are not superior to one maximal
stimulus to cause the greatest training effect. There was
no difference between trials or between test and retest,
and the schedule of five or more trials in the pre-test with
a retest two weeks later was concluded to be highly reliable
and free from non-pertinent effects. Kroll was unable to
explain the contradictory results of these last two studies
(49,50), but feels that this should not hinder the use of
the latter measurement schedule for research purposes.

Although the reliabilities of the above study were
high, Kroll (51) decided to test the method with the applica-
tion of an elementary model for assessing change. Difference
scores between the test and retest were calculated, and

true differences were approximated by use of a regression equation. The difference between the observed differences and the true differences was very low. Kroll concluded that this schedule was highly reliable, with no demonstrated intrusion of learning or strength development effects.

Henry (31) described a method of calculating instrument error by taking three readings with different apparatus connected in parallel, and then partitioning variance with the use of simultaneous equations. The intra-individual variance and the measurement error were then subtracted from the variance of observed scores, to give the variance of true scores. The product moment correlation can then be calculated with error removed. The change in the reliability coefficient was demonstrated with the test-retest and the split-halves techniques, and when single trials were used as compared with mean scores. The highest increase in reliability was from 0.574 to 0.589 when single trials were used. It was concluded that with reaction times and movement times at least, the major source of un-reliability is variation in the response of the individual rather than in error of measurement.

Henry (32) also demonstrated the influence of measurement error and intra-individual variation on the reliability of grip strength and vertical jump tests. The measurement error of a hand dynamometer was calculated

by gathering two sets of data from the same instrument. One set was obtained from the dial of the Smedley dynamometer, and the other from a specially constructed adaptation to the dynamometer. The differences between the two sets of data were calculated and the squared standard deviation of these deviation scores was said to be equal to the sum of the uncertainties of the two indicating systems. The error of one system could not be larger than this sum. The instrument error variance was then subtracted from the variance of the observed scores. Removal of this variance raised the reliability coefficient between test and retest only from 0.753 to 0.782 in men and from 0.876 to 0.897 in women. A similar procedure was also employed with measurement of the vertical jump. The vertical jump was also measured simultaneously, with two types of apparatus. No appreciable increases were found in test-retest reliabilities when the error variance was removed since a maximum of 1.07 per cent of the variance was attributed to measurement error. Henry (32) concluded, as he had for grip strength, that the main source of error is the intra-individual variation of the subjects who are tested.

Baumgartner (5) explained the methods which he feels are the most appropriate when all test trials are administered on the same day. The test-retest method,

the split-half method, and the intraclass correlation method were discussed together with the criterion measure which should be used. Baumgartner agrees with Kroll (48) and Feldt and McKee (24) that the intraclass method is the most favourable method because three sources of variation may be considered, and because it allows flexibility in the choice of the criterion score. Baumgartner stresses the necessity of administering an a priori test of trend before calculating the intraclass method. If a trend is found, Baumgartner suggests the selection of a group of several trials in which trend is not significant. The test-retest method is ranked second in order of preference as a method of reliability estimation, and the split-half is ranked as the least acceptable since it tends to estimate the upper limit of reliability.

Reliability estimation in the measurement of strength has been studied by Alderman and Banfield (2). The purpose of the study was to determine the reliability of eight strength measures using a standard measuring chair that was used by Howell et. al. (44). Reliabilities ranging from 0.63 for arm flexion to 0.98 for grip strength were reported using analysis of variance techniques as described earlier in this review. Measurement error calculations were made as suggested by Henry (32), and it was found to be 0.13 pounds for the tensiometer. Removal of the variance caused by measurement error raised the

reliabilities from as little as .924 to .926 for right leg
extension to 0.848 to 0.857 for right arm extension. The
variance ratio method, or intraclass method yielded higher
coefficients than the test-retest method, but these dif-
ferences were not significant.

Best Versus Average Scores. Considerable contro-
versy has occurred over the question of whether experimenters
should utilize best or average scores in the measurement of
physical performance. Utilization of the best score is based
on the logical argument that this score is the best indication
of a true maximal score, or fastest time, and most closely
approximates the best performance of the subject. Utilization
of the average scores is based on the logical argument that
there is always a degree of error of measurement, which makes
the scores depart from the theoretical true score. Since
these scores theoretically fluctuate randomly about this true
score, the average represents a better approximation of this
"true score." The effects of using the average score com-
pared to the best score in the Sargent jump test were
compared by Henry (27). Scores based on the average of
several trials were concluded to be more representative of
individual ability in this test than best scores. Henry
reaffirmed his partiality to the use of average scores (28).
The effects of discarding discrepant data were demonstrated
by gathering data using a stop watch and timing ten second

intervals from an electric clock. It was demonstrated
statistically that the discarding of discrepant data did
not improve the accuracy of predicting true time from the
measurements. Since it has been shown before that the
mean is an independent statistic, and unrelated to experi-
mental error, and since accuracy is not improved, the
author recommends use of mean scores. In view of Henry's
strong support of the use of mean scores, it is rather
surprising that Henry elected to use maximum scores in a
grip strength study in 1959 (32).

Methods of scoring tests of motor learning were
analyzed by McGraw in 1955 (61). McGraw suggested a prac-
tice of allowing the subject to perform a relatively large
number of trials, and selecting the maximum score which
occurs anywhere amongst these trials. This position, then,
is in contrast to a method of taking the mean of the last
three or five trials as many experimenters had employed in
motor learning experiments.

Whitley and Smith (85) compared the reliabilities
which were obtained from average and best scores in strength
and speed of movement scores. Significantly higher correla-
tions were obtained with average scores, so the authors con-
cluded that the practice of using average scores was the
most desirable. Berger and Sweney (9) disagreed with
Whitley and Smith stating that the use of average scores

was based on no sound or logical basis. Eight scores for fifty hypothetical subjects were selected by Berger and Sweney from a table of random numbers, and it was demonstrated that higher correlations were obtained using the best scores. The conclusion was that the choice of which score to use should be based on the degree of variability within subjects. Henry (34) subsequently replied to Berger and Sweney, since Whitley and Smith had based their paper largely on studies previously conducted by Henry (27,28). Henry's purpose was to explain the logical basis for Whitley's and Smith's findings, and also to demonstrate with random numbers the mechanisms involved. Henry obtained higher correlations using averages, and concluded that the practice of using best rather than average scores does not rest on a solid foundation.

An explanation of the logical basis for the utilization of average scores based on reliability analysis and theory has also been presented by Kroll (52). The reasoning of Whitley and Smith was agreed with, but Berger and Sweney were criticized. Since Berger and Sweney confined the range of the random scores to within thirty, the average individual scores between subjects would be expected to show less variability than the best score. Therefore, the best score would be expected to have the highest correlations under these conditions. Kroll

concluded that the correct criterion measure to use was the mean of all available trials, provided no trial-to-trial trend is present.

Summary. Utilization of analysis of variance to estimate reliability has several advantages over the correlation coefficient. These are:

1. Fluctuations in scores can be assigned to either the true score variance or to the error variance, depending upon which is correct in the specific circumstances being evaluated.

2. Approximations can be made of the reliability of a few trials as compared to a larger number.

3. Estimation can be made as to the number of trials necessary to achieve a satisfactory reliability coefficient.

4. Reliability can be calculated with the error classified under different headings for comparative purposes.

5. The estimate of reliability is sensitive to fluctuations in means and variances.

Henry (31,32) has described methods of partitioning the total variance, in such a way that instrument error, inter-individual variation, and intra-individual variation can be separated. Instrument error was shown to be small in proportion to the intra-individual variation for the

instruments and testing techniques considered.

Controversy has existed in the literature concerning the use of best scores or average scores. Most authors recommend the use of average scores. This is based on the assumption that errors are randomly distributed about the true score, and consequently the mean represents the best estimate of this true score.

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CHAPTER III

PROCEDURE

Subjects

The subjects for this investigation were grade five boys from Lynnwood and Elmwood elementary schools in Edmonton, Alberta. 110 subjects took the pre-test, 105 took the post-training test, and 98 took the post-detraining test. Of the final 98, two subjects were dropped to make the four groups of equal size. The post-training test was conducted during the last week of school in June, and three boys left early for summer vacation, one had influenza and another had appendicitis. No boy was measured on the post-detraining test that had not been measured on the post-training test. The seven boys who were missed on the post-detraining test either had transferred to another school, or were late reporting after the summer vacation, as the post-detraining test was carried out during the first week of school in September. The loss of subjects during the experiment, although undesirable, was not expected to influence the results because: the number of subjects was relatively large; and because the drop-outs were not due to any experimental treatment, so could be

interpreted as having occurred at random.

Following the pre-test, the subjects were assigned to four treatment groups. The subjects were first ranked on the basis of the total of their pre-test raw scores, and the four subjects having the highest totals were randomly assigned to the four groups. Next, the following four subjects were randomly assigned to the four groups. This assignment by blocks was repeated until all of the subjects were assigned to a group. Use of this procedure assured that the groups were equated, and fulfilled the requirement of randomization. The groups were subsequently randomly assigned to one of the four treatment conditions. The mean age of the subjects was 10.88 years, the standard deviation was 0.49 years, and the ages ranged from 9.75 years to 12.58 years.

Measurement Apparatus

A strain gauge testing instrument was especially designed and constructed for this experiment. An electronic instrument was selected since a permanent recording is provided, calibration is linear, and the internal resistance of the instrument itself is minimal. The new instrument was designed to eliminate the following weaknesses: distortion of the gauge with use; sensitivity to changes in room temperature; and of not being adaptable to as many testing situations as the cable-tensiometer.

The design of the instrument was as shown in figure 3. The two arms of the instrument were each one inch by three and three-quarter inch tooled steel. The two arms were forged to a third piece of metal at one end, so each arm of the instrument was a cantilever beam. The canitlever beam arrangement is an extremely sensitive one, but it is not considered quite as sensitive as the ring arrangement, although is superior in ability to return to original shape, since all pieces of metal in the instrument are at rest in their normal state. In the ring design, the metal is bent into this shape, so the molecules on the inside of the ring are compressed, while those on the outside are extended. Tooled steel was selected, since this metal has the quality of being brittle, but of returning to original shape rapidly after being distorted, provided of course that the capacity of the metal is not exceeded.

Four 120 ohm SR-4 strain gauges manufactured by Baldwin-Lima-Hamilton were bonded to the instrument. Since all four strain gauges were mounted on the same type of metal, the temperature effects on each were identical, so neutralized. The four strain gauges were mounted as diagrammed in figure four. The wires from the strain gauges were inter-connected in such a way as to form a Wheatstone Bridge. The resulting Wheatstone bridge is illustrated in figure 5.
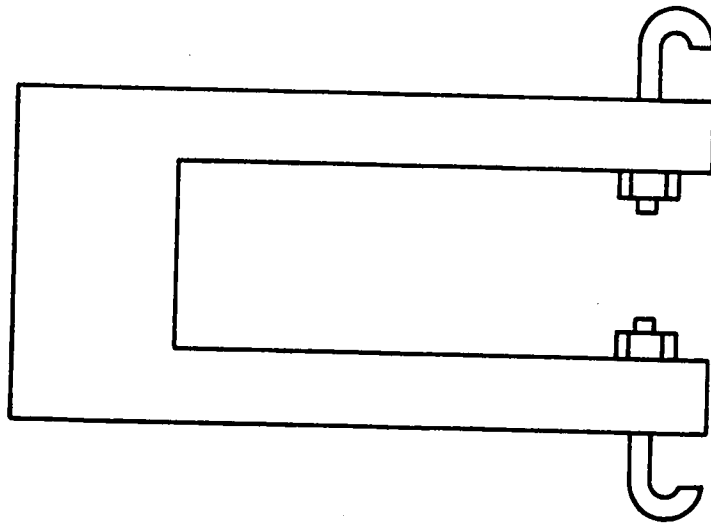
FIGURE 3. CANTILEVER BEAM ARRANGEMENT
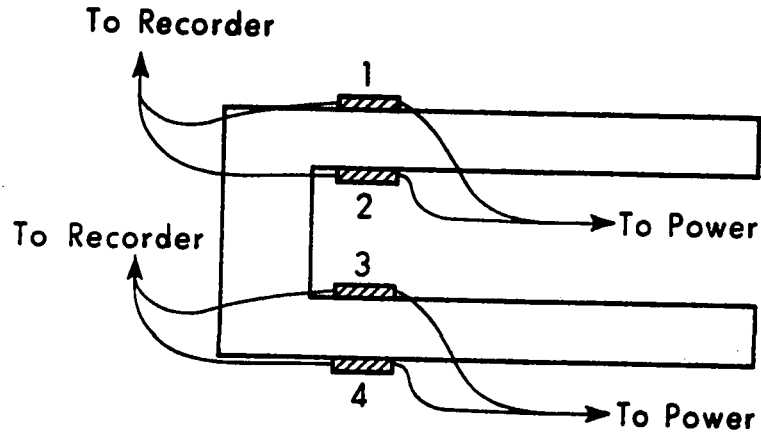
FIGURE 4. LOCATION OF STRAIN GAUGES
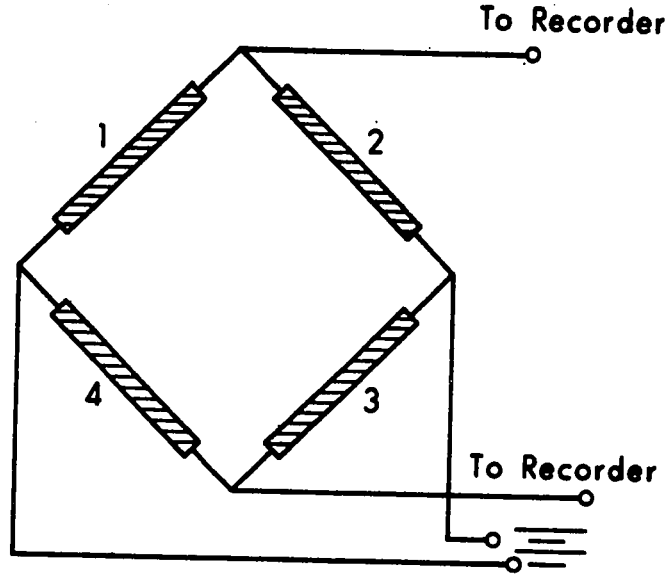
FIGURE 5. WIRING OF WHEATSTONE BRIDGE

When the resistances of arm-1 and arm-4 are equal
to arm-2 and arm-3 of the Wheatstone Bridge, there will
be no voltage across a recorder connecting the two halves
of the bridge (1). When the resistances are changed, so
the two halves of the bridge are unbalanced, there will
be a voltage at the recorder. The magnitude of this voltage
will increase linearly as the resistances are changed be-
cause:

$$R_1/R_2 \; = \; R_3/R_4 \qquad \text{(1; p. 160)}$$

Similarly, the amount of change in resistance of
the strain gauges has a direct linear relationship with
the amount of strain suffered by the metal because:

$$\epsilon \; = \; \frac{1}{F} \cdot \frac{\Delta R}{R}$$

where F = gauge factor
       R = resistance of gauge
       R = change in resistance   (1; p. 343)
       ϵ = strain

Therefore, the instrument designed was theoretically
linear in operation. That is, the amount of voltage supplied
to the input of the recorder would increase linearly for each
pound of additional strain that was applied to the metal.
This means that increasing the strain from zero to ten pounds
should cause exactly the same displacement of the recorder
pen as increasing the strain from 70 to 80 pounds, for exam-
ple. This linearity was checked with known weights, and the
theoretical results was proved to be in accord with results

actually obtained.

The recorder used was a Sargent Recorder Model SR. On the post-training test, the wire leading to the recorder from the strain gauges was divided, with a branch leading to two recorders. Use of the two similar recorders simultaneously produced duplicate scores which were used to calculate the instrument error variance. A tensiometer was also used simultaneously to record the post-training scores, but these scores were not used in the data analysis of the experiment.

A six volt power supply was transmitted to the strain gauges by way of an Acoptan Technical Company Regulated Power Supply Model 6A10. The 110 voltage from the wall plug was transformed into six volts, which is most appropriate for the purposes of energizing strain gauges.

A special chair constructed for the purpose of measuring the ability to exert muscular forces designed by Howell et. al. (2) was used to standardize the subjects for testing. The chair was selected since it had shoulder brackets to hold the subjects shoulders stationary, so that force could be exerted on the instrument only by elbow flexion. The seat was also set in a position high enough so as to have the feet of the subject hanging freely. This ensured that the feet were not used to push with as

would have been possible if the feet were allowed to touch the floor.

Two major alterations were made in the chair for the purposes of this experiment. The first of these was to make a bracket into which the subject's left elbow was inserted. This bracket is illustrated in figure 6. Two pieces of two and one-half inch by one-half inch aluminum were connected together with a hinge to form the bracket. One piece of aluminum had a pin attached on a surface, which fitted into a clamp on the chair. A belt of webbing was attached to the other piece of aluminum. This belt circled the subject's forearm, and served to secure the forearm into position and also to ensure that each subject had the resistance applied at exactly the same distance from the hinge on all three tests. The second piece of aluminum also was attached to a hook, which was for the purpose of attaching to the strain gauge instrument.

The second adjustment in the chair was to attach three hooks at the base of the chair. These hooks were attached in such a way that when a chain was connected from the rear hook to the measuring instrument, the angle between the chain and the lower portion of the bracket was 90 degrees when the angle at the hinge was 120 degrees. A second hook was located directly below the measuring in-
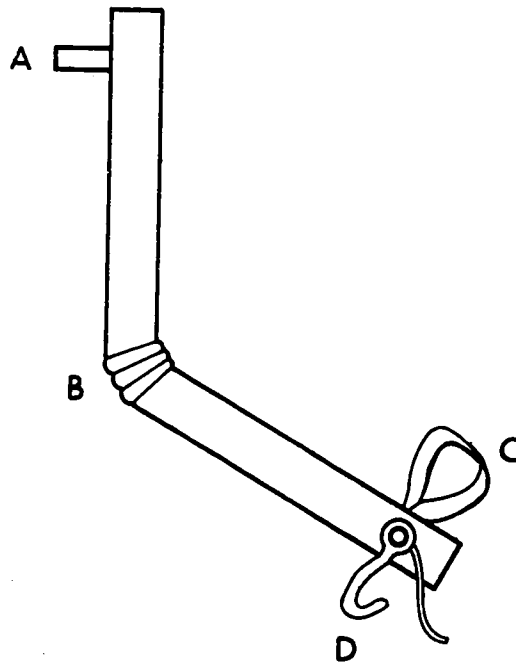
FIGURE 6. BRACKET TO SECURE ARM FOR TESTING

strument when the angle at the hinge was 90 degrees, and
the third hook was placed so that when a chain ran from this
hook to the measuring instrument, the angle between the
chain and the lower portion of the bracket was 90 degrees
when the angle at the hinge was 60 degrees.

Testing Procedure

All subjects in the experiment were tested three
times. Each of these tests were identical, with one occur-
ring at the commencement of the experiment, one at the
conclusion of the training period, and one at the conclusion
of the detraining period. On each of these occasions, the
subjects were tested for their ability to develop torque
three times with their elbow at a 60 degree angle, three
times with their elbow at a 90 degree angle, and three times
with their elbow at an 120 degree angle. The order of the
three testing positions was varied at random. Prior to the
testing, each subject was asked to turn over three coins
marked 60, 90, and 120. The order the coins were turned
over determined the order the individual would perform the
tests. This randomization of testing order was for the
purpose of causing any error caused by such factors as
learning, warm-up or fatigue to be randomly distributed,
and therefore uncorrelated with any set of test scores.

Before beginning the test at any one of the three

angles, each subject was given one practice trial. There-
fore, each subject practiced once and pulled officially
three times at each angle, or a total of three practice
trials, and nine official trials. Between the practice
trial and the first trial, and between each official trial,
a rest period of 30 seconds was given to the subject. The
rest period between the completion of the test at one angle,
and the commencement of testing at the next angle was deter-
mined by the amount of time necessary for the testor to
ready the apparatus by shifting the chain from one hook to
the other, and to set the angle of the elbow bracket at
precisely the correct angle. The time for preparing the
apparatus ranged from one to two minutes.

The official score was taken as the mean of the three
scores at the angle being tested. This procedure was
followed on the assumption that the scores recorded are
randomly distributed about the true score, and consequently,
the mean represents the best approximation of the true score.
The ability to develop torque was taken as the mean of the
three trials times the length of the resistance arm. The
length of the resistance arm was maintained as equal as
possible for all subjects under the conditions of the experi-
ment. Any variation in the length of the resistance arm
would be caused by the amount of inter-individual variation
of the subjects in the distance from the tip of the elbow

to the axis of rotation of the elbow joint. This variation is relatively small, but since this distance could not be ascertained precisely, it does place some limits upon the accuracy of the torque scores. The measured distance from the point of the bracket where the tip of the elbow fitted to the point where the resistance was applied was five and one-half inches. For the purpose of this experiment, it was assumed that the distance from the tip of the elbow to the axis of rotation of the elbow joint was one-half inch. Therefore, the length of the resistance arm was taken to be five inches multiplied by the mean score in pounds received from the three trials.

Figure 7 illustrates a subject being tested at the 90 degree angle. Precisely the same procedure was employed when testing at the 60 degree angle and the 120 degree angle; except for the positioning of the eblow bracket. For testing at the 120 degree angle, the chain was moved to the rear hook and adjusted in length until the angle of the elbow bracket was at 120 degrees. For testing at the 60 degree angle, the chain was transferred to the front hook, and adjusted until the angle of the elbow bracket was 60 degrees.

Some subjects in preliminary tests with the apparatus in a pilot project had difficulty pulling properly at the 60 degree angle with their elbow in the bracket. This dif-
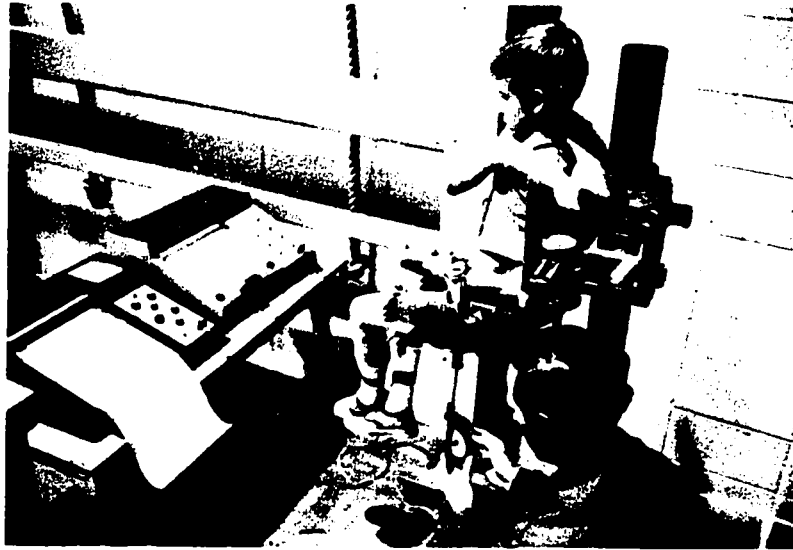
FIGURE 7. SUBJECT BEING TESTED AT 90 DEGREES

ficulty was not encountered when the elbow was moved for-
ward one inch in the bracket. This procedure was employed
in the experiment for the 60 degree angle only, so the
resistance arm was four inches in length for the 60 degree
angle, and five inches for both the 90 degree angle and
the 120 degree angle. The subjects, therefore, obtained a
better mechanical advantage at the 60 degree angle, but
obtained no advantage when the torque scores were employed
instead of the mean of the raw scores.

Training Procedure

Group One. Group one trained only with their elbow
flexed at 90 degrees. The subjects sat on a bench placed
parallel to gymnasium wall bars as shown in figure 7 . A
strap from the bottom wall bar was placed around the fore-
arm at about the same position as the strap was placed
during testing. The length of the strap was adjusted by
the subject, with the aid of the experimenter, so that the
elbow was at a 90 degree angle. On a command from the ex-
perimenter, the subjects performed nine maximal six second
contractions. A rest period of 30 seconds was allowed after
the first, second, fourth, fifth, seventh and eighth contrac-
tions, and a rest period of two minutes was allowed after
the third and sixth contractions. The subjects repeated the
training twice per week for a period of eight weeks.

FIGURE 8. SUBJECT TRAINING AT 90 DEGREES

Group Two. Group two was a treated control group. A piece of apparatus was constructed which was supposedly for the purpose of generating ultrasound waves. Actually, the apparatus was composed of a cake pan mounted upside down on a piece of wood. A small electric motor placed inside the cake pan simulated the noise of an electric shaver. Authentic type lettering was used on each side of the cake pan to print "Ultrasound Wave Generator." Electrical leads ran from the motor to the wall plug-in, and a second cable led to a white ball-shaped object, which was actually a very fine grindstone.

This stone was very uncommon, so the possibility of a subject recognizing it was very unlikely. The stone was also slightly abrasive like fine sandpaper, so gave the subjects a tingling sensation when rubbed on the skin that could easily have been interpreted as being a small electric current.

The subjects in all of the groups were shown the apparatus, and the experimenter explained that ultrasound was frequently used on international amateur athletes, and professional athletes, but was being used for the first time on young boys. Further explanations stated that group two was the only group which would have the opportunity to be treated with the machine.

FIGURE 9. SUBJECT RECEIVING PSEUDO-ULTRASOUND TREATMENT

The subjects in group two rubbed the stone over their upper arm for a period of twenty seconds twice weekly at the beginning of each physical education class for eight weeks. The subjects of this group, then, were given as much attention as the experimental subjects, and these subjects as well as other members of the school were made to believe that their treatment was at least as good as that of the experimental groups.

Group Three. Group three trained at 60 degrees, 90 degrees and 120 degrees. All training procedures were identical to group one for the first three pulls. After the first three pulls were completed, the straps were lengthened until the angle at the elbow was 120 degrees. Three maximal six second bouts were then performed at an angle of 120 degrees, with a rest period of 30 seconds between bouts, and then the straps were shortened, until the forearm was raised high enough so that the angle of the elbow joint was at 60 degrees. At the 60 degree angle, three more maximal six second bouts of isometric training were performed, with a rest period of 30 seconds between each bout. The subjects repeated this procedure twice weekly for eight weeks.

Group Four. Group four was a non-treated control group, and did not participate in the experiment, except for the three tests. The members of this group were allowed to

join with the other members of the class, and participate
in their normal physical education period.

The members of groups one, two and three joined the
other members of their class as soon as their training was
completed on each practice day, and engaged in their normal
physical education class. The total time for one training
period was approximately twelve minutes.

Statistical Procedures

Reliability estimation was performed by both the
test-retest-retest method, and the between trials method.
Analysis of variance techniques were utilized in each case.
Analysis of variance techniques were also administered to
the post-training test scores in order to partition out the
various sources of error variance, and specifically the
percentage of the total variance attributable to the new
testing instrument constructed for the present experiment.

Comparisons between groups, between angles, between
tests, and their interactions were tested with a three-way
analysis of variance design with repeated measures on the
last two factors (4; p. 319). If significant differences
were found to occur, the Newman-Keuls a posteriori test
(3; p. 91) was selected to determine the source of the dif-
ferences. Before the experiment, the decision was made to

declare differences at the 0.05 level as being significant.

The pre-test data was analyzed to determine the degree of generality of scores from angle to angle. Two alternatives to the traditional method of calculating the percentage of the variation attributable to generality are employed, and compared with the traditional method. The traditional method defines the generality variance as being equal to the squared correlation coefficient. Alternative definitions are presented, employing analysis of variance, and principal components analysis.

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CHAPTER IV

ANALYSIS AND INTERPRETATION OF DATA

Reliability of Measurement

The coefficient of reliability was estimated in
three ways. The first of these was to analyze the pre-test
raw scores in order to determine whether the measuring
instrumentation and methodology were satisfactory to pro-
ceed with the experiment. The second was to analyze the
post-training raw scores which were collected on two
recording systems simultaneously in order to determine the
percentages of measurement error variance attributable
to intra-individual differences and instrument error res-
pectively. The third method was to make use of the control
group means to give an estimate of the test-retest-retest
reliability.

Reliability of Pre-test Raw Scores. Analysis of
variance techniques as described by Winer (26; p. 124)
were utilized to analyze the pre-test raw scores to obtain
an estimate of the reliability of measurement. The analysis
of variance method allows for the calculation of reliability
coefficients based either on single scores, or on the mean.

Since mean scores are used in the interpretation of the results of this experiment, the reliability of the mean of the three trials was the coefficient of reliability selected. The reliabilities were estimated to be 0.958, 0.971 and 0.932 at 60 degrees, 90 degrees, and 120 degrees respectively. These reliabilities were assumed to be satisfactory, and the data was used as the pre-test for the experiment.

Partitioning of Instrument Error Variance. Because the measuring instrument was used for the first time in this experiment, an analysis of the post-training scores was conducted to determine the per cent of the error variance attributable to the instrument. The wires of the output from the testing instrument were divided and attached to two recorders, in a similar fashion to that described by Henry (7, 8). With this arrangement, two scores were received on each subject, for each trial. When mean scores are employed, the sources of fluctuation in scores are between subjects, between instruments, and error.

A two factor analysis of variance model, with one subject per cell, is suitable for partitioning these sources of variance. The between subjects mean square is an estimate of the error variance plus the number of subjects multiplied by the between instruments variance, and the interaction between subjects and instruments is an estimate

of the error variance. These estimates are summarized in table 1.

TABLE 1

ESTIMATED COMPONENTS OF MEAN SQUARES

FROM A TWO-WAY ANALYSIS OF VARIANCE

WITH ONE SUBJECT PER CELL

Mean Squares	Estimated Variances
Between Subjects	$\sigma^2_{Error} - 2\sigma^2_{Subjects}$
Between Instruments	$\sigma^2_{Error} - N\sigma^2_{Instruments}$
Subjects X Instruments	σ^2_{Error}

The true score variance is described as the variance between subjects, and the reliability is defined as the true score variance divided by the true score variance plus error variance. The error of the two instruments would be the error variance added to the between instruments variance. However, since only the results of one instrument are utilized in the present experiment, the between instruments variance is not added to the error variance. Therefore, the estimated reliability coefficient (r) $= \sigma^2_{Subjects}$ divided by ($\sigma^2_{Subjects} + \sigma^2_{Error}$).

From the mean squares in table 2, $\sigma^2_{Subjects}$ was estimated to be 79.335, $\sigma^2_{Instruments}$ was estimated to be

0.140 and error was estimated to be 3.031, at 60 degrees.

$$r = \sigma^2\text{Subjects}/(\sigma^2\text{Subjects} + \sigma^2\text{Error})$$

$$r = 79.335/(79.335 + 3.031) = 0.963$$

Adding σ^2Instruments to the error would have lowered r only to $79.335/(79.335 + 3.171) = 0.962.$

TABLE 2

ANALYSIS OF VARIANCE RESULTS UTILIZING
POST-TRAINING MEAN SCORES AT 60 DEGREES FROM TWO RECORDERS

Source of Variation	Sum of Squares	D. of F.	Mean Squares
Between Subjects	16,816.938	104	161.701
Between Instruments	17.688	1	17.688
Subjects X Instruments	315.250	104	3.031

From the mean scores in table 3, σ^2Subjects was estimated to be 65.094, σ^2Instruments was estimated to be 0.055, and σ^2Error was estimated to be 2.511, at 90 degrees.

$$r = \sigma^2\text{Subjects}/(\sigma^2\text{Subjects} + \sigma^2\text{Error})$$

$$r = 65.094/(65.094 + 2.511) = 0.963.$$

Adding σ^2Instruments to the error would have lowered r only to $65.094/(65.094 + 2.566) = 0.962.$

TABLE 3

ANALYSIS OF VARIANCE RESULTS UTILIZING
POST-TRAINING MEAN SCORES AT 90 DEGREES FROM TWO RECORDERS

Source of Variation	Sum of Squares	D. of F.	Mean Squares
Between Subjects	13,991.750	104	134.536
Between Instruments	14.250	1	14.250
Subjects X Instruments	85.813	104	0.825

From the mean squares in table 4, σ^2Subjects was estimated to be 66.856, σ^2Instruments was estimated to be 0.128 and σ^2Error was estimated to be 0.825, at 120 degrees.

$$r = \sigma^2\text{Subjects}/(\sigma^2\text{Subjects} + \sigma^2\text{Error})$$

$$r = 66.856/(66.856 + 0.825) = 0.988$$

Adding σ^2Instruments to the error would have lowered r only to $66.856/(66.856 + 0.953) = 0.986$.

TABLE 4

ANALYSIS OF VARIANCE RESULTS UTILIZING

POST-TRAINING MEAN SCORES AT 120 DEGREES FROM TWO RECORDERS

Source of Variation	Sum of Squares	D. of F.	Mean Scores
Between Subjects	13,991.750	104	134.536
Between Instruments	14.250	1	14.250
Subjects X Instruments	85.813	104	0.825

Henry (8) compared the percentage of error attributed to the instrument with that attributed to intra-individual variation. Use of mean scores eliminates the intra-individual component of the variance, but if raw scores are employed, trial to trial fluctuations in scores can be attributed to intra-individual variation. A three factor analysis of variance model, with one subject per cell is required to partition out all sources of variation.

Abbreviating subjects as s, trials as t, instruments as i, and residual as r, the various sources of variation and

the variances which are estimated are shown in table 5 for the post-training test.

TABLE 5

ESTIMATED COMPONENTS OF MEAN SQUARES

FROM A THREE-WAY ANALYSIS OF VARIANCE

WITH ONE SUBJECT PER CELL

Mean Squares	Estimated Variances
Between Subjects	$\sigma_e^2 + 2\sigma_{sxt}^2 + 3\sigma_{sxi}^2 + 6\sigma_s^2$
Between Trials	$\sigma_e^2 + 2\sigma_{sxt}^2 + 105\sigma_{txi}^2 + 210\sigma_t^2$
Between Instruments	$\sigma_e^2 + 3\sigma_{sxi}^2 + 105\sigma_{txi}^2 + 315\sigma_i^2$
Subjects X Trials	$\sigma_e^2 + 2\sigma_{sxt}^2$
Trials X Instruments	$\sigma_e^2 + 3\sigma_{sxi}^2$
Subjects X Instruments	$\sigma_e^2 + 105\sigma_{txi}^2$
Subjects X Trials X Instruments (Residual)	σ_e^2

From table 5, it follows that the variances of the main effects and interactions can be estimated by:

$$\sigma_s^2 = \frac{MS_s + MS_r - MS_{sxi} - MS_{sxt}}{6}$$

$$\sigma_t^2 = \frac{MS_t + MS_r - MS_{sxt} - MS_{txi}}{210}$$

$$\sigma_i^2 = \frac{MS_i + MS_r - MS_{sxi} - MS_{txi}}{315}$$

$$\sigma^2_{txi} = \frac{MS_{txi} - MS_r}{105}$$

$$\sigma^2_{sxt} = \frac{MS_{sxt} - MS_r}{2}$$

$$\sigma^2_{sxi} = \frac{MS_{sxi} - MS_r}{3}$$

$$\sigma^2_e = MS_r$$

The results of the three-way analysis of variance using the raw scores collected at the 60 degree angle are shown in table 6.

TABLE 6

ANALYSIS OF VARIANCE RESULTS UTILIZING

POST-TRAINING RAW SCORES AT 60 DEGREES FROM TWO RECORDERS

Source of Variation	Sum of Squares	D. of F.	Mean Squares
Between Subjects	50,500.766	104	485.584
Between Instruments	27.240	1	27.240
Between Trials	30.727	2	15.363
Subjects x Instruments	896.257	104	8.618
Subjects x Trials	4,789.496	208	23.026
Instruments x Trials	6.727	2	3.363
Error	222.269	208	1.069

Using the estimated variances from table 5, the

variances attributable to each source are summarized in table 7.

TABLE 7

SOURCES OF VARIANCE AND THEIR PERCENTAGES OF TOTAL

VARIANCE AT THE 60 DEGREE ANGLE ON POST-TRAINING

SCORES

Source of Variation	Amount	Percentage of Total
Between Subjects	75.835	83.821
Between Trials	-0.047(0)*	0.000
Between Instruments	0.052	0.057
Subjects X Trials	10.979	12.135
Subjects X Instruments	2.516	2.781
Trials X Instruments	0.022	0.024
Error	1.069	1.182
Total	90.473	

The calculated percentages in table 7 illustrates that at the 60 degree angle on the post-training scores, 12 percent of the total variance was due to the interaction between subject and trials, or intra-individual variation and 2.782 percent was due to the interaction between subjects and instruments or instrument error. Therefore, at the 60 degree angle, intra-individual variation proved to be 4.364 times as great of a source of unreliability as instrument error.

* The variances listed in table 7 are estimations of universe variances. A negative variance in this case would mean that the universe variance being estimated would be equal to zero or very close to zero. For calculations of percentages the between trials variance was considered to be zero (5).

The percentages of the total variance were partitioned in a similar fashion for the 90 and 120 degree angles. The results of the analysis of variance for these two tests are included in Appendix A.

At 90 degrees, the intra-individual variation was found to be 8.54 percent and instrument error was found to be 3.02 percent of the total variance. Intra-individual variation proved to be 2.83 times as great a source of unreliability as instrument error. At 120 degrees, the intra-individual variation was found to be 12.60 percent and instrument error was found to be 0.99 percent. Intra-individual variation proved to be 12.73 times as great a source of unreliability as instrument error.

Test-Retest-Retest Reliability. The mean scores obtained by the non-treated control group on all three tests were utilized to estimate the test-retest-retest reliability. Analysis of variance was used as described in Winer (26; p. 124). The reliability coefficients obtained were 0.827 at 60 degrees, 0.920 at 90 degrees, and 0.867 at 120 degrees.

Analysis of the Data

The five hypotheses to be tested in the experiment were that the experimental groups would not be different

from the non-treated control group after eight weeks of training; the treated control group would not differ from the non-treated control group after eight weeks of treatment; the effects of training would not be retained over a detraining period of ten weeks; the effects of training would be general, and not specific to the angle at which the training occurred, and that scores between angles would not differ. The 0.05 level of significance was selected as the criterion for rejection of the null hypothesis, and a three factor analysis of variance model with repeated measures on the last two factors as described in Winer (26; p. 319) was chosen as the test statistic. The results of the analysis of variance are shown in table 8.

TABLE 8

ANALYSIS OF VARIANCE OF EXPERIMENTAL TORQUE SCORES

Source of Variation	Sum of Squares	d.f.	Mean Squares	F	Crit. F
Between Subjects	995,040.00	95			
Between Groups	2,992.00	3	997.333	.09	2.72
Subjects Within Groups	992,048.00	92	10,783.129		
Within Subjects	657,920.00	768			
Between Tests	14,992.00	2	7,496.000	9.99*	3.98
Groups x Tests	6,944.00	6	1,157.333	1.54	2.72
Tests x Subjects W. Gp	138,048.00	184	750.261		
Between Angles	231,776.00	2	115,888.000	187.02*	3.96
Groups x Angles	3,680.00	6	613.333	0.99	2.72
Angles x Subjects W. Gp	114,016.00	184	619.652		
Tests x Angles	12,896.00	4	3,224.000	9.27*	3.96
Gps x Tests x Angles	7,616.00	12	634.617	1.83	2.72
Tests x Angles x Subj W. Gp	127,952.00	368	347.696		

*Significant at the 0.05 level.

For the calculation of all F ratios in which repeated measures were involved, the conservative F test has been used as recommended by Winer (26; p. 322). Of the seven F ratios calculated, three exceeded their critical F value. The interaction between tests, groups and angles effect would have been significant with the usual test, but since the conservative test was appropriate in this case, it has not been declared significant. A description of the results of the above statistical tests are given below.

1. The between groups main effect was not significant.

2. The between tests main effect was significant. The Newman-Keuls test* as described in Kirk (14; p. 93) was applied to the data to determine which comparisons were significant. In the Newman-Keuls test, the two means being compared must have a difference exceeding their corresponding W value to be declared significant. For the total group of subjects, the pre-test mean was 179.91, the post-training mean was 187.35, and the post-detraining mean was 189.68. Since W_2 was calculated to be 3.22, and W_3 was calculated to be 3.85, the post-training test and post-detraining test were both significantly higher than the pre-test, but the difference between the post-training and post-detraining test was not significant.

3. The interaction effect between groups and tests was not significant. Therefore, the hypothesis that the

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*All a posteriori test calculations are included in Appendix B.

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3. The interaction effect between groups and tests was not significant. Therefore, the hypothesis that the

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*All a posteriori test calculations are included in Appendix B.

experimental groups would not be different from the non-treated control group after eight weeks of training is not rejected. Likewise, the hypothesis that the treated control group would not differ from the non-treated control group after eight weeks of training is not rejected. Since no significant training effect occurred, the hypothesis that the effects of training would not be retained over a detraining period of detraining cannot be rejected.

4. The between angles main effect was significant. Therefore, the hypothesis that the subjects would obtain equal scores at each of the three angles is rejected.

The Newman-Keuls test (14; p. 91) was applied to the mean of 164.30 at 60 degrees, 204.11 at 90 degrees, and 188.53 at 120 degrees. Since the W_2 equals 4.07 and the W_3 equals 4.87, both the 90 degree angle and the 120 degree angle are significantly higher than the 60 degree angle, and the 90 degree angle is significantly higher than the 120 degree angle.

5. The interaction effect between tests and angles was significant. The means received at each of the three angles on each of the three tests are shown in table 9 and are illustrated in figure 10.

To determine the source of the interaction between tests and angles, the following simple mean effects were tested:
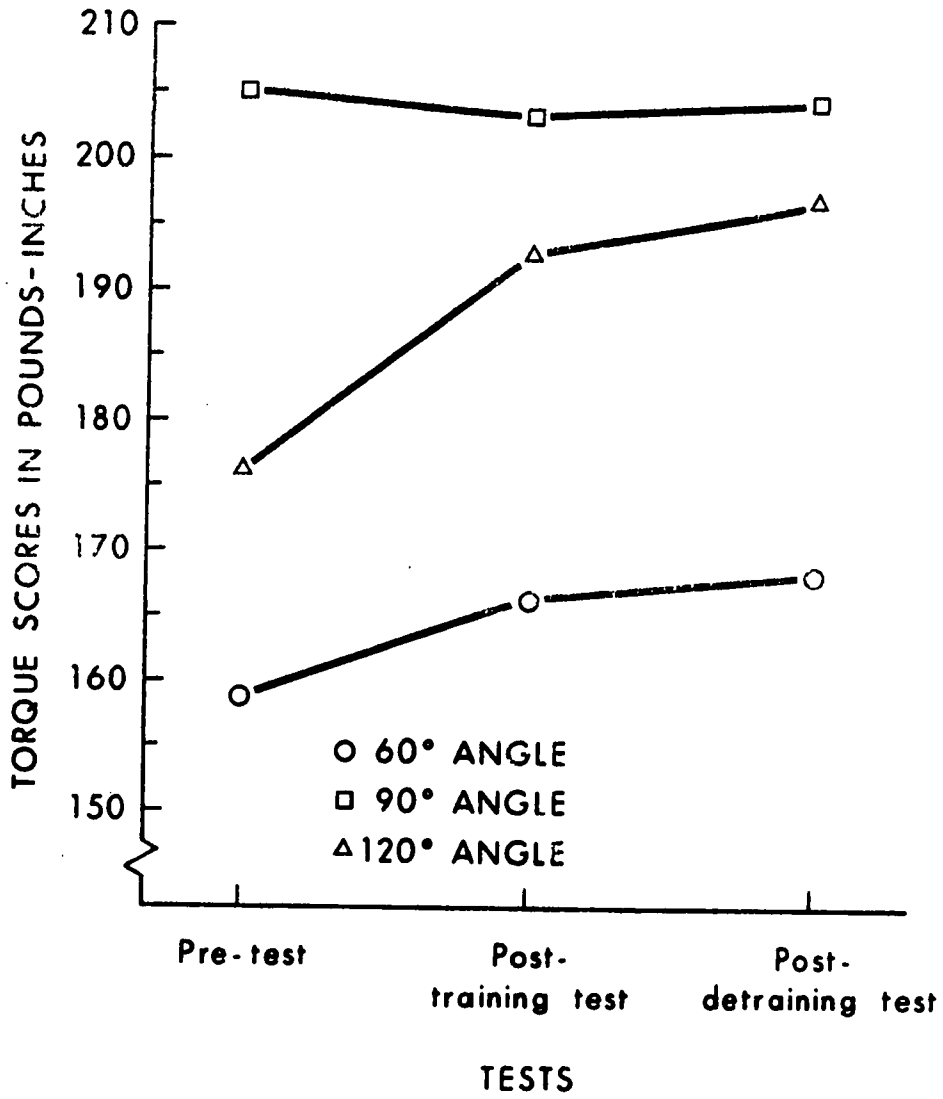
FIGURE 10. TESTS TIMES ANGLES INTERACTION

TABLE 9

TEST MEANS AT 60, 90, AND 120 DEGREES

Test	60 degrees	90 degrees	120 degrees
Pre-test	158.66	204.96	176.11
Post-training test	166.14	203.20	192.73
Post-detraining test	168.11	204.17	196.75

   (a) Between Tests at 60 degrees,

   (b) Between tests at 90 degrees,

   (c) Between tests at 120 degrees,

   (d) Between angles at the pre-test,

   (e) Between angles at the post-training test,

   (f) Between angles at the post-detraining test.

A one way analysis of variance with repeated measures as described by Winer (26; p. 105) was used as the model for all six of the above tests. The conservative test was used in each case as recommended by Winer (26; p. 111).

Significant differences were found to occur in all of the simple main effects listed above except between tests at 90 degrees. The calculated F of 0.0693 did not exceed the critical F of 3.96., so the hypothesis of equality of means at this point was not rejected. At each of the other five simple main effects, the Newman-Keuls test was administered to determine which comparisons of means were signi-

ficant. The results of the Newman-Keuls tests are summarized in tables 10 and 11.

TABLE 10

SUMMARY OF NEWMAN-KEULS TESTS RESULTS FOR SIMPLE MAIN EFFECTS FOR THE 60, 90, AND 120 DEGREE ANGLES

Simple Main Effect	Means			Newman-Keuls Test Results		
	Pre-test	Post-training	Post-detraining	$T_2 > T_{1*}$	$T_3 > T_2$	$T_3 > T_1$
Between tests at 60°	158.39	166.30	168.22	yes	yes	yes
Between tests at 90°	204.91	203.52	203.89	no	no	no
Between tests at 120°	176.01	192.54	197.03	yes	yes	yes

* means statistically greater than.
T_1 means pre-test, T_2 means post-training test, and T_3 means post-detraining test.

TABLE 11

SUMMARY OF NEWMAN-KEULS TEST RESULTS FOR SIMPLE MAIN EFFECTS FOR THE PRE-TEST, POST-TRAINING TEST AND POST-DETRAINING TEST

Simple Main Effect	Means			Newman-Keuls Test Results		
	60°	90°	120°	90° > 60°	120° > 60°	90° > 120°
Between angles at Test 1*	158.09	176.01	204.91	yes	yes	yes
Between angles at Test 2	166.30	192.55	203.52	yes	yes	yes
Between angles at Test 3	168.22	197.03	203.89	yes	yes	yes

*Test 1 is the pre-test, Test 2 is the post-training test, and Test 3 is the post-detraining test.

No irregularities were found to exist on the between angle comparisons. The difference between angles was statistically significant on all of the tests. Likewise, the 90 degree was higher than both the 60 degree angle and 120 degree angle, and the 120 degree angle was higher than the 60 degree angle on all three tests, so the interaction did not arise from differences between angles. However, on the between tests comparisons, irregularities were present. The 60 degree angle and the 120 degree angle increased from the pre-test to the post-training test, whereas the 90 degree angle did not. Also, the means on the post-detraining test at 90 degrees and at 120 degrees were significantly higher than their corresponding mean on the pre-test, while this was not so at the 90 degree angle. The interaction between tests and angles is accounted for by these irregularities.

7. The interaction effect between groups and tests and angles was not statistically significant since the calculated F of 1.54 did not exceed the critical F of 2.72.

Generality Versus Specificity

Research conducted to test the specificity theory has generally used product-moment correlational techniques (2, 6, 9, 10, 16, 18, 19, 24, 25). This research has been based on the assumption that the squared correlation coefficient

represents the common variance between the two variables
being compared. The squared correlation coefficient
maultiplied by 100 then, is assumed to be equal to the per-
centage of the total variance which may be attributed to
specificity. The present author questions the validity
of this assumption.

The basis for the assumption is that the correlation
coefficient squared is equal to the variance of predicted
scores calculated by a regression equation based on the two
variables divided by the variance of the observed scores.
This can be shown by the formula:

$$r^2 = s_{\hat{y}}^2 \div s_{\bar{y}}^2$$

In the formula, the coefficient of correlation
squared is equal to the variance of the predicted scores
divided by the variance of the observed scores. If the two
variables are X and Y, B_1 and B_0 are the regression coef-
ficients, and e is the error, the following proof verifies
the above relationship.

The familiar regression equation is expressed as:

$$Y = B_1 \cdot X + B_0 + e$$

$$\text{Now } B_0 = \bar{Y} - B_1 \bar{X}$$

$$\text{so } Y = B_1 X + \bar{Y} - B_1 \bar{X} + e$$

$$Y - \bar{Y} = B_1 (X - \bar{X}) + e$$

The deviation score $Y - \bar{Y}$ can be expressed as y
and $X - \bar{X}$ as x so that:

$$y = B_1 x + e$$

$$\hat{y} = B_1 x \text{ where } \hat{y} \text{ is the predicted deviation score.}$$

The variance of the $\hat{Y}$ can be expressed as:

$$S_{\hat{Y}}^2 = B_1^2 \cdot S_X^2$$

B_1 can be expressed as:

$$B_1 = r_{XY} \frac{S_Y}{S_X}$$

Then $$S_{\hat{Y}}^2 = r_{XY}^2 \cdot \frac{S_Y^2}{S_X^2} \cdot S_X^2$$

$$S_{\hat{Y}}^2 = r_{XY}^2 \cdot S_Y^2$$

From which $r_{XY}^2 = S_{\hat{Y}}^2 / S_Y^2$

There is no argument that this relationship exists,
but some difficulty does arise in the interpretation of this
relationship. Does the relationship mean that r^2 amount of
variance is common to both X and Y, or that r^2 amount of
variance in Y can be attributed to that in X? It is true
to say that as r^2 increases, the variance of the predicted
scores becomes closer and closer to the variance of the
actual Y scores, and vice versa. However, it must be
pointed out that because the variance of the predicted
scores is equal to r_{xy}^2 times the variance of the y scores
($S_{\hat{Y}}^2 = r_{xy}^2 \cdot S_Y^2$), there is no justification for concluding

that the variance of one is caused by the other, or that one is common to the other. Making this assumption is analagous to declaring that two piles of apples have arisen from the same source, simply because one happens to be one half the size of the other for example. If one pile of apples has six, and one has twelve, it is correct that one has half as many apples as the other, or that it is equal to one half of the larger pile. However, this statement of equality does not imply membership. It simply means that the size of one can be calculated from the other if the ratio is known.

An alternative to the partitioning of variance by the squared correlation is to employ analysis of variance. If two variables are measured, typically a number of trials are taken on each of these two variables. Therefore, scores can vary for the following reasons.

1. Variance between subjects,

2. Variance between test trials,

3. Variance between variables,

4. Variance caused by the interaction between the variables and the trials,

5. Variance caused by the interaction between the variables and the subjects,

6. Variance caused by the interaction between the trials and the subjects,

7. Residual variance.

The data can be analyzed by utilizing a three way analysis of variance fixed effects model. One factor would be the variables, one the trials, and the third would be subjects, with only one subject per cell. The expected mean squares for this design are illustrated in table 12. Let subjects be s, trials be t, variables be v, and residual be r.

TABLE 12

ESTIMATED COMPONENTS OF MEAN SQUARES FROM A THREE-WAY ANALYSIS OF VARIANCE WITH ONE SUBJECT PER CELL

Source of Variation	Expected Mean Squares
Between Subjects	$\sigma_e^2 - 2\sigma_s^2 \times t - 3\sigma_s^2 \times v - 6\sigma_s^2$
Between Variables	$\sigma_e^2 - 3\sigma_s^2 \times v \quad 110\sigma_t^2 \times v \quad 330\sigma_v^2$
Between Trials	$\sigma_e^2 - 2\sigma_s^2 \times t \quad 110\sigma_t^2 \times v \quad 220\sigma_t^2$
Subjects X Variables	$\sigma_e^2 - 3\sigma_s^2 \times v$
Subjects X Trials	$\sigma_e^2 - 2\sigma_s^2 \times t$
Variables X Trials	$\sigma_e^2 - 110\sigma_t^2 \times v$
Residual	σ_e^2

From these expected mean squares, it follows that the above variances can be estimated in the following manner.

$$\sigma_s^2 = \frac{M^S{}_s - M^S{}_r - M^S{}_s \times t - M^S{}_s \times v}{6}$$

$$\sigma_v^2 = \frac{MSv - MSr - MSt \times v - MSs \times v}{330}$$

$$\sigma_t^2 = \frac{MSt - MSr - MSt \times v - MSs \times t}{220}$$

$$\sigma^2 s \times v = \frac{MSs \times v - MSr}{3}$$

$$\sigma^2 s \times t = \frac{MSs \times t - MSr}{2}$$

$$\sigma^2 t \times v = \frac{MSt \times v - MSr}{110}$$

$$\sigma^2 e = MSr$$

If each subject scored exactly equal scores on both
variables, and there was no trial-to-trial error, all of the
variance would be between subjects. Therefore, the between
subjects variance shall be defined as generality variance.
The interaction between subjects and variables is caused
by differences in scores obtained by the same individual on
the different variables as distinct from the overall dif-
ference that may exist between the variables. Therefore,
this variance shall be defined as specificity variance.
Utilization of these definitions of generality and specifi-
city leaves portions of the total variance undefined. The
variance between variables belongs neither to specificity
nor generality, since the relative magnitude of scores is
of no consequence. The degree of generality or specificity
is based solely on the relationship of one set of scores
with another. The between trials variance shall be attri-
buted to error variance, as will any variance occurring
due to: the interaction between subjects and trials; the
interaction between trials and variables; and the residual
variance.

An advantage of the analysis of variance model over the squared correlation method is that sources of error variance may be isolated as such. Ordinarily, error variance is averaged out, or somehow a criterion score is selected to represent all of the trials. Therefore, all of the data collected, cannot be used in the analysis. The purpose of analysis of variance is to partition the total variance into its appropriate parts, and all of the data collected in the investigation can contribute to a more thorough understanding of all sources of variation.

The analysis of variance method of partitioning variance can be applied directly to two sets of variable scores, which are marked on the same scale, and where the magnitude of the scores is expected to be similar. Where the scores are marked on a different scale such as strength and speed of movement, the scores would have to be converted to standard scores, before the analysis of variance would be meaningful.

Analysis of variance was conducted on the raw scores of the pre-test in the present experiment. The variables were the 60 and 90 degree angles. The product moment correlation coefficient between the mean scores at 60 degrees and at 90 degrees was 0.685 and 0.710 when corrected for attenuation. Those authors who calculate generality by the squared correlation method usually correct for attenuation by dividing the correlation coefficient by the square

root of the product of the reliabilities. The reliability
at 60 degrees was 0.972. Therefore, r (corrected) $=$
0.685 $\div \sqrt{(0.958 \times 0.972)}$ $=$ 0.710. Use of the squared
correlation method of calculating generality and specificity
would have yielded the conclusion that since $r^2 = 0.5041$,
only 50.41 percent of the variance can be attributed to
generality, and 49.59 percent to specificity. The results
of the analysis of variance are shown in table 13.

TABLE 13

ANALYSIS OF VARIANCE OF PRE-TEST RAW SCORES

AT THE 60 AND 90 DEGREE ANGLES

Source of Variation	d. f.	S. of S.	M. S.
Between Subjects	109	45525.547	417.666
Between Trials	2	8.639	4.320
Between Variables	1	240.006	240.006
Subjects X Variables	109	8,999.231	82.507
Subjects X Trials	218	2,070.618	9.498
Trials X Variables	2	5.930	2.965
Residual	218	2,016.617	9.251
Total	659	50,766.60	

Using the expected values of the mean squares in
table 12, the variances associated with each source of
variation may be calculated to be: $\sigma_s^2 = 55.819$; $\sigma_t^2 = 0.005$; $\sigma_v^2 = 0.496$; $\sigma_{s \times t}^2 = 0.124$; $\sigma_{s \times v}^2 = 24.419$;

$\sigma^2_{t \times v}$ = -0.057 (0.000); and σ^2_e = 9.251. Using these estimated variances, the degree of generality, specificity, and error may now be calculated. The values of the generality, specificity, and error variances are as follows:

Generality Variance = σ^2_s = 55.829

Specificity Variance = $\sigma^2_s \times v$ = 24.429

Error Variance = σ^2_r + σ^2_t + $\sigma^2_s \times t$ + $\sigma^2_v \times t$ = 9.38

Expressed as percentages:

Generality = $\sigma^2_s / (\sigma^2_s + \sigma^2_s \times v + \sigma^2_e)$ = 55.819/89.618 X 100

= 62.29%

Specificity = $\sigma^2_s \times v / (\sigma^2_s + \sigma^2_s \times v + \sigma^2_e)$ = 24.419/89.618

X 100 = 27.45%

Error = $\sigma^2_e / (\sigma^2_s + \sigma^2_s \times v + \sigma^2_e)$ X 100

= 9.380/89.618 X 100 = 10.47%

The same procedure was applied to compare scores obtained on the pre-test for 60 degrees against those obtained at 120 degrees, and for 90 degrees against 120 degrees. The calculations for these tests are in Appendix C . The product moment correlation coefficient between the average scores at 60 degrees and 120 degrees was 0.674 and 0.713 when corrected for attenuation. Using analysis of variance, the generality variance (σ^2_s) was calculated to be 50.530, the specificity variance ($\sigma^2_s \times v$) was calculated to be 24.285, and the error variance was calculated to be 10.693. Expressed as percen-

tages, using the analysis of variance method, the generality was 59.093 percent, the specificity was 28.40 percent, and the error variance amounted to 12.51 percent. Use of the squared correlation method would have attributed 50.84 percent to generality and 49.16 to specificity.

The product moment correlation coefficient between the average pre-test scores at 90 degrees and 120 degrees was 0.851 and 0.894 when corrected for attenuation. Using analysis of variance, the generality variance (σ^2_s) was calculated to be 51.648, the specificity variance (σ^2_s x v) was calculated to be 6.869, and the error variance was calculated to be 7.642. Expressed as percentages using the analysis of variance method, generality was 78.07 percent, specificity was 10.38 percent, and the error variance was 11.55 percent. The squared correlation method would have attributed 79.92 percent to generality, and 20.08 percent to specificity.

Using the Z transformation procedure as described in Mode (20; p. 246) the corrected correlations between the 60 and 90 degree angle scores, between the 60 and 120 degree angle scores, and between the 90 and 120 degree angle scores were averaged. The mean correlation was found to be 0.791. This mean correlation squared is 0.6256, so use of the squared correlation method would have attributed 62.56 percent of the variance between the three angles to generality,

and 37.44 percent to specificity. When the scores from all three angles were treated by the analysis of variance method, the generality variance (σ_s^2) was found to be 52.665, the specificity variance $(\sigma_s^2 \times v)$ was found to be 18.524, and the error variance was found to be 9.144. Expressed as percentages using the analysis of variance method, the generality was found to be 65.56 percent, the specificity was found to be 23.06 percent, and the error was found to be 11.38 percent.

A summary of the generality and specificity values obtained with the analysis of variance and squared correlation techniques is presented in table 14. Except for the 90 and 120 degree comparison, the generality factor was larger when calculated by analysis of variance, than by the squared correlation method. In every case, the specificity factor was lower when calculated by analysis of variance, than when the squared correlation coefficient was used.

TABLE 14

AMOUNTS OF GENERALITY AND SPECIFICITY OBTAINED WITH SQUARED CORRELATION METHOD AND WITH ANALYSIS OF VARIANCE METHOD

Angles	r	r(corr)*	Squared Correlation Method General	Specific	Analysis of Variance Method General	Specific
60°-90°	.685	.710	50.41	49.59	62.29	27.25
60°-120°	.674	.713	50.84	49.16	59.04	28.40
90°-120°	.851	.894	79.92	20.08	78.07	10.38
60°-90°-120°		.791	62.56	37.44	65.56	23.06

*correlation coefficient corrected for attenuation

Table 15 illustrates the relative size of generality
and specificity where calculated by both the squared correla-
tion and analysis of variance methods. The generality/
specificity ratio is much larger for each comparison with
the analysis of variance results compared to the squared
correlation results.

TABLE 15

GENERALITY/SPECIFICITY RATIOS OBTAINED BY THE SQUARED
CORRELATION AND ANALYSIS OF VARIANCE METHODS

Angles	Squared Correlation Method	Analysis of Variance Method
$60°-90°$	1.017	2.286
$60°-120°$	1.034	2.079
$90°-120°$	3.980	7.521
$60°-90°-120°$	1.671	2.843

A second alternative to the squared correlation
procedure of partitioning generality variance is the imple-
mentation of principal components analysis techniques.
Principal component analysis as described in Morrison (21;
p. 221) allows for the extraction of a set of uncorrelated
linear composites from a correlation matrix. The variance
of successive composites is given by the characteristic
roots of the matrix. The technique is such that the first
linear composite, or principle component as it is more
commonly called, has the largest possible variance for any

linear composite. If a definition of generality is approximated by the first principal component, then the ratio of the first root to the sum of the roots would be an approximation of the degree of generality. The loadings of the variables on the first component are equal to the correlation between the variable and the composite. Thus, the proportion of generality for each variable might be taken as the square of the loading.

The principal components analysis was applied to the pre-test data as was done earlier with analysis of variance. The first principal component is defined as the generality factor. The correlations among angles can be arranged as shown in table 16.

TABLE 16

CORRELATION MATRIX AMONG ANGLES

Angle	60 degrees	90 degrees	120 degrees
60 degrees	1.000	0.685	0.674
90 degrees	0.685	1.000	0.851
120 degrees	0.674	0.851	1.000

The principal component analysis of table 16 is shown in table 17. The characteristic roots are 2.476, 0.375, and 0.149. The first principal component or generality accounts for 2.476/(2.476 - 0.375 - 0.149) X 100 = 82.53 percent of the variance. The correlation of the generality factor

with 60 degrees is 0.887, with 90 degrees is 0.920 and with 120 degrees is 0.953. The ratio of the variance of the generality factor with each angle is given by the squared correlation. Therefore, the ratio of the generality factor with 60 degrees is 73.65 percent, with 90 degrees is 87.32 percent, and with 120 degrees is 86.60 percent.

TABLE 17

PRINCIPAL COMPONENTS ANALYSIS OF INTER-ANGLE

CORRELATION MATRIX

Angle	I	Component II	III
60 degrees	0.8582	0.5128	0.0097
90 degrees	0.9345	-0.2235	-0.2765
120 degrees	0.9306	-0.2485	0.2688
Root	2.476	0.375	0.149
% Variance	82.53		

Table 17 is based on average scores over trials for each child at each angle. As such, the effects due to trial variation, and all interactions with trials, which are included in the analysis of variance model, are included. Consequently, for the present case, the principal components analysis likely overestimates the degree of generality. The principal components analysis does indicate that the true generality is likely higher than the estimate obtained from the square of single correlations.

Discussion

The experimental results of this investigation are
not in agreement with those reported by Adamson (1),
Hergert (11), Bready (4), Hutinger (13), Schweid et. al.
(23) and Hettinger (12). No positive training effects
were obtained in the present experiment, whereas each
of the other authors listed did report significant im-
provement resulting from training programs conducted on
young boys. Comparison between these studies and the
present study is difficult due to the wide disparity in
testing and training procedures employed. For example,
Schweid et. al. (23) used a testing procedure in which the
subjects were required to hold the resistance for a period
of five seconds, so scores received are more correctly
classified as endurance, rather than a maximum force score.
Hutinger (13) used a horizontal ladder for the training
apparatus. Significant improvements in pushing and pulling
strength were reported, but failure to obtain a significant
difference in grip strength was accounted for by the fact
that those muscles were not specifically exercised in the
training program in the manner tested. Hettinger (12),
has not supplied detailed information of the experiments
conducted on young boys, but has simply stated that 60
percent of the training effect can be expected in young boys
as compared to men between 20 and 30 years of age.

More study is required before decisive conclusions
can be drawn concerning the trainability of young boys.
Before the present experiment was conducted, the few
studies on this topic would have tended to indicate that
young boys may be expected to respond to isometric train-
ing in a positive fashion. However, the present experiment
casts doubt on the validity of this conclusion. An inte-
resting observation, also, is that although only a very
few experimenters have conducted training programs on
young boys, an unusually high percentage have reported at
least a portion of their findings as non-significant.
Adamson (1) did find significant improvement in groups
trained isometrically and isotonically in back extension
strength. However, in Adamson's study the group trained
isotonically did not make significant improvement in elbow
flexion strength. Also, Hutinger (13), as mentioned earlier,
did not obtain significant improvement in grip strength on
either right or left hands. Therefore, although the six
studies reviewed, which did conduct training programs on
young boys, reported results which are generally opposed
to those of the present study, two of these did find non-
significant differences in at least one segment of the
body.

Other possible explanations for the lack of a
training effect have been proposed by other authors.
Royce (22) in discussing a study by Muller and Rohmert

has suggested that the degree of trainability of subjects is dependent upon the degree to which their present level departs from a maximal strength plateau related to the particular training method. If this theory is correct, one may hypothesize from the present findings that young boys are closer to this plateau. One could reason that since the average man between 20 and 30 years of age has a level of muscle development which is a great deal below this plateau, a high degree of trainability is exhibited. Contrarily, due to maturational factors, and due to the fact that young boys are more physically active than adults, the average level of muscular development rests much closer to the maximum potential, and consequently a smaller degree of trainability is attainable.

Lawther (15) has pointed out that although groups who are trained either isotonically or isometrically have almost always made significant improvements, it is not unusual for individuals within groups to either remain at a constant level, or even decrease as a result of training. Of the 48 experimental subjects in the present investigation, 33 made improvements in their total scores over the three angles as a result of training, whereas 15 either failed to improve or scored less after training. Perhaps the experimental groups simply contained a larger percentage of these individuals for whom the training was inappropriate.

Another possible explanation is that the training program was not satisfactory. Two training sessions were held per week for eight weeks. Although the total number of training sessions was approximately equal to the average as reported in the literature, training twice per week was below average. Berger (3) has stated that training four or five times per week may not be as beneficial as training twice per week. Macintosh (17) conducted elbow flexion isometric training three times per week for eight weeks, and obtained a positive training effect. Berger's statements, and Macintosh's findings indicate that some other factor is operative besides the frequency and duration of training.

Large differences were shown to exist in the estimated magnitude of the generality/specificity ratio among angles when generality was defined as the between subjects variance calculated with analysis of variance, compared with when generality was defined as being equal to the squared correlation coefficient. The specificity theory, as outlined by Henry (6) has proven very beneficial to physical education in that the notion of the "general athlete" has been largely dispelled. Physical educators are now more apt to judge athletes as well as non-athletes on specific physical and ability traits. However, the analysis of variance method of analysis of data conducted in the present study indicates that the squared correlation method

tends to underestimate the relationship of ability of one variable to another. Principal components analysis also found a generality factor which exceeded that calculated with the squared correlation, and in fact, exceeded that found with analysis of variance.

The testing methods and instrumentation employed in the present investigation were found to be satisfactory. The intra-individual variation was found to be from 2.87 to 12.73 times as great a factor causing unreliability as was instrument error. Henry (8), using similar procedures, found intra-individual variation 5.66 as great as instrument error for grip strength measurement on men, and 4.42 times as great for grip strength measurement on women. In the present experiment, average scores were used as the criterion scores for the analysis of the experimental data. When average scores were considered, the reliabilities of measurement, computed by the analysis of variance method, were found to be 0.963 at 60 degrees, 0.963 at 90 degrees, and 0.988 at 120 degrees.

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CHAPTER FIVE

SUMMARY AND CONCLUSIONS

Summary

Purposes. The primary purpose of this investigation was to determine if young boys would respond to isometric training in a similar fashion to high school and college men. Secondary purposes of the study were to determine the effects of detraining immediately following the training period; to determine if the effects of training are specific or general; to determine if the ability to develop torque is general or specific; and to determine the effects of a pseudo-ultrasound treatment. The decision was made to utilize torque scores rather than the recorded force scores. Most experimenters use the word strength, but strength is a rather ambiguous word since the magnitude of scores is based on the length of the resistance arm, and also because the word strength tends to be associated with the physiological capacity of the muscle. Statements concerning the physiological capacity of the muscle can not be made if they are based solely on the force scores recorded on a measuring instrument.

Procedure. The subjects were studied over a period of training of eight weeks, and of detraining of ten weeks. Ninety-six subjects were tested three times. A chair constructed especially for the measurement of muscular forces was utilized in connection with a strain gauge instrument, which was designed and constructed for this experiment. After the pre-test, the subjects were randomly assigned to four groups, and the four groups were randomly assigned to four treatment conditions. Group one received isometric training twice weekly with the left elbow at 90 degrees; group two received pseudo-ultrasound treatment twice weekly; group three received isometric training twice weekly with the left elbow at 60 degrees, 90 degrees and 120 degrees; and group four served as a control group and received no treatment.

Statistical Procedures. The equality of the groups was checked at the commencement of the experiment with a simple one way analysis of variance. To obtain an estimate of reliability, analysis of variance procedures were used. A one-way analysis of variance with repeated measures model was used to estimate both the between trials reliability and the between task reliability. The variance attributable to instrument error was partitioned out by two procedures. The first procedure was to employ average scores, and analyzing the data with a two way analysis of variance

allowed for the calculation of a reliability coefficient with the only source of error being instrument error. For the second procedure, a three way analysis of variance was calculated for the purpose of determining the percentage of error of measurement which was attributable to instrument error, and intra-individual variation respectively.

The experimental data was analyzed with a three factor analysis of variance model with repeated measures on the last two factors. The first factor was between groups, and the two factors with repeated measures were between tests and between angles.

The degree of generality among angles was analyzed using three methods. The first method was the most frequently used squared correlation method, the second was with analysis of variance, and the third was with principal components analysis.

Results. Although the groups were equated at the beginning of the experiment, neither the treatments administered during the eight weeks of training, nor the ten weeks of detraining caused a significant difference to arise between groups on the post-training test or on the post-detraining test. The subjects, as a whole, scored significantly higher after the eight week training period

at 60 degrees and at 120 degrees. These higher scores were maintained over the ten weeks of detraining. No significant change was observed at the 90 degree angle over the three tests.

Since the groups which received isometric training did not improve significantly more than the control group, there were no effects of training. Therefore, conclusions cannot be made from the experiment that training effects were either general or specific.

Large differences were shown to exist in the estimated magnitude of the generality/specificity ratio depending upon the definition employed. When the generality factor was defined as being the between subjects variance in analysis of variance, the generality/specificity ratio was found to be larger than when defined as the squared correlation coefficient. Similarly, when generality was defined as the first principal component in principal components analysis, the generality factor was found to be much larger than that found with the squared correlation coefficient, and in fact was larger than that found with analysis of variance. Since the principal components analysis employed average scores, and consequently ignored any effects due to trial variation, or interaction with trials, the generality factor is likely overestimated. However, the principal components analysis, together with

the analysis of variance, do illustrate that the true generality factor is higher than that calculated with the squared correlation method.

The newly constructed strain gauge instrument was shown to be sufficiently reliable. When instrument error alone was considered, estimates of reliability employing analysis of variance techniques were found to be 0.963 at 60 degrees, 0.963 at 90 degrees and 0.988 at 120 degrees. When instrument error and intra-individual error were both considered, intra-individual variation was found to be 4.36 times as great as instrument error at 60 degrees, and 2.87 times as great at 90 degrees, and 12.73 times as great at 120 degrees. Although the testing instrument was designed especially for this experiment, it is suitable for use in any situation in which a tensiometer might be used.

Conclusions

1. Grade five boys training isometrically twice weekly for eight weeks with the left elbow at 90 degrees did not score significantly higher on a post-training test than did the control group.

2. Grade five boys training isometrically twice weekly for eight weeks with the left elbow at 60 degrees,

90 degrees and 120 degrees did not score significantly higher on a post-training test than did the control group.

3. Pseudo-ultrasound treatment administered to grade five boys as a psychological control did not cause the psychologically controlled subjects to score better on a post-training test than did the control group.

4. Ten weeks of detraining did not cause either of the experimental groups, the psychological control group, or the control group to score significantly differently on a post-detraining test.

5. The subjects in the experiment as a whole improved significantly over the eight week training period. This improvement was maintained over the ten weeks of detraining, and the difference between the post-training and post-detraining scores was not significantly different. These improved scores occurred at the 60 degree and 120 degree angles. No differences were recorded at the 90 degree angle over the three tests.

6. Although the group as a whole did improve significantly over the course of the experiment, there were no significant differences recorded between any of the four groups on the pre-test, post-training and post-detraining tests.

7. On the pre-test, post-training test, and post-detraining test, the total groups of subjects scored significantly higher torque scores at the 90 degree angle,

than either the 60 degree angle or 120 degree angle, and higher at the 120 degree angle than at the 60 degree angle.

8. Analysis of the scores received at the 60 degree, 90 degree, and 120 degree angles revealed the presence of a high amount of between angles generality.

9. The squared correlation method of computing generality underestimated the degree of relationship among angles, as compared with results obtained with analysis of variance, and principal components analysis.

10. Training effects in this experiment were not found to be specific.

11. The testing instrument designed for this experiment proved to be both practical and reliable.

12. The major source of unreliability in testing was not from the testing procedure and equipment, but from intra-individual variation of the subjects from trial-to-trial.

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APPENDIX A

PARTITIONING OF VARIANCES OF PRE-TEST RAW SCORES AT 90 AND

120 DEGREES

TABLE 18

ANALYSIS OF VARIANCE RESULTS UTILIZING POST-TRAINING
RAW SCORES AT 90 DEGREES FROM TWO RECORDERS

Source of Variation	Sum of Squares	D.ofF.	Mean Squares
Between Subjects	41,418.523	104	398.255
Between Instruments	2.173	1	2.173
Between Trials	463.600	2	236.800
Subjects x Instruments	769.990	104	7.404
Subjects x Trials	2,784.670	208	13.388
Instruments x Trials	0.775	2	0.387
Error	175.554	208	0.844

TABLE 19

SOURCES OF VARIANCE AND THEIR PERCENTAGES OF TOTAL
VARIANCE AT THE 90 DEGREE ANGLE ON POST-TRAINING SCORES

Source of Variation	Amount	Percentage of Total
Between Subjects	63.051	85.86
Between Instruments	0.015	0.02
Between Trials	1.066	1.45
Subjects x Instruments	2.187	3.02
Subjects x Trials	6.272	8.54
Trials x Instruments	-0.004 (0)	0.00
Error	0.844	1.15
Total	73.435	

TABLE 20

ANALYSIS OF VARIANCE RESULTS UTILIZING POST-TRAINING
RAW SCORES AT 120 DEGREES FROM TWO RECORDERS

Source of Variation	Sum of Squares	D.of F.	Mean Squares
Between Subjects	41,960.316	104	403.464
Between Instruments	22.102	1	22.102
Between Trials	322.156	2	161.078
Subjects x Instruments	276.229	104	2.656
Subjects x Trials	4,020.093	208	19.327
Trials x Instruments	0.308	2	0.154
Error	89.355	208	0.430

TABLE 21

SOURCES OF VARIANCE AND THEIR PERCENTAGES OF TOTAL VARIANCE
AT THE 120 DEGREE ANGLE ON POST-TRAINING SCORES

Source of Variation	Amount	Percentage of Total
Between Subjects	63.652	84.86
Between Instruments	0.063	0.08
Between Trials	0.676	0.90
Subjects x Instruments	0.742	0.99
Subjects x Trials	9.449	12.60
Trials x Instruments	-0.003 (0)	0.00
Error	0.430	0.57
Total	75.012	

APPENDIX B

A POSTERIORI TESTS

TABLE 22

NEWMAN-KEULS TEST RESULTS BETWEEN TESTS

Tests in Order	Pre-Test	Post-training Test	Post-detraining Test
Means	179.91	187.35	189.68
179.91	---	7.44*	9.77*
187.35		---	2.33
189.68			---

*Difference significant at the 0.05 level.

$q_2 = 2.77$ $q_3 = 3.31$

$$W_r = q_r \sqrt{\frac{MS\ error}{N}}$$

$$W_2 = 2.77 \sqrt{\frac{750.261}{288}} = 2.77 \times 2.614 = 4.471$$

$$W_3 = 3.31 \times 2.614 = 8.652$$

TABLE 23

NEWMAN-KEULS TEST RESULTS BETWEEN ANGLES

Angles in Order	90 Degrees	120 Degrees	60 Degrees
Means	204.11	188.53	164.30
204.11	---	15.58*	39.81*
188.53		---	24.23*
164.30			---

*Difference significant at the 0.05 level.

$q_2 = 2.77$ $q_3 = 3.31$

$$Wr = \sqrt{\frac{MSerror}{N}}$$

$$W_2 = 2.77 \quad \frac{619.652}{288} = 2.77 \times 1.467 = 4.07$$

$$W_3 = 3.31 \times 1.467 = 4.87$$

TABLE 24

SIMPLE MAIN EFFECT BETWEEN TESTS AT 60 DEGREES

Source of Variation	SS	DF	MS	F	Crit. F.
Between People	342,653.00	95	3,606.87		
Between Tests	5,176.00	2	2,588.00	4.366	3.95
Residual	112,635.00	190	592.82		

NEWMAN-KEULS TEST RESULTS BETWEEN TESTS AT 60 DEGREES

Tests in Order	Pre-Test	Post-Training Test	Post-detraining Test
Means	158.39	166.30	168.22
158.39	---	7.91*	9.83*
166.30		---	1.92
168.22			---

* Difference significant at the 0.05 level.

$$q_2 = 2.77 \quad q_3 = 3.31$$

$$W_r = q_r \sqrt{\frac{MS\ error}{N}}$$

$$W_2 = 2.77 \sqrt{\frac{592.82}{96}} = 2.77 \times 2.485 = 6.88$$

$$W_3 = 3.31 \times 2.485 = 8.23$$

TABLE 25

SIMPLE MAIN EFFECT BETWEEN TESTS AT 90 DEGREES

Source of Variation	SS	DF	MS	F	Crit. F.
Between People	393,704.00	95	4,144.25		
Between Tests	48.00	2	24.00	0.069	3.95
Residual	65,775.00	190	346.18		

TABLE 26

SIMPLE MAIN EFFECT BETWEEN TESTS AT 120 DEGREES

Source of Variation	SS	DF	MS	F	Crit. F.
Between People	376,576.00	95	3,963.96		
Between Tests	23,504.00	2	11,752.00	2.164	3.95
Residual	103,181.00	190	543.06		

TABLE 27

NEWMAN-KEULS TEST RESULTS BETWEEN TESTS AT 120 DEGREES

Tests in Order	Pre-Test	Post-Training Test	Post-Detraining Test
Means	176.01	192.55	197.03
176.21	---	16.54*	21.02*
192.55		---	4.48
197.03			---

* Difference significant at the 0.05 level.

$q_2 = 2.77 \quad q_3 = 3.31$

$$W_r = q_r \sqrt{\frac{MS\ error}{N}}$$

$$W_2 = 2.77 \sqrt{\frac{543.06}{96}} = 2.77 \times 2.378 = 6.588$$

$$W_3 = 3.31 \times 2.378 = 7.87$$

TABLE 28

SIMPLE MAIN EFFECT BETWEEN ANGLES ON THE PRE-TEST

Source of Variation	SS	DF	MS	F	Crit. F.
Between People	322,318.00	95	3,392.82		
Between Angles	105,883.00	2	52,941.50	131.05	3.95
Residual	76,754.00	190	403.97		

TABLE 29

NEWMAN-KEULS TEST RESULTS BETWEEN ANGLES ON THE PRE-TEST

Angles in Order	60 degrees	120 degrees	90 degrees
Means	158.39	176.01	204.91
158.39	---	17.62*	46.52*
176.01		---	28.90*
224.91			---

* Difference significant at the 0.05 level.

$$q_2 = 2.77 \quad q_3 = 3.31$$

$$W_r = q_r \sqrt{\frac{MS\ error}{N}}$$

$$W_2 = 2.77 \sqrt{\frac{403.968}{96}} = 2.77 \times 2.05 = 5.68$$

$$W_3 = 3.31 \times 2.05 = 6.79$$

TABLE 30

SIMPLE MAIN EFFECT BETWEEN ANGLES
ON THE POST-TRAINING TEST

Source of Variation	SS	DF	MS	F	Crit. F.
Between People	362,749.00	95	3,818.41		
Between Angles	70,178.00	2	35,089.00	77.50	3.95
Residual	86,025.00	190	452.76		

TABLE 31

NEWMAN-KEULS TEST RESULTS BETWEEN ANGLES
ON THE POST-TRAINING TEST

Angles in Order	60 degrees	120 degrees	90 degrees
Means	166.30	192.55	203.52
166.30	---	26.25*	37.22*
192.55		---	10.97*
203.52			---

* Difference significant at the 0.05 level.

$q_2 = 2.77 \quad q_3 = 3.31$

$$W_r = q_r \sqrt{\frac{MS\ error}{N}}$$

$$W_2 = 2.77 \sqrt{\frac{452.763}{96}} = 2.77 \times 2.172 = 6.02$$

$$W_3 = 3.31 \times 2.172 = 9.17$$

TABLE 32

SIMPLE MAIN EFFECT BETWEEN ANGLES
AT THE POST-DETRAINING TEST

Source of Variation	SS	DF	MS	F	Crit. F.
Between People	454,394.00	95	4,783.09		
Between Treatments	68,728.00	2	34,364.00	70.75	3.95
Residual	92,286.00	190	485.72		

TABLE 33

NEWMAN-KEULS TEST RESULTS BETWEEN ANGLES
ON THE POST-DETRAINING TEST

Angles in Order	60 degrees	120 degrees	90 degrees
Means	168.22	197.03	203.89
168.22	---	28.81*	35.67*
197.03		---	6.86*
203.89			---

* Difference significant at the 0.05 level.

$q_2 = 2.77 \quad q_3 = 3.31$

$$W_r = q_r \sqrt{\frac{MS\ error}{N}}$$

$$W_2 = 2.77 \sqrt{\frac{485.72}{96}} = 2.77 \times 2.249 = 6.23$$

$$W_3 = 3.31 \times 2.249 = 7.44$$

APPENDIX C

CALCULATION OF GENERALITY, SPECIFICITY AND ERROR COMPONENTS
OF VARIANCE BETWEEN 60 AND 120 DEGREES, BETWEEN 90 AND 120
DEGREES, AND BETWEEN 60, 90 AND 120 DEGREES

I. Calculation of Generality and Specificity Using 60 and 120 Degree Scores

TABLE 34

THREE WAY ANALYSIS OF VARIANCE OF PRE-TEST RAW SCORES AT 60 AND 120 DEGREES

Source of Variation	SS	DF	MS
Between Subjects	42,157.02	109	386.76
Between Variables	3,368.30	1	3,368.30
Between Trials	22.11	2	11.06
Subjects X Variables	9,096.04	109	83.45
Subjects X Trials	2,338.14	218	10.73
Variables X Trials	7.43	2	3.71
Residual	230.94	218	10.59

$$\sigma^2_s = \frac{MS_s + MS_r - MS_{sxv} - MS_{sxt}}{6}$$

$$= \frac{386.76 + 10.59 - 10.73 - 83.45}{6} = 50.53$$

$$\sigma^2_v = \frac{MS_v + MS_r - MS_{sxv} - MS_{vxt}}{330}$$

$$= \frac{3.368 + 10.59 - 3.71 - 83.45}{330} = 9.97$$

$$\sigma^2_t = \frac{MS_t + MS_r - MS_{sxt} - MS_{txv}}{220}$$

$$\sigma_t^2 = \frac{11.06 + 10.59 - 3.71 - 10.73}{220} = 0.03$$

$$\sigma_{sxv}^2 = \frac{MS_{sxv} - MS_r}{3} = \frac{83.45 - 10.59}{3} = 24.29$$

$$\sigma_{sxt}^2 = \frac{MS_{sxt} - MS_r}{2} = \frac{10.73 - 10.59}{2} = 0.07$$

$$\sigma_{txv}^2 = \frac{MS_{txv} - MS_r}{110} = \frac{3.71 - 10.59}{110} = -0.06$$

$$\sigma_e^2 = MS_r = 10.59$$

$$\text{Generality} = \frac{50.53}{50.53 + 10.59 + 24.29} \times 100 = 59.16\%$$

$$\text{Specificity} = \frac{24.29}{50.53 + 10.59 + 24.29} \times 100 = 28.43\%$$

$$\text{Error} = \frac{10.59}{50.53 + 10.59 + 24.29} \times 100 = 12.39\%$$

II. Calculation of Generality and Specificity Using 90
and 120 Degree Scores

TABLE 35

THREE WAY ANALYSIS OF VARIANCE OF PRE-TEST RAW SCORES
AT 90 AND 120 DEGREES

Source of Variation	SS	DF	MS
Between Subjects	36,856.65	109	338.13
Between Variables	5,406.55	1	5,406.55
Between Trials	5.32	2	2.66
Subjects X Variables	3,022.22	109	27.73
Subjects X Trials	1,665.98	218	7.64
Variables X Trials	14.34	2	7.17
Residual	1,552.24	218	7.12

$$\sigma^2_s = \frac{MS_s + MS_r - MS_{sxv} - MS_{sxt}}{6}$$

$$= \frac{338.13 + 7.12 - 7.64 - 27.73}{6} = 51.65$$

$$\sigma^2_v = \frac{MS_v + MS_r - MS_{sxv} - MS_{txv}}{330}$$

$$= \frac{5,406.55 + 7.12 - 7.17 - 27.73}{330} = 16.30$$

$$\sigma^2_t = \frac{MS_t + MS_r - MS_{sxt} - MS_{txv}}{220}$$

$$\sigma_t^2 = \frac{2.66 + 7.12 - 7.17 - 7.64}{220} = -0.023$$

$$\sigma_{sxv}^2 = \frac{MS_{sxv} - MS_r}{3} = \frac{27.73 - 7.12}{3} = 6.87$$

$$\sigma_{sxt}^2 = \frac{MS_{sxt} - MS_r}{2} - \frac{7.64 - 7.12}{2} = 0.52$$

$$\sigma_{txv}^2 = \frac{MS_{txv} - MS_r}{110} = \frac{7.17 - 7.12}{110} = 0.00045$$

$$\sigma_e^2 = MS_r = 7.12$$

$$\text{Generality} = \frac{51.65 \quad x\ 100}{51.65 + 6.87 + 7.64} = 78.07\%$$

$$\text{Specificity} = \frac{6.87 \quad x\ 100}{51.65 + 6.87 + 7.64} = 10.38\%$$

$$\text{Error} = \frac{7.64 \quad x\ 100}{51.65 + 6.87 + 7.64} = 11.55\%$$

III. Calculation of Generality and Specificity Using 60, 90 and 120 Degrees

TABLE 36

THREE WAY ANALYSIS OF VARIANCE OF PRE-TEST RAW SCORES AT 60, 90 AND 120 DEGREES

Source of Variation	SS	DF	MS
Between Subjects	58,750.52	109	539.00
Between Variables	6,009.90	2	3,004.95
Between Trials	13.42	2	6.71
Subjects X Variables	14,074.29	218	64.56
Subjects X Trials	2,057.62	218	9.44
Variables X Trials	18.46	4	4.62
Residual	3,918.99	436	8.99

$$\sigma_s^2 = \frac{MS_s + MS_r - MS_{sxv} - MS_{sxt}}{9}$$

$$= \frac{539.00 + 8.99 - 64.56 - 9.44}{9} = 52.67$$

$$\sigma_v^2 = \frac{MS_v + MS_r - MS_{sxv} - MS_{txv}}{330}$$

$$= \frac{3,004.95 + 8.99 - 64.56 - 4.62}{330} = 8.92$$

$$\sigma_t^2 = \frac{MS_t + MS_r - MS_{sxt} - MS_{txv}}{330}$$

$$\sigma_t^2 = \frac{6.71 + 8.99 - 9.44 - 4.62}{330} = 0.005$$

$$\sigma_{sxv}^2 = \frac{MS_{sxv} - MS_r}{3} = \frac{64.56 - 8.99}{3} = 18.52$$

$$\sigma_{sxt}^2 = \frac{MS_{sxt} - MS_r}{3} = \frac{9.439 - 8.99}{3} = 0.15$$

$$\sigma_{txv}^2 = \frac{MS_{txv} - MS_r}{110} = \frac{4.62 - 8.989}{110} = 0.039$$

$$\sigma_e^2 = MS_r = 8.99$$

$$\text{Generality} = \frac{52.67}{52.67 + 18.52 + 9.14} \times 100 = 65.56\%$$

$$\text{Specificity} = \frac{18.52}{52.67 + 18.52 + 9.14} \times 100 = 23.06\%$$

$$\text{Error} = \frac{9.14}{52.67 + 18.52 + 9.14} \times 100 = 11.38\%$$

APPENDIX D

RAW DATA

PRE-TEST RAW DATA

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Northcott	3	54	51	51	38	43	37	28	27	30
Brennan	2	23	26	23	25	25	24	20	21	19
Bugaresti	1	31	38	40	40	36	41	35	36	29
Franke	1	42	44	52	38	37	38	20	30	30
Davies	4	37	41	41	44	46	45	38	33	36
McFarlane	4	45	49	44	40	38	36	34	35	35
Rix	2	33	35	38	35	37	35	41	32	31
Fettig	1	33	39	43	32	36	37	33	28	30
Phipps	3	41	44	42	38	37	39	37	43	38
Chelmick	4	23	21	26	27	28	28	17	21	22
Friesen	4	57	56	51	45	42	42	34	38	35
Weidner	4	28	33	31	32	31	35	27	28	27
Meaney	4	33	37	34	27	34	33	31	39	33
Darling	2	43	43	43	39	41	39	44	41	42
Korzan	2	49	53	47	49	45	45	47	41	43
Moore	2	34	31	40	37	37	38	34	36	35
Bottrell	1	41	42	38	40	37	40	46	35	37
Roder	2	39	36	40	38	43	38	32	35	31
Armstrong	2	34	34	41	47	41	37	36	30	41
Aldridge	4	40	47	41	45	40	42	33	29	30
Bickell	1	48	46	45	46	47	52	41	41	42
Beyerstein	3	20	32	37	37	46	45	34	35	38
Bond	4	42	50	49	51	45	44	41	43	42

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Bonkowski	1	43	52	48	43	46	43	47	46	46
Bromlee	3	23	12	23	40	39	39	35	38	37
Dobbin	3	38	40	33	42	44	43	52	42	43
Douglas	2	31	18	26	38	45	50	41	48	46
Hill	1	39	48	47	41	37	37	34	31	33
Lee	3	40	37	33	35	38	35	33	29	34
Lewin	2	39	42	46	43	43	43	36	33	35
Ratsoy	4	41	40	40	37	39	37	32	33	33
Kuipers	2	32	40	36	43	42	41	37	42	40
Steele, T.	1	34	35	34	32	32	31	30	23	22
DeWolfe	3	35	35	33	40	40	35	41	39	35
Neudorf	3	24	24	19	42	34	38	27	34	29
Spiers	2	37	35	42	42	37	36	38	37	36
Milton	2	32	35	33	31	30	31	28	28	25
Steele, J.	4	37	37	33	37	39	32	31	30	32
Thomas	2	37	34	35	39	35	36	31	26	28
Speers	4	43	49	59	53	50	53	51	50	43
Tuckwell	1	43	40	44	48	49	50	37	44	46
Smith, M.	1	35	34	33	37	36	39	28	30	30
Fehr	3	32	35	40	33	38	37	23	27	26
Casavan	2	43	31	39	36	38	39	34	36	36
Barabash	3	40	42	40	38	39	38	31	29	33
Stefaniuk	1	66	62	58	54	56	53	43	42	37
Gotte	3	59	60	67	57	57	57	43	46	47

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Richter	1	23	20	23	23	26	28	20	18	18
Webb	2	40	52	40	44	45	46	46	47	43
Hawkins	1	48	50	41	45	43	43	38	37	40
Lyseng	1	28	23	27	23	28	31	27	25	25
Glover	2	33	34	35	36	37	38	30	37	32
Nyberg	3	51	51	49	63	68	55	55	44	48
Bye	3	32	33	34	32	36	36	28	28	29
Harding	3	30	29	27	28	25	28	23	24	22
McLennan	4	34	35	40	32	33	33	27	29	31
Vanleerusum	2	60	59	57	53	52	52	41	41	40
Schneider	1	31	31	33	40	40	41	32	30	31
Laughington	2	39	41	39	37	36	36	32	33	33
Poworoznik	1	25	31	23	42	41	41	40	38	39
McLachlin	2	21	21	16	35	30	35	25	22	21
Williams	4	36	36	42	43	45	42	26	29	29
McDowell	3	43	48	49	44	44	41	41	41	38
Scott	2	43	43	33	38	38	39	31	30	31
Goodwin	2	71	76	74	59	60	60	67	51	46
Gehon	2	53	53	55	41	41	43	41	41	40
Redding	4	38	39	38	35	35	37	31	33	32
Sanderson	4	38	34	31	25	25	26	23	22	23
Michniuk	4	39	40	38	40	38	37	38	35	35
Carrie	4	49	50	51	48	43	46	42	39	37
Ingram	4	57	59	56	59	57	56	53	51	51

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Radloff	3	32	30	33	42	38	33	30	30	35
Vanleeuwen	3	36	30	34	43	46	43	34	32	35
Bishop	2	35	38	40	51	50	51	41	40	39
Kirillo	4	39	40	42	46	45	48	40	42	43
Sterling	1	46	47	42	50	46	47	41	38	39
Entwhistle	1	46	50	52	52	52	50	38	42	40
Goertz	3	32	32	30	40	40	39	35	31	33
Briscoe	4	50	43	40	43	49	46	40	35	33
Oussoren	3	40	41	54	48	57	57	47	42	44
Visser	1	60	58	56	45	45	51	38	33	45
Hatch	4	37	39	47	59	59	59	45	40	48
Stevenson	3	39	39	42	41	44	52	36	37	40
Stewart	3	50	48	43	48	45	49	42	48	37
Mckone	3	37	36	37	35	32	30	32	33	31
Vestby	1	58	40	46	57	58	55	48	48	42
Lassey	3	49	50	45	45	50	49	40	40	43
Degaust	2	32	30	33	34	30	30	18	20	21
Flett	4	53	53	54	42	42	43	41	47	44
Prychitko	1	37	32	37	33	31	33	27	30	35
Ritchie	1	37	40	32	36	39	31	34	31	37
Rusnak	3	24	29	28	38	34	30	30	27	28
Smith , C.	1	71	70	67	58	54	58	58	58	58
Hore	1	25	27	29	29	31	33	33	32	33
Kish	2	39	38	37	37	40	38	36	30	40

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Kroychy	4	31	23	25	40	44	47	34	34	35
Leite	1	35	32	37	29	29	31	23	22	26
Daryluk	2	43	40	37	35	40	37	34	28	32
Pennyfather	2	50	53	52	50	52	55	39	40	43
Wildman	3	34	25	31	55	49	54	34	34	46
Milne	4	32	23	28	41	41	42	39	37	40
Harris	1	40	38	40	42	42	41	31	28	30
Levenick	3	52	52	50	49	54	55	40	41	50
Pedersen	4	55	57	61	43	47	49	34	38	41
Vaage	4	45	41	38	31	32	32	33	30	30
Earnshaw	4	42	40	44	55	50	50	45	41	38
Kozub	1	45	40	41	43	43	43	33	34	37
Rust	2	33	35	32	25	27	30	30	30	29
McCorchuk	3	40	27	33	32	37	28	23	29	26
Robinson	4	41	41	40	50	44	44	34	35	37

POST-TRAINING TEST
(Official Recorder)

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Northcott	3	55	49	54	42	40	41	40	35	40
Brennan	2	41	38	40	30	29	30	33	31	29
Bugaresti	1	39	43	39	39	36	36	34	33	35
Franke	1	52	54	43	42	35	39	39	36	39
Davies	4	49	41	38	40	33	39	32	37	38
McFarlane	4	47	47	50	43	41	43	44	33	32
Rix	2	33	36	36	39	27	35	30	26	26
Fettig	1	37	45	45	39	36	35	36	36	34
Phipps	3	60	62	68	55	50	44	41	44	45
Chelmick	4	34	37	40	28	24	23	24	27	24
Friesen	4	36	36	40	38	35	34	37	33	35
Weidner	4	44	43	44	33	34	33	25	25	30
Meaney	4	43	37	32	40	38	42	39	40	36
Darling	2	53	52	46	50	51	46	38	42	40
Korzan	2	62	66	66	45	42	42	41	42	45
Moore	2	30	23	35	32	30	31	33	27	33
Bottrell	1	40	38	37	36	36	42	35	43	36
Roder	2	54	50	51	35	34	29	39	34	39
Armstrong	2	35	40	38	43	41	38	42	35	39
Aldridge	4	42	37	38	36	40	33	33	34	32
Bickwell	1	43	44	40	45	40	41	47	47	40

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Beyerstein	3	39	36	40	44	39	42	39	40	40
Bond	4	46	37	42	39	38	35	35	39	37
Bonkowski	1	45	42	45	41	42	42	31	35	33
Bromlee	3	37	36	32	34	31	33	32	32	30
Dobbin	3	41	40	44	39	35	38	41	43	40
Douglas	2	51	51	48	41	44	40	46	40	42
Hill	1	41	34	33	39	42	43	37	38	32
Lee	3	30	36	31	42	35	33	26	30	29
Lewin	2	42	41	40	41	40	38	34	32	33
Ratsoy	4									
Kuipers	2	40	42	43	43	36	38	38	33	35
Steele, T.	1	32	32	33	37	35	36	27	25	28
DeWolfe	3	51	53	50	36	35	42	43	44	40
Neudorf	3	34	40	38	40	41	38	45	42	40
Spiers	2	44	43	46	38	38	34	36	37	39
Milton	2	34	35	40	29	29	27	25	28	25
Steele, J.	4	28	29	30	35	36	34	32	32	30
Thomas	2	29	35	35	32	30	33	34	30	29
Speers	4	56	60	59	55	54	53	57	62	52
Tuckwell	1	53	43	45	45	39	45	44	40	44
Smith, M.	1	30	33	31	40	39	35	40	40	33
Fehr	3	46	36	45	36	33	36	31	32	31
Casavant	2	34	28	29	31	26	25	38	33	35
Barabash	3	50	43	44	53	52	50	54	50	48

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Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Stefaniuk	1	61	54	67	62	61	56	58	57	48
Gotte	3	60	60	61	56	52	52	50	44	42
Richter	1	32	32	33	28	25	24	29	28	27
Webb	2	57	56	58	52	43	50	39	33	38
Hawkins	1	59	56	60	55	53	52	49	51	49
Lyseng	1									
Glover	2	29	35	34	37	36	34	36	32	29
Nyberg	3	51	50	55	52	54	53	54	59	73
Bye	3	29	33	34	35	31	33	31	25	25
Harding	3	35	30	29	32	28	27	26	30	27
McLennen	4	28	33	36	40	30	30	36	34	33
Vanleerusum	2	56	56	54	45	48	40	47	45	40
Schneider	1	45	45	38	50	45	44	52	46	46
Laughington	2	30	30	35	32	33	32	30	29	27
Poworoznik	1	37	45	50	50	50	48	41	39	35
McLachlin	2	46	48	42	37	39	40	37	36	42
Williams	4	35	36	37	40	46	50	42	50	42
McDowell	3	50	55	55	53	45	46	53	42	39
Scott	2	43	50	40	48	42	43	42	44	34
Goodwin	2	56	56	62	48	53	46	53	60	53
Gehon	2	51	57	54	47	39	43	56	40	48
Redding	4									
Sanderson	4	35	37	32	32	30	28	28	25	26
Michniuk	4	43	39	42	40	38	33	40	40	38

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Currie	4	42	40	43	43	43	40	44	40	38
Ingram	4	52	57	45	64	68	64	56	54	58
Radloff	3	33	29	29	40	42	41	32	31	30
Vanleeuwen	3	34	31	34	43	48	49	43	45	43
Bishop	2	53	52	58	58	50	49	38	38	39
Kirillo	4	41	47	45	45	48	45	43	44	45
Sterling	1	30	34	36	50	48	45	44	47	45
Entwhistle	1	41	42	44	45	50	48	48	47	37
Goertz	3	37	34	29	39	38	49	32	35	35
Briscoe	4	39	48	44	44	43	45	40	33	38
Oussoren	3	49	48	50	65	64	65	64	61	55
Vissor	1	40	42	53	53	53	51	50	46	40
Hatch	4	37	50	50	53	54	52	45	53	46
Stevenson	3	44	42	38	41	40	50	46	40	42
Stewart	3	36	39	34	44	44	51	50	46	46
Mckone	3	37	35	28	36	31	35	37	37	30
Vestby	1									
Lassey	3	35	47	42	45	40	38	51	62	50
Degaust	2	32	33	29	33	30	29	33	24	26
Flett	4	52	52	58	47	44	40	46	47	50
Prychitko	1	26	30	29	28	26	28	24	23	23
Ritchie	1	30	26	27	28	26	26	29	26	27
Rusnak	3	37	35	34	38	33	35	29	28	30
Smith, C.	1	59	48	60	52	50	50	53	50	50

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Hore	1	25	26	24	26	28	29	27	26	27
Kish	2	27	35	33	31	31	29	36	37	34
Kraychy	4	31	33	30	36	36	36	41	36	33
Leite	1	31	31	33	42	41	36	32	36	39
Daryluk	2									
Pennyfather	2	42	43	45	45	50	49	50	52	48
Wildman	3	39	38	33	47	44	44	41	43	41
Milne	4	51	45	44	43	37	34	36	35	45
Harris	1	32	31	32	41	41	46	34	33	35
Leveniuk	3	53	50	48	48	47	47	45	46	45
Pedersen	4	45	35	39	34	39	37	44	36	40
Vaage	4	45	42	41	43	46	45	40	39	42
Earnshaw	4	39	43	46	45	42	38	41	39	43
Kozub	1	44	51	50	35	30	34	33	35	29
Rust	2	35	30	32	28	28	25	30	27	30
McCorchuk	3	49	44	40	39	33	37	39	35	41
Robinson	4	53	50	55	49	46	46	45	45	42

POST-TRAINING TEST

(Auxillary Recorder)

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Northcott	3	54	49	52	41	41	41	38	34	40
Brennan	2	40	37	40	30	30	30	32	30	29
Bugaresti	1	42	44	41	41	38	38	36	35	37
Franke	1	52	58	45	45	37	40	40	38	40
Davies	4	48	43	39	42	34	38	34	37	38
McFarlane	4	44	45	50	42	40	40	43	32	30
Rix	2	32	37	34	42	40	33	28	26	25
Fettig	1	38	45	45	38	35	34	35	35	33
Phipps	3	60	61	66	55	48	43	41	43	46
Chelmick	4	34	37	40	30	24	26	25	27	23
Friesen	4	36	35	38	38	34	33	36	34	35
Weidner	4	42	44	43	35	37	33	28	24	28
Meaney	4	42	36	30	39	34	42	38	39	36
Darling	2	52	50	47	48	49	45	38	42	40
Korzan	2	63	65	66	48	44	42	43	42	45
Moore	2	29	21	36	31	30	30	31	26	31
Bottrell	1	38	37	37	36	36	41	35	41	35
Roder	2	53	49	51	38	33	30	40	33	39
Armstrong	2	36	41	38	43	41	37	43	35	39
Aldridge	4	41	37	38	36	38	32	31	33	32
Bickwell	1	42	43	40	44	38	40	46	46	39

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Beyerstein	3	38	36	38	43	40	41	40	40	40
Bond	4	46	37	43	41	38	35	37	40	39
Bonkowski	1	44	43	44	40	40	40	33	34	31
Bromlee	3	35	35	30	32	30	31	30	30	28
Dobbin	3	40	39	43	37	36	37	39	41	39
Douglas	2	49	49	46	40	42	39	41	43	41
Hill	1	38	27	42	41	36	36	37	38	32
Lee	3	30	36	30	42	35	38	25	29	29
Lewin	2	41	40	38	41	38	37	33	31	33
Ratsoy	4									
Kuiper	2	39	41	42	42	35	36	37	32	34
Steele, T.	1	30	30	32	36	33	34	28	28	29
DeWolfe	3	50	52	50	38	33	40	42	43	38
Neudorf	3	33	40	39	40	41	38	45	42	39
Spiers	2	44	43	46	39	41	34	37	38	39
Milton	2	32	33	38	31	28	30	27	28	24
Steele, J.	4	25	26	29	33	34	32	30	31	29
Thomas	2	27	34	33	30	30	32	33	29	27
Speers	4	55	57	58	54	53	52	56	62	50
Tuckwell	1	50	42	45	45	38	45	38	38	43
Smith, M.	1	52	50	47	56	55	54	40	40	32
Fehr	3	45	33	44	35	32	37	30	31	30
Casavant	2	35	28	29	32	27	26	40	33	35
Barabash	3	47	40	42	51	51	48	52	47	43

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Stefaniuk	1	62	55	66	62	66	55	58	57	47
Gotte	3	58	57	59	54	49	50	47	40	39
Richter	1	30	30	30	26	33	22	27	25	24
Webb	2	57	55	58	52	45	49	39	34	39
Hawkins	1	57	54	57	52	50	50	45	48	45
Lyseng	1									
Glover	2	31	37	37	40	40	37	38	35	30
Nyberg	3	51	50	56	53	54	53	54	54	73
Bye	3	30	35	35	35	31	33	30	27	27
Harding	3	34	29	29	31	28	28	25	29	27
McLennen	4	28	35	38	41	33	30	37	34	34
Vanleerusum	2	58	57	53	45	48	37	48	46	44
Schneider	1	46	46	39	50	47	45	53	48	45
Laughington	2	30	30	36	33	35	32	30	30	29
Poworoznik	1	38	45	50	50	50	48	41	39	35
McLachlin	2	37	39	44	38	40	41	38	37	43
Williams	4	36	35	38	40	46	50	41	48	42
McDowell	3	50	55	55	53	47	46	54	43	40
Scott	2	43	50	41	48	42	43	42	40	34
Goodwin	2	59	57	63	48	52	46	51	60	53
Gehon	2	50	56	55	46	39	43	56	40	48
Redding	4									
Sanderson	4	36	37	32	31	31	28	26	25	24
Michniuk	4	42	38	42	38	33	32	39	39	38

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Currie	4	43	42	52	43	42	42	45	40	40
Ingram	4	51	57	45	65	70	66	57	55	60
Radloff	3	33	29	28	39	42	40	34	32	31
Vanleeuwen	3	35	31	33	43	48	49	45	45	45
Bishop	2	53	52	58	59	51	49	37	37	39
Kirillo	4	42	47	45	55	48	45	43	44	45
Sterling	1	31	32	36	50	47	45	44	47	45
Entwhistle	1	43	44	43	44	50	48	48	46	38
Goertz	3	37	35	30	38	38	48	32	35	35
Briscoe	4	39	49	40	40	42	45	41	35	39
Oussoren	3	48	47	50	65	64	65	65	62	55
Visser	1	39	41	54	53	52	50	50	46	38
Hatch	4	37	50	50	54	55	53	47	53	47
Stevenson	3	42	39	37	39	38	48	45	37	40
Stewart	3	34	36	30	40	39	47	47	43	44
Mckone	3	34	32	26	33	28	32	34	35	27
Vestby	1									
Lassey	3	32	44	39	41	38	35	48	61	48
Degaust	2	29	30	27	33	29	28	30	23	25
Flett	4	49	50	55	46	43	39	44	45	47
Prychitko	1	24	27	27	25	25	26	22	22	22
Ritchie	1	29	25	26	27	27	27	28	25	26
Rusnuk	3	34	33	32	36	30	33	28	26	29
Smith, C.	1	58	50	63	50	48	50	53	49	49

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Hore	1	23	25	22	24	27	28	25	24	27
Kish	2	25	33	32	30	30	27	36	36	34
Kraychy	4	29	32	28	34	35	36	40	34	32
Leite	1	28	28	29	38	38	33	28	33	37
Daryluk	2									
Pennyfather	2	39	40	43	44	48	47	45	48	44
Wildman	3	38	37	32	46	43	43	40	42	40
Milne	4	50	44	43	45	37	34	37	35	45
Harris	1	35	33	35	43	44	43	37	34	37
Levenick	3	53	50	49	48	ʼ8	49	47	48	48
Pedersen	4	46	37	39	35	38	38	44	40	41
Vaage	4	47	41	46	43	45	45	42	40	42
Earnshaw	4	40	44	48	45	42	39	43	37	43
Kozub	1	44	50	50	36	33	33	34	35	28
Rust	2	35	31	33	31	29	27	30	28	30
McCorchuk	3	48	43	40	40	32	37	38	33	40
Robinson	4	48	46	46	52	48	54	42	45	40

POST-DETRAINING TEST RESULTS

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Northcott	3	39	33	38	34	32	31	35	30	37
Brennan	2	36	35	33	35	33	33	34	35	35
Bugaresti	1	32	37	36	44	42	43	44	41	41
Franke	1	40	48	41	30	39	41	32	31	34
Davies	4	36	35	31	38	39	39	50	45	48
McFarlane	4	38	42	49	44	40	49	35	35	35
Rix	2	37	33	36	36	37	33	37	39	28
Fettig	1	40	49	43	39	40	39	32	35	37
Phipps	3									
Chelmick	4	50	47	37	35	30	33	31	37	39
Friesen	4									
Weidner	4	32	37	36	31	29	30	33	30	29
Meaney	4	35	37	33	39	40	40	42	41	43
Darling	2									
Korzan	2	75	70	77	50	49	50	45	41	40
Moore	2	35	40	43	35	33	35	35	38	34
Bottrell	1	34	43	37	39	40	35	37	36	36
Roder	2	42	40	50	41	39	44	34	30	30
Armstrong	2	45	42	45	48	45	49	46	45	46
Aldridge	4	36	36	35	39	38	37	34	32	32
Bickell	1	35	39	45	49	42	51	37	40	41

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Beyerstein	3	40	43	52	46	40	42	36	46	38
Bond	4									
Bonkowski	1	38	36	35	40	43	44	41	38	41
Bromlee	3	29	31	34	40	36	30	31	31	35
Dobbin	3	33	35	32	44	42	40	34	35	35
Douglas	2									
Hill	1	40	39	37	37	38	34	33	30	32
Lee	3	32	32	32	30	32	34	33	31	32
Lewin	2	34	32	36	41	41	40	33	30	34
Ratsoy	4									
Kuipers	2	47	46	43	44	57	45	76	72	61
Steele, T.	1	30	29	32	33	30	33	29	32	29
DeWolfe	3	44	44	45	41	47	41	42	45	43
Neudorf	3	23	30	28	38	35	31	40	35	33
Spiers	2	40	42	38	40	40	34	37	35	38
Milton	2									
Steele, J.	4	30	39	35	38	37	40	40	39	43
Thomas	2	29	31	30	30	31	30	36	35	38
Speers	4	61	54	65	65	61	60	62	62	60
Tuckwell	1									
Smith, M.	1	31	30	27	38	37	38	33	36	35
Fehr	3	40	44	48	35	36	34	36	30	30
Casavant	2									
Barabash	3	41	45	45	46	40	40	40	41	38

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Stefaniuk	1	47	42	41	60	61	58	59	54	53
Gotte	3	70	62	62	55	54	57	49	73	60
Richter	1	31	36	35	27	25	35	30	22	28
Webb	2	55	60	56	46	45	44	39	40	48
Hawkins	1	46	46	50	47	45	43	50	51	48
Lyseng	1									
Glover	2	40	30	36	41	39	36	32	33	35
Nyberg	3	58	57	54	55	52	53	50	60	64
Bye	3	26	22	21	33	36	35	32	32	25
Harding	3	30	27	30	33	31	32	35	30	30
McLennen	4	39	36	34	36	33	35	31	39	39
Vanleerusum	2	57	58	62	50	53	45	48	41	40
Schneider	1	58	54	52	43	47	41	47	35	37
Laughington	2	45	35	42	39	38	39	39	33	35
Poworoznik	1	45	48	45	48	51	46	49	56	60
McLachlin	2	44	37	36	40	38	34	35	33	37
Williams	4	30	30	30	40	40	38	56	53	56
McDowell	3	52	56	55	46	36	41	36	35	33
Scott	2	35	46	39	46	49	49	40	39	39
Goodwin	2	71	70	70	58	63	52	61	60	68
Gehon	2	40	40	36	42	50	45	45	47	47
Redding	4									
Sanderson	4	32	33	30	30	27	26	26	25	31
Michniuk	4									

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Currie	4	58	56	53	51	50	44	43	42	38
Ingram	4	63	80	70	57	58	53	65	48	50
Radloff	3	37	36	32	32	33	33	33	32	30
Vanleeuwen	3	50	50	45	48	45	45	45	42	44
Bishop	2									
Kirillo	4	53	50	51	51	48	46	52	43	45
Sterling	1	51	57	60	50	48	49	52	48	57
Entwhistle	1	47	48	46	48	44	46	44	40	40
Goertz	3	38	36	37	37	37	37	30	29	29
Briscoe	4	49	46	47	43	37	42	32	37	38
Oussoren	3	78	73	73	60	56	57	63	52	50
Visser	1	53	48	50	48	49	42	45	43	44
Hatch	4	56	58	61	53	60	66	57	59	53
Stevenson	3	40	32	43	48	39	37	41	41	41
Stewart	3	41	39	40	47	45	45	44	48	42
Mckone	3	41	38	40	39	38	35	36	30	30
Vestby	1									
Lassey	3	51	50	53	47	45	42	41	40	37
Degaust	2	22	24	21	29	29	28	35	27	30
Flett	4	58	62	57	49	58	59	69	60	62
Prychitko	1	30	32	33	39	36	38	28	27	27
Ritchie	1	20	20	28	21	20	23	23	19	21
Rusnak	3	34	36	34	39	36	36	39	42	43
Smith, C.	1	73	68	52	64	58	63	50	50	58

Name	Group	60 Degrees			90 Degrees			120 Degrees		
		1	2	3	1	2	3	1	2	3
Hore	1	31	30	27	26	28	27	27	31	37
Kish	2	34	30	32	32	38	39	32	31	35
Kraychy	4	25	30	33	40	37	37	34	34	33
Leite	1	27	30	27	31	30	29	26	29	28
Daryluk	2	32	35	35	30	33	31	32	32	38
Pennyfather	2	39	38	38	49	47	48	48	44	40
Wildman	3	48	48	35	39	38	36	35	35	35
Milne	4	38	44	42	34	34	32	43	42	39
Harris	1	41	45	43	39	37	34	35	31	30
Levenick	3	54	51	53	48	47	43	38	37	39
Pedersen	4	34	32	32	34	33	33	35	42	34
Vaage	4	47	41	42	41	40	43	41	37	43
Earnshaw	4	35	37	41	46	46	44	42	41	39
Kozub	1	46	51	44	39	38	37	39	37	47
Rust	2	29	30	30	31	33	31	30	27	27
McCorchuk	3	47	50	52	35	32	33	33	31	30
Robinson	4	48	39	46	50	47	47	45	42	45