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A study to compare the strength changes after training the abductor digiti minimi in young adults and in geriatric adults

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A STUDY TO COMPARE THE STRENGTH CHANGES AFTER TRAINING THE ABDUCTOR DIGITI MINIMI IN YOUNG ADULTS AND IN GERIATRIC ADULTS

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ABSTRACT

A paucity of research exists in the strength training and aging literature. Hettinger (1958) reported that strength declined with age and that older persons gained less with strength training than younger persons. This study altered Hettinger's design by using a different muscle and a different strengthening routine. The purpose of this study was to compare the effects of isometric strength training of the non-dominant left abductor digiti minimi muscles of young subjects and old subjects. The ten young female subjects, mean age 22.6 years, were all nursing students. The ten older female subjects, mean age 69.2 years, did not constitute a similar homogeneous group; although they all lived in the metropolitan area of Richmond, Virginia. All subjects were volunteers. Training consisted of each subject performing twenty maximal isometric contractions of the left abductor digiti minimi three times weekly for six weeks. A pretest and six weekly measurements of strength were made on a strain gauge. The results of this study are not in agreement with Hettinger's findings. Significant strength increases were found for the pretest-post-test measurements within each group at the same $P < .0001$ level. However, when the young and older groups were compared on the initial strength measurements, no statistically significant differences were found. Therefore the null hypotheses were accepted.

CHAPTER I

INTRODUCTION

Research in Gerontology is necessitated by the fact that the size of the older population in the United States is growing each year. In 1900, approximately 3.1 million persons or 4.1 percent of the American population were 65 years old or older. By 1970, these numbers had increased to almost 20 million persons, representing 9.8 percent. By 1977, the figure had increased to almost 23.5 million persons, constituting 10.9 percent of the total population in the United States. The Administration on Aging (1978) has projected that by the year 2000, 31.8 million Americans will be 65 years old or older. This will represent between 12.2 and 12.9 percent of the total American population. A concomitant increase is found in publicly financed health care for the aged population. Medicare reimbursements have climbed from $886.9 million in 1966 (Social Security, 1975) to $23.4 billion 1978 (Social Security, 1978).

Part of the cost of medical care for the geriatric population results from the number of accidents which older persons suffer. Accidents are the sixth largest cause of death in the 65 to 74 year old age group, accounting for 62 deaths per 100,000. In the 75 and over age group, accidents remain the sixth ranked cause of death, but the rate increases to 174 deaths per 100,000 (Accident Facts, 1978).

One factor that has been associated with accidents and medical care in the geriatric population is muscle weakness. Waller (1974) reported that 31 percent of 150 aged persons, treated at the emergency room of the Medical Center Hospital of Vermont, had limited mobility or stamina which he associated with decreased strength. Rodstein (1964) reported on 48 accidents which were suffered by 29 individuals. Twelve of these persons or 41 percent had muscle weakness or gait problems. Steinberg (1972) discussed the association of weakness of pelvic musculature, especially hip extensors, with gait disorders which are common among the elderly population. Kraus (1978) attributed disability among the geriatric age group to losses of aerobic capacity and muscle strength. Liss (1975) suggested that the incidence of hip fractures could be reduced in senior adults by improving their lower extremity strength and cardiopulmonary function. However, Andriola (1978) warned that muscle weakness, being a common complaint among elderly persons, must not be considered an innocuous characteristic of old age because it may be a symptom of pathology. Thus, muscle weakness must not be casually shrugged off as an insidious result of aging like wrinkles or gray hair, but loss of strength must be viewed as a possible serious neuromuscular, musculoskeletal, or rheumatological medical problem (Andriola, 1978; Swezey and Spiegel, 1979).

In the strength and aging literature, confusion exists about the magnitude of the age-related strength loss because of the varied amounts of strength decline that have been reported. Fisher and Birren (1947) stated that grip strength of the dominant hand declined 16.5 percent from age 25 to 60 years. Burke et al., (1953) found a 21.5 percent decline when comparing persons in their early twenties with persons in their early sixties. By the ages 75 to 79 the decline in strength was 38 percent. In a longitudinal study of 40 years, Asmussen, Fruensgaard, and Nørgaard (1975) reported a decline in mean grip strength of 27.7 percent in nineteen men with a mean age of 61 years. In the same study, a greater loss of mean grip strength, amounting to 36.7 percent, was found in six women, mean age 63.2 years. In contrast to these above reports, other investigators have not found any decline in grip strength in slightly younger males, aged 51 to 62 years (Petrofsky and Lind, 1975) or in males aged 56 to 57 years (Damon, 1965). The confusion in this literature stems from these apparantly conflicting reports.

Perhaps the amount of age-related strength loss is not as pertinent to physical therapists as is the amount of strength that older persons can gain; because by increasing muscle strength, some of the common geriatric medical problems could be reduced (Liss, 1976; Steinberg, 1972; Kraus, 1978). Several studies have indicated that aged subjects did increase strength after exercising. Hettinger (1958) reported that strength gains were found in older men, mean age 58.5 years, and in older women, mean age 60.7 years; however, when compared to strength gains in men, ages 20 to 30 years, the older subjects gained less than 40 percent of what the younger subjects gained. Similarly, Liemohn (1975) reported that five men in their eighth decade of life gained strength in bilateral elbow flexion and extension and in bilateral knee flexion and extension; but none of the eight muscle groups showed significant increases in strength. In contrast, five middle-aged men in their fifth decade of life significantly increased strength in three of the eight muscle groups. These two studies have indicated that older persons gained strength with training, but the gains were not as great as in middle-aged or younger persons.

However, there is a paucity of research dealing with the effects of strength training on the geriatric population, especially when compared to the effects of strength training on younger persons. Consequently, this study was designed to investigate the comparability of strength training on younger and older samples. The purpose of the study was to answer the following questions: How much strength can older persons gain during six weeks of isometric strength training? How much strength can younger persons gain during the same strength training routine? How do the strength gains in older persons compare with those in younger persons?

SIGNIFICANCE OF THE STUDY

There are several reasons why these questions need to be addressed. First, the great majority of strength training studies have been done with young subjects (Hellenbrandt and Houtz, 1956; Delorme, 1945; Rasch, 1963; Hansen, 1963). However, as previously pointed out (Hettinger, 1958; Liemohn, 1975), the ability to gain strength declined with age. This suggests that senile muscle does not respond to strength training exactly as a younger muscle. Consequently, further research is necessary to clarify the strength training ability of older persons.

A second reason for raising these questions is that Hettinger's study (1958) was the only one that actually trained young and old persons. But, the number of subjects was small, 3 women and 4 men, and the mean ages were relatively young, 60.7 years and 58.5 years, respectively. Based on the results of only one study, it is of dubious validity to generalize that older persons cannot benefit from strength training as much as younger persons. Thus, the question is relevant, and unanswered to date.

If there is a difference between young and old patients in ability to strengthen, the physical therapist should be aware of this so that realistic goals may be established. By avoiding unrealistic goals, the therapist will keep the costs of physical therapy care to a minimum. If there is no difference in the strengthening abilities of young and old persons, the physical therapist may be dealing with more than a simple age-related problem of muscle weakness if a geriatric patient fails to gain strength (Andriola, 1978). Without the knowledge of the potential to strengthen geriatric patients, the physical therapist may attribute a patient's failure to gain strength to poor motivation and such a mistake must be avoided.

STATEMENT OF THE PROBLEM

This study compared the effect of a six week course of isometric training exercises on the weekly and the cumulative strength changes in the non-dominant abductor digiti minimi muscles of young adults with those of geriatric adults.

STATEMENT OF THE HYPOTHESES

The first null hypothesis states that there is no significant difference between the change in isometric strength of the non-dominant abductor digiti minimi muscles of young adults and that of geriatric adults after an isometric strength training routine conducted three times weekly for 6 weeks.

The second null hypothesis states that there is no significant difference between young adults and that of geriatric adults in the change of isometric strength of the non-dominant abductor digiti minimi from week to week during a six week isometric training period.

ASSUMPTIONS AND LIMITATIONS OF THE STUDY

1. Limitations existed in the samples. First, the samples were limited to females who were right hand dominant. Second, both young adult and geriatric adult samples were limited to ten subjects each. Third, the young adult subjects were all nursing students at the Medical College of Virginia, Richmond, Virginia. Possibly the homogeneity of the young adults was greater than that of the geriatric adults because the latter had no similar association or membership in a club, church or organization. The geriatric adults were all drawn from the metropolitan area of Richmond, Virginia. Futhermore, it was assumed that all subjects would put forth their best efforts.
2. Limitations existed in the instrumentation because the tension which was generated on a strain gauge was not recorded on a polygraph as was done by others (Edwards, 1978; Liberson and Asa, 1958). However the measurements of strength were consistantly taken as the highest reading on the voltmeter. This procedure was recognized as possibly introducing a small degree of error.
3. The strength training routine was limited to 20, six-second isometric contractions, three times weekly for six weeks. Alteration in one or more of these variables may have yielded different results. Also, it was assumed that the training routine provided a sufficient stimulus over a sufficient period of time so that strength gains would manifest.

DEFINITIONS OF TERMS

Strength: For this study, strength is defined as the isometric tension exerted by the abductor digiti minimi on a strain gauge with its line of force placed perpendicularly to the middle phalanx of the fifth finger.

Young adult: For this study, young adult is defined as a person between the ages of 20 and 29 years (Hettinger, 1961).

Geriatric adult: For this study, geriatric adult is defined as a person between the ages of 65 and 74 years (Rodahl and Issekutz, 1962).

Maximal isometric strength: For this study, maximal isometric strength is defined as the highest tension developed and recorded with a strain gauge. The best of three trials will be accepted as the maximal isometric strength (Astrand and Hedman, 1963).

Non-dominant: For this study, non-dominant is defined as the hand which is not used to write or throw a ball (Patterson, 1965).

ORGANIZATION OF THE REMAINING CHAPTERS

The remaining chapters of this thesis are organized so that Chapter 2 presents a review of the pertinent literature; Chapter 3 describes the procedures of the experiment including the method of data collection and analysis; and Chapter 4 presents the results of the investigation. Chapter 5 discusses possible interpretations of the stated results, offers recommendations for further study, and makes conclusions based on this completed study.

CHAPTER II

LITERATURE REVIEW

This literature review is divided into four (4) sections. The first section describes the age-related decline in strength. The second section describes the age-dependent morphological changes in muscle that may be primary factors in strength loss. The third section deals with the results of strength training of aged subjects. The final section presents the rationale for the selection of the abductor digiti minimi as the muscle to be trained.

THE AGE-RELATED DECLINE IN STRENGTH

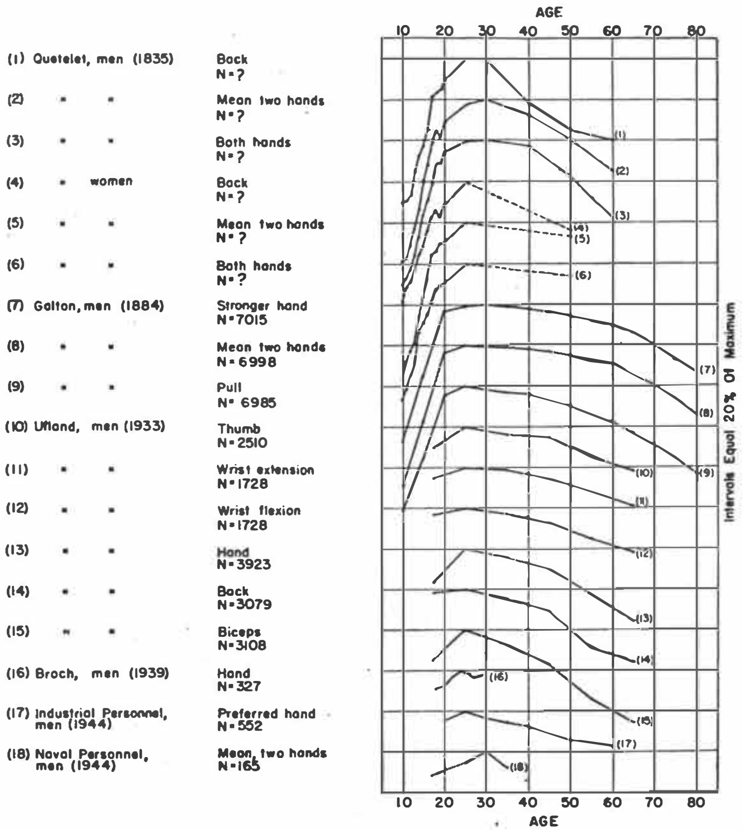
An age-related decline in muscle strength has been well documented. Burke et al. (1953) measured grip strength in 311 normal males, between the ages of 12 and 79 years. The highest mean strength, 121 pounds was found in the 11 subjects comprising the 20 to 24 year old group. The mean strength was 95 pounds in the 11 subjects in the 60 to 64 year old group which represented a 21.5 percent decline from the strongest group. In the 4 subjects in the 75 to 79 year old group, the mean strength was 75 pounds which was a decline of 38 percent. The grip strength of the 75 to 79 year old age group had ebbed to a level similar to the 73 pounds mean grip strength in the 12 to 15 year old group. These data are presented in Table 1.

Fisher and Birren (1947) studied dynamometric grip strength in 552 male manual workers; between the ages of 18 to 68 years. The highest mean strength, 56.05 kilograms, was in the 23 to 27 year old group, while the lowest mean score, 46.8 kilograms, representing a 16.5 percent decline from the maximum strength, was in the 53 to 68 year old group. These data are represented in Table 1. Fisher and Birren used the data from other investigators, to plot curves relating strength and age. The close parallel which was found among the curves, verified the finding that strength declined with age. These authors indicated that this evidence was especially persuasive because the curves had been constructed from the data of several authors who reported their findings over a 100 years time span on various muscles and with different measuring devices. These curves are presented in Figure 1. Fisher and Birren stated that job imposed muscle disuse could explain part of the decrease in strength with age. However, they indicated their 552 subjects were employed in jobs which required approximately equal activity. The implication was that a decline in strength was age-dependent.

Similarly, Astrand and Hedman (1963) reported a decline in isometric strength of elbow flexors in 71 males, ages 50 to 64 years, who were employed as drayman, manual laborers. The mean isometric strength of the elbow flexors was 25 kilograms in the 44 subjects in the 50 to 54 year old age group; 26 kilograms in the 22 subjects in the 55 to 59 year old group; and 21 kilograms in the 5 subjects in the 60 to 64 year old age group. When compared to the youngest group, the mean strength of the oldest subjects declined 16 percent during this 15 year life span. But, no discussion was offered to explain why the mean strength of the middle group was highest.

FIGURE 1

STUDIES OF STRENGTH RELATED TO AGE COMPILED BY FISHER AND BIRREN (1947)



Values are plotted as per cent of the maximum. Each curve is drawn to a different baseline, separated by 20% from the next.

TABLE I

STUDIES OF STRENGTH RELATED TO AGE

AUTHOR	MEASUREMENT		n	AGES	STRENGTH		PERCENT OF CHANGE
Asmussen Fruensgaard and Nørgaard 1975	grip stronger hand	M	19	21-27	55.8±7.0	kg.	0%
		F	6	22-26	33.8±3.9		0%
		M	19	53-64	40.3±6.8		↓27.8%
		F	6	60-66	21.4±5.1		↓36.7%
Astrand and Hedman 1963	elbow flexion stronger arm		44	50-54	25 ± .5	kp	0%
			22	55-59	26 ± .8		↑ 4%
			5	60-64	21 ±1.0		↓16%
Burke et al. 1953	grip dominant hand		97	12-15	73 ± 22	lb.	↓39.7%
			11	20-24	121 ± 16		0%
			9	65-69	100 ± 25		↓17.4%
			3	70-74	69 ± 2		↓43.0%
			7	75-79	75 ± 22		↓38.0%
Fisher and Birren 1947	grip preferred hand		82	23-27	56.1	kg.	0%
			20	53-68	46.8		↓16.5%

TABLE I (continued)

AUTHOR	MEASUREMENT	n	AGES	STRENGTH		PERCENT OF CHANGE
Kuta	grip right					
Pârízková	hand					
and Dycká	group					
1970	intense	17	64.6	47.0±7.9	kg.	0%
	exercise	10	73.9	39.9±5.4		↓15.1%
	recreation	17	65.3	45.1±4.7		0%
	exercise	17	73.9	38.0±4.3		↓15.8%
	non-active	60	65.3	43.7±7.8		0%
		11	74.4	37.9±5.0		↓13.3%
Montoye and	grip, sum of	104	10	23.6±8.8	kg.	↓77.2%
Lamphiear	left and	198	25-29	103.6±15.6		0%
1977	right hands	144	50-59	89.4±16.1		↓13.7%
Petrofsky and	grip	25	22-29	48.8	kg.	0%
Lind		23	30-39	52.5		↑7.9%
1975		25	41-49	48.5		↓0.6%
		27	51-62	47.5		↓2.7%
Shock and	combined	150	20-69	150	kg.	0%
Norris	arm and	26	70-79	130		↓13.3%
1970	shoulder	4	80-89	105		↓30.0%

The work by Petrofsky and Lind (1975) may be interpreted to support Fisher and Birren's (1947) contention that job-related muscle disuse may be a factor in the decline of muscle strength during senesence. Petrofsky and Lind (1975) evaluated grip strength in 100 industrial workers of which 27 were between the ages of 51 and 62, mean age 54.8 years. The remaining 73 subjects were distributed almost equally among the third, fourth, and fifth decades of life. Their results indicated that there were no significant differences in grip strength among the four age groups. The mean strengths were 48.8, 52.5, 48.5 and 47.5 kilograms for the 4 different age groups. These data are presented in Table 1.

A similar finding was reported by Damon (1965) in a longitudinal study of 108 males. Right hand grip strength was 52.6 kilograms when the subjects were college freshmen, mean age 18.6 years. Thirty-seven to thirty-eight years later, when the mean age of the same subjects was 57.1 years, the mean grip strength was 53.2 kilograms. Range and standard deviations were not presented. Although Damon did not discuss the occupations or activities of daily living of his subjects, he did question the validity of the age-dependent strength loss that had been reported by studies using the cross-sectional design (Fisher and Birren, 1947; Astrand and Hedman, 1963; Burke et al., 1953).

Damon's subjects may have been too young to reflect the age-dependent decline in strength, when viewed with the results of Shock and Norris (1970). These investigators developed a composite strength score from four isometric measurements on a hand dynamometer. They studied 218 subjects between the ages of 20 to 89 years. They reported that between the third and seventh decades of life there was no decline in strength; mean score was 150 kilograms. The age-related strength loss was first found in the 26 subjects in their 8th decade of life, and a greater decline was reported for the 4 subjects in the 9th decade of life. The mean scores were 130 and 105 kilograms which represented losses of 13.3 percent and 30 percent for the 8th and 9th decades, respectively. These data are contained in Table 1.

Montoye and Lamphiear (1977) reported on the results of a comprehensive gerontologic study of a community of 6000 persons. They reported that strength increased from age 10 years to a peak in the 25-29 year old group, for males and females. These investigators reported that there was little loss of strength until after the age of 50 years. A combined total of left and right grip strength was 103.6 kilograms at ages 25-29 and 89.4 kilograms at ages 50-59 for males and 52.2 kilograms and 44.0 kilograms for the same ages in females. These represented declines of 13.7 percent for males and 11.9 percent for females. These data are included in Table 1.

Kuta, Pâríźková, and Dyčká, (1970) studied the effects of life-long physical activity on strength measurements in 132 old men. Bilateral grip, flexion and extension of the elbows and knees were measured and complied into an average strength score. The sample was divided according to chronological age into a group of 60-69 year old persons and a group of 70-79 year old persons. Each of these groups was further sub-divided into categories according to levels of physical activity. The intensively exercised group consisted of persons who for at least 15 years practiced and competed in intense physical training such as skiing, playing football, and canoeing. The recreationally exercised group was composed of persons engaged in physical activity, but only on a recreational basis. The inactive group was not engaged in any physical training. In the 60-69 year old subjects, the intensively exercised and the recreationally exercised groups were significantly stronger than the inactive group by 15.7 percent and 11.5 percent, respectively. In the 70-79 year old group, the intensively exercised group was 8.7 percent stronger than the inactive group, but only the strength measurements of elbow flexion and knee extension were significantly different. The recreationally exercised group was 3 percent stronger than the inactive group, although the differences were insignificant for all measurements. The data for grip strength are presented in Table 1. These investigators suggested that life-long regular exercise was the reason for the significant differences found between the exercised groups and the non-exercised group. Despite the favorable influence of exercise on strength, these same researchers reported that on all but one measurement, strength declined between the 7th and 8th decades.

From the above reviewed studies, several inconsistancies are gleaned. First, the ages, are not identical, for example, 53-68 years (Fisher and Birren, 1947), 50-59 years (Montoye and Lamphiear, 1977), 80-89 years (Shock and Norris, 1970), and 50-64 years (Astrand and Hedman, 1963). Second the time span of years over which the strength decrease was found has varied with declines of: 27.8 percent over 40 years (Asmussen, Fruensgaard and Nørgaard, 1975); 16 percent over 15 years (Astrand and Hedman, 1963); 16.5 percent over 35 years (Fisher and Birren, 1947); 2.7 percent over 30 years (Petrofsky and Lind, 1975); and 15.1 percent over 10 years (Kuta, Pařízková, and Dycká, 1970). Third, the sample sizes of the young and older groups were usually not identical, most often the older groups were small in number. For example, Burke et al., (1953) compared 97 young subjects with 7 old subjects. Fourth, the methods of strength measurement were often dissimilar; for example, Shock and Norris (1970) combined arm and shoulder strength; Montoye and Lamphiear (1977) summed grip strength; and Fisher and Birren (1947) used preferred hand grip strength. The cross-sectional methodological design was commonly employed (Burke et al., 1953; Fisher and Birren, 1947; Shock and Norris, 1970), but the longitudinal design was also used (Asmussen, Fruensgaard and Nørgaard, 1975; Damon, 1965).

With the above incongruities in mind, several conclusions may be cautiously drawn from this literature review. First, strength declines with age; however, the decline may not manifest until the seventh or eighth decade of life (Shock and Norris, 1970). Second the amount of decline is influenced by occupational and recreational activities (Astrand and Hedman, 1963; Petrofsky and Lind, 1975; Kuta, Pařízková and Dycká, 1970).

MORPHOLOGIC CHANGES IN MUSCLE

Several morphologic changes in muscle have been described that may explain why a loss of strength is found with age. Inokuchi et al., (1975) studied biopsies from the rectus abdominus muscles of 135 human autopsy cases, ages from the third to the ninth decades of life. All subjects who showed signs of muscle disease, extreme emaciation, or extreme muscular hypertrophy were excluded from their results. These investigators found that muscle cytoplasm decreased with age so that by the ninth decade of life, fat made up the largest percentage of the muscle components, 50.3 percent in the males and 58.1 percent for the females. Additionally, they (Inokuchi et al., 1975) reported that the number of muscle fibers in a cross-sectional area decreased with age. The mean number of muscle fibers in the rectus abdominus muscle was greatest during the third decade of life. From this peak, the decline in the number of muscle fibers was 46.5 percent in the seventh decade; 55.2 percent in the eighth decade; and 78.3 percent in the ninth decade.

Similar findings have been reported in laboratory animals. Gutmann and Hanzlíková (1966) reported the mean number of soleus muscle fibers decreased 25.4 percent from 2357 fibers in the 4 month old adult rats to 1758 fibers in the 24 month old-aged rats.

The same results were found by Rowe (1969) in the anterior tibialis, extensor digitorum longus, soleus, sternocleidomastoid and biceps brachii muscles of young (137 days) and old (750 days) mice. The loss of muscle fibers was statistically significant in the biceps brachii muscles of the male mice and in the extensor digitorum longus and soleus muscles of the female animals. These declines were 13.4 percent, 16.1 percent, and 21.0 percent respectively. In addition to the loss of fibers, Rowe reported that muscle weight declined significantly in the male animals in each of the studied muscles except the soleus. In contrast the female mice suffered very little loss of muscle weight; however, Rowe pointed out that this may have been related to the significant increase ($P < .05$) in body weight which was found in the females, only.

An identical finding was reported by Yiengst, Barrows, and Shock (1959). They studied ten male and ten female rats between the ages of 12 and 14 months and the same number of rats between the ages of 24-27 months. The muscle weight declined significantly with age ($P < .003$) in the male but not in the female rats. Like Rowe's (1969) work with mice, the older female rats had significantly increased body weights ($P < .001$); whereas the male animals lost body weight.

Using these same rats, Andrew, Shock, Barrows and Yiengst (1959) described the histological changes in the calf muscle of rats up to the age of 33 months. They described that with age, muscle fibers are lost and replaced by fibrous connective tissue and adipose tissue. Complete quantitative data were not presented. These descriptive findings are similar to those observed by Inokuchi et al., (1975) in human muscle.

Further support for this finding of increased connective tissue comes from Haseeb and Patnaik (1978), who studied the collagenous and non-collagenous protein in skeletal muscles of male garden lizards. Non-collagenous proteins were not explicitly defined; however it was implied that this term connoted contractile and sarcoplasmic proteins of muscle. These investigators reported that in the fully mature and older lizards, collagenous protein increased and the non-collagenous proteins decreased. It was suggested that the effects of these changes were to increase the tensile strength of older muscle, to reduce the flexibility, and to hamper the muscle metabolism by interferring with the transport of oxygen and nutrients to the muscle cells.

Evidence to uphold Haseeb's and Patnaik's first suggestion was found in a non-invasive clinical study by Botelho, Cander, and Guiti (1954). They measured the passive tension of the adductor pollicis brevis in eleven student nurses, ages 18 to 24 years and in thirteen older females, ages 45 to 61 years. Passive tension was defined as the amount of tension developed as the muscle was passively stretched and during which no electrical activity was recorded on an electromyograph. These investigators found that the passive tension was greater in the older group than in the younger group. When the muscle was 100 to 103 percent of its minimum length, the passive tension was 50 grams and 81 grams in the younger and older group, respectively. When the muscle was stretched to 120 to 130 percent of its minimum length, the passive tension was 461 grams and 1281 grams for the respective age groups. These researchers did not make any histological measurements, but they did allude to reports of age-related increases of connective tissue in skeletal muscles.

In conclusion of this section, several morphological changes in aged skeletal muscle have been described which may contribute to the strength loss that was discussed in the first section of this literature review. These changes which have been described in humans and in laboratory animals are: loss of muscle fibers (Inokuchi et al., 1975; Andrew et al., 1959; Rowe, 1969); loss of muscle weight (Rowe 1969; Yiengst, Barrows and Shock, 1959); increase of connective tissue within the muscle (Inokuchi et al., 1975; Andrew et al., 1959; Haseeb and Patnaik, 1978); and an increase in adipose tissue (Inokuchi et al., 1975).

This section has dealt with the age-related structural changes in muscle that may effect a loss in strength. However, it is important to recognize that muscle strength is influenced by metabolic and neuromuscular input and thus, changes in these systems would also effect a loss in strength. Gutmann and Hanzlíková (1972) reported that the synapse of the neuromuscular junction was wider and even separated in senile rat muscles. Mitolo (1968) described the electromyographic activity of the biceps brachii muscles in elderly humans as showing an abundance of polyphasic potentials. Also on electromyography, Carlson, Alston and Feldman (1964) found a decline in amplitude of motor unit potentials on maximal contraction and a decay in amplitude of interference pattern on sustained contractions in their elderly and not their younger human subjects. Sohal (1976) observed mitochordrial degeneration and fusion of small mitchordria into larger ones in the flight muscles of adult flies. Ermini (1976) reported that the age-dependent reduction in mitochondrial activity lead to a diminution of cell metabolism. Therefore, if aging muscle does not receive a nerve impulse, shows a degradation of motor unit electrical activity, or has no adenosintriphosphate for muscle contractions, strength will be lost even if there is no morphological change.

STRENGTH TRAINING OF AGED SUBJECTS

This section of the literature review will discuss articles that have dealt with the trainability of muscles of older persons. Although strength declines with age, some of the loss can be mitigated by strength training.

Several investigators have addressed the issue of strength training in the older population. Rodriquez, De Palma, and Daykin, (1965) trained 20 members of the Soldiers Domiciliary of the Vetern's Administration

Hospital, Los Angeles; mean age 69 years, range 55-81 years. The training stimulus of isometric contraction for a six second duration was administered five days per week for six weeks. No pre-test or post-test measurements were reported. Only actual increases in isometric strength were reported. The mean increases were 8.95 pounds in the arm flexors; 4.5 pounds in the arm extensors; 16.5 pounds in the leg flexors; and 10.3 pounds in the leg extensors. The report did not specify which muscles were measured, other than the flexors and extensors of the arm and leg.

deVries (1970) studied the effects of a vigorous physical conditioning regimen on 112 males, ages 52-87 years. The subjects performed calisthenics three times weekly and swam thirty minutes per week. Significant increases were found in isometric strength of the elbow flexors after six weeks and after forty-two weeks. The increases amounted to 6.4 percent at six weeks and 11.9 percent at forty-two weeks.

Similarly, Sidney and Shephard (1977) studied the effects of a 34 week physical conditioning program which consisted primarily of endurance activities. They reported significant increases in right but not left hand grip strength for males and females. These increases were 8.7 percent and 11.1 percent for the males and females respectively. Strength of the right knee extensors increased 8.6 percent in the men and 17.4 percent in the women, but was significant only in the latter. No explanation was offered to relate why grip strength increased, even though the training stimulus was an endurance activity designed to raise the heart rate above 120 beats per minute.

Liemohn (1975) compared the ability to strengthen the upper extremity and the lower extremity of 49 residents of the Iowa Soldier's Home. He divided the subjects, ages 41 to 80 years, into groups according to their chronological ages. Bilateral knee flexion and extension and bilateral elbow flexion and extension were measured for a total of 8 measurements. He reported that after 6 weeks, strength increases were found for each age group; however, the number of significant improvements in strength declined with each successive decade of life. The 5th decade group showed significant increases on 3 of the 8 measurements; the 6th decade group showed significant increases on 2 of the 8; the 7th decade group on 1 of the 8; and the 8th decade group showed significant increases on none of the 8 measurements. Liemohn stated the strengthening of muscle appeared to decrease with increasing age.

Perkins and Kaiser (1961) compared isometric and isotonic training routines in 15 females and 5 males, ages 62 to 84 years, mean age 73.6 years. Plantar flexors, knee extensors, and hip extensors were studied. The training stimulus was 3 repetitions of maximal isometric strength for 6 seconds and 3 repetitions of 1/2 maximal isometric strength. Training sessions were conducted 3 times each week for 6 weeks. The isotonic exercise group followed the 10 repetition maximum according to Delorme (1945). A plateau of strength was reached usually at 6 weeks, for both groups after which the exercise program was terminated. Composite strength increases were 56.88 percent for the isotonic exercise group and 45.82 percent for the isometric exercise group. Five months after cessation of the formal exercise program, the subjects' strength was remeasured. When compared to the initial pretest measurements, gains of 30.81 percent for the isometric group and 43.11 percent for the isotonic group remained. The rate of strength gain was nearly the same for both groups.

Hettinger (1958) reported on the effects of isometric strength training of the right and left elbow flexors and extensors in young and old subjects. His young sample was composed of 10 females, mean age 30.6 $\pm$ 9.1 years and

20 males, mean age 26.9 ± 6.6 years; while his older sample consisted of 3 females mean age 60.7 ± 3.8 years and 4 males, mean age 58.5 ± 1.2 years. The training stimulus was one daily maximal isometric contraction; duration of training varied between 8 and 23 weeks. The mean strength increases for elbow flexion were for the young, males 8.4 kilograms, females 2.9 kilograms and for the old males 2.4 kilograms, females 1.0 kilograms. For elbow extension the respective increases were 9.7, 3.0, 1.6 and 1.1 kilograms. These data are presented in Table 2.

Hettinger plotted a graph using the largest increase of strength to represent 100 percent. The young males gained the most strength; therefore all other strength changes were expressed as percentages of the increase found in the young males. When viewed in this manner, the older males gained less than 40 percent of what the young males had gained. The older females gained less than 30 percent of what the young males had gained.

TABLE 2

STRENGTH MEASUREMENTS FROM HETTINGER'S (1958) STUDY

		Elbow flexion in kg.		Elbow extension in kg.	
		PRE	POST	PRE	POST
Young	males	30.9	39.3	18.4	28.1
	females	17.6	20.5	10.8	13.8
Old	males	25.9	28.3	15.6	17.2
	females	15.8	16.8	9.7	10.8

In summary, strength gains have been found in older persons after training with isometric exercises (Rodriquez, De Palma, and Daykin, 1965; Liemohn, 1975: Perkins and Kaiser, 1961); with isotonic exercises (Perkins and Kaiser

1961); and with physical conditioning endurance activities (Sidney and Shephard, 1977; deVries, 1970). With increasing age, the gains in strength were less than those in younger persons (Liemohn, 1975, Hettinger, 1958).

THE MUSCLES THAT HAVE BEEN STUDIED IN THE STRENGTH AND AGING LITERATURE

It has been suggested that the age-related decline in strength may be influenced by occupational or recreational use of the muscles (Petrofsky and Lind, 1975; Fisher and Birren, 1947; Astrand and Hedman, 1963). The muscles that have been studied to date are used frequently in activities of daily living. They include muscles involved in grip, flexion and extension of elbows and knees (Kuta, Pārízková and Dycká, 1970); combined arm and shoulder motion (Shock and Norris, 1970); thumb adduction (Botelho, Cander, Guiti, 1954); and ankle plantar flexion and hip extension (Perkins and Kaiser, 1961). Liberson and Asa (1958) selected the abductor digiti minimi muscle to determine the efficacy of strengthening regimens because they believed that any change in strength would be the result of the experimental exercise and not of uncontrolled occupational or recreational activity. Using this same rationale, the abductor digiti minimi was chosen as the muscle to be trained in this study.

A second major reason for selecting the abductor digiti minimi was that the investigator wanted to minimize the discomfort of the strength training. Several researchers have reported that older subjects suffered more discomfort than younger ones with a training program (Kilbom et al., 1969; Mann et al., 1969; Tzankoff et al., 1972). Kilbom et al., reported that 48 percent or 30 out of 63 subjects suffered pain mostly in the knees, lower legs, and feet. Any cases of muscle soreness which "normally" accompanies a muscle training routine were not included in this 48 percent. Hellenbrandt and Houtz (1956) reported that their young subjects complained of tense, painful, and swollen muscles after doing maximal effort exercises. This finding has been reported by others (Hansen, 1963; Pierson, 1963; Rasch, 1963). Eleven out of fifteen upper class students from the California College of Medicine suffered "severe arm and forearm pains" after doing maximal isometric contractions of the elbow flexors (Pierson 1963). In that study, the subjects who did not suffer pain showed significantly greater strength gains than those subjects who suffered pain. Hansen (1963) reduced the number of daily isometric endurance contractions because of muscle tenderness in his nine young adult subjects, ages 23 to 26 years.

One other consideration influenced the selection of the abductor digiti minimi as the muscle to be studied. A rise in blood pressure occurs during isometric exercise which may represent a potential hazard to the cardiovascular system (Steinberg, 1971). A small muscle such as the abductor digiti minimi should have less of an effect on the cardiovascular system than a larger muscle such as the biceps or quadraceps. This concern was particularly important because clearance by a physician was not required of any subjects. Also, not every training session was conducted in a medical facility where immediate care would have been available.

This review of the literature cannot be terminated without explicit recognition that the abductor digiti minimi is not the only hypothenar muscle that is active during abduction of the small finger. Forest and Basmajian (1965) reported that the mean electromyographic activity during abduction of the small finger was greatest in the abductor digiti minimi; but the flexor digiti minimi brevis and the opponens digiti minimi were also significantly active. Additionally, the extensor digiti minimi muscle may also contribute to an abduction force of the small finger. Therefore, the term abductor digiti minimi is used in this thesis because that muscle is the prime mover in abduction of the small finger.

In summary of this literature review, the salient points are that the age-dependent strength loss may not occur until after the seventh or eighth decade of life; while use/disuse of the muscle in occupational or recreational activity appears to influence the strength loss. Age-related morphologic changes such as loss of muscle cells and muscle weight, may effect a decline in strength. Despite these derogatory changes, strength training in older persons has produced increases in strength. However, the muscles that have been exercised in past strength training programs are those that are likely to be used/disused in activities of daily living. In an effort to reduce this outside factor, the abductor digiti minimi muscle was chosen to be exercised in this study.

CHAPTER III

METHODS AND PROCEDURES

This chapter is divided into several sections. The first three are devoted to a discussion of the subjects, the process of their selection, and the pre-test procedures which they underwent. In the fourth section, the instruments that were used for the data collection are described. The final three sections of the chapter deal with the test position, the training sessions, and the methods of data analysis.

SUBJECTS

The subjects consisted of ten young females between the ages of 20 and 26 years and ten older females between the ages of 65 and 73 years, mean ages 22.6 and 69.2 years, respectively. The young subjects were all nursing students in their Senior year at Virginia Commonwealth University/Medical College of Virginia, Richmond, Virginia. The older subjects were not affiliated with any specific institution, but were drawn from the metropolitan area of Richmond, Virginia. None of the subjects were hospitalized or living in a nursing home; but several of the older women suffered from maladies that are common among the geriatric population. These included an arthritic left shoulder, bilateral hip fractures, angina pectoris, and an unknown neurologic disorder. All of the young subjects were healthy, as none were undergoing any medical treatment at the time of the study. All twenty subjects were right-hand dominant as determined by asking each subject which hand she wrote with and which hand she threw a ball with.

SUBJECT SELECTION

The training and test procedures were explained at a meeting of the Senior nursing class of the Medical College of Virginia. Nineteen out of sixty-seven persons volunteered. The volunteers were randomly selected after which, the subjects were contacted in order to confirm their willingness to participate. Two of the first ten subjects chose not to participate and another individual was left-hand dominant which excluded her from the study.

The training and test procedures were explained at four different Senior citizen congregational areas in Richmond, Virginia, including the Imperial Plaza, Newbridge Baptist Church, Westminister Canteberry, and two separate meetings at the Senior Center. At these locations, a total of 108 eligible subjects were contacted, of which 13 volunteered. One subject died before the project started and two others were left-hand dominant which eliminated them. The elderly sample was composed of the remaining ten volunteers.

PROCEDURES

Each subject read the Explanation of Procedures (Appendix A) and signed a Consent Form (Appendix B). On the pre-test day, each subject was taught how to perform an isometric contraction and each subject practiced five isometric contractions of the right abductor digiti minimi muscle. Only one older subject required more than 5 attempts to learn how to do this, in which case 7 contractions were necessary. A pre-test measurement of maximal isometric strength of the left abductor digiti minimi muscle was recorded one to three days before the training sessions commenced. Following Astrand and Hedman's method (1963), the best of three trials was accepted as maximal isometric strength. The six weekly measurements of all 20 subjects were made on the same days.

MATERIALS

The apparatus was devised to stabilize each subject's left forearm and hand, while simultaneously allowing for adjustments in order to accomodate different forearm and hand sizes. The materials that were constructed to provide this stabilization and accomodation are described in this section and are pictured in Figures 2 and 3.

A 34.3 by 57.2 centimeters platform was constructed to provide a base for a sliding platform, measuring 2.54 by 35.6 by 18.4 centimeters. This latter platform was allowed to slide between two aluminum runners 2.54 centimeters high and 33.0 centimeters long which were attached to the base platform. This was constructed to allow these stabilizing instruments to be adjusted for different wrist, hand, and finger sizes. Attached to the moveable platform was an Orthoplast [1] forearm cuff which was open at the top. Three velcro [2] straps were attached to this forearm cuff so that it could be tightened securely. A 6 millimeter foam pad was used to line the inside of

[1] Johnson & Johnson, New Brunswick, N.J. 08903

[2] Cascade Orthopedic Supply, Rt. 1, Westwood, Calif. 96137

FIGURE 2

THE APPARATUS

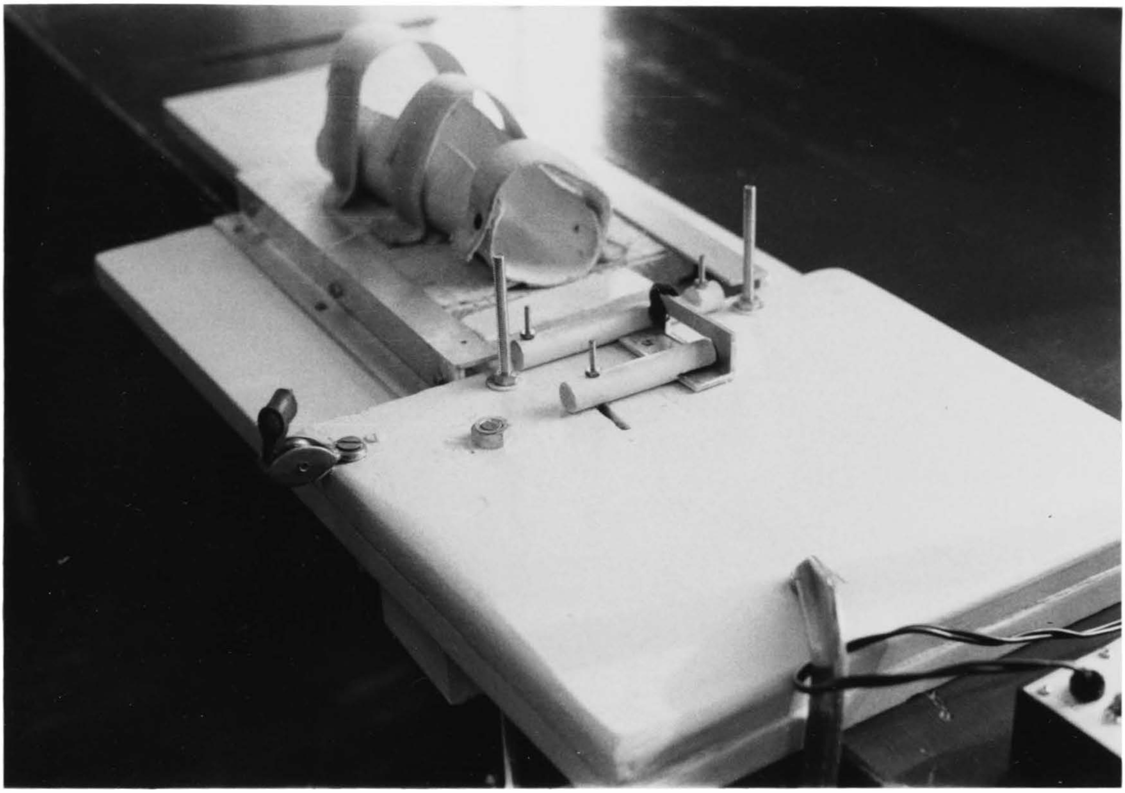
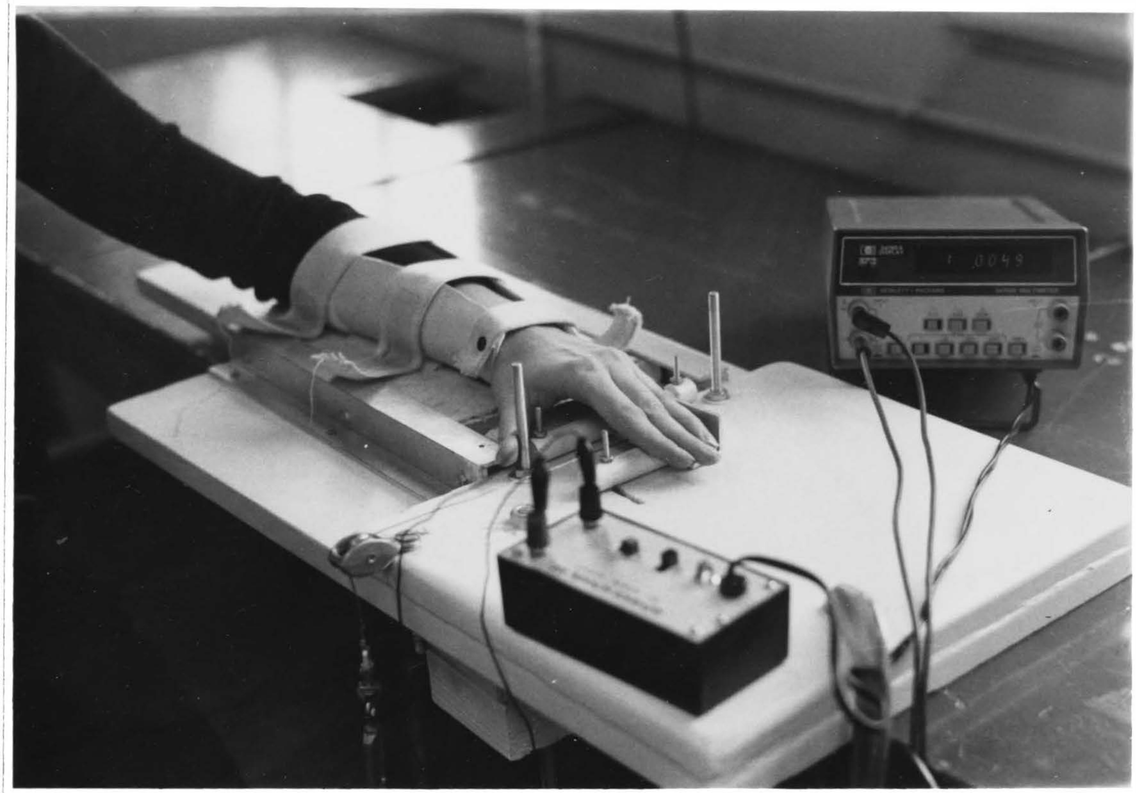


FIGURE 3

THE TRAINING POSITION



the cuff for most subjects. This pad was removed for subjects with larger forearms.

A 1.5 centimeter wooden dowel was attached to the main platform. The metacarpophalangeal joints of the subjects were placed over this dowel. A small notch of 60 millimeters deep by 2.54 centimeters wide was cut into the dowel to flatten the surface under the fifth metacarpophalangeal joint for the subjects' comfort.

A 6.25 centimeter long aluminum bar was placed between the fourth and fifth fingers. Felt padding was placed where the web space between these fingers came into firm contact with the metal bar. A 3.6 by 1.0 centimeter hole was cut into this aluminum bar block to allow the steel cable from the force transducer to pass through to the leather finger cuff which was placed around the middle phalanx of the fifth finger. A second moveable dowel (1.5 centimeters diameter), was placed distally toward the distal interphalangeal joints. These dowels prevented the fingers from contacting the steel cable.

A .9 centimeter diameter steel dowel, 33.0 centimeters long, was embedded in 11.4 centimeters of wood. The force displacement transducer was attached to this dowel, which protruded beneath the main platform. The abduction force was transmitted from the finger cuff to the steel cable which ran over an aluminum pulley and descended to a number one turnbuckle. This turnbuckle enabled adjustments to be made for differing finger widths. The turnbuckle was attached by a steel cable to the lug of the cantilever on the force displacement transducer. These angles were maintained in perpendicular relationships as determined by a T square and a level.

When strength measurements were made, a foam-padded rectangular wooden block, 21.0 by 8.5 centimeters, was placed over the dorsum of the hand to minimize changes in the structural arches of the hand, especially the distal palmar arch of the metacarpophalangeal joint line. Wing-nuts secured this block to the main platform which was fastened to a table at each of the testing and training locations by two C clamps.

METHOD OF DATA COLLECTION

Maximal isometric strength of the non-dominant abductor digiti minimi muscle was measured on a Grass Model Ft. 030 Force Displacement Transducer[3]. This instrument allows a maximal displacement of 1.5 millimeters and is accurate to $\pm$ 1 percent. The bridge in the transducer was driven by 6 volts from an Advance Schools, Inc., D. C. Power Supply[4]. The read-out was taken from a Hewlett-Packard 34740A Display/34702A Multimeter[5], which has a performance accuracy of $\pm$ 0.03 percent. This measurement system was calibrated by suspending known gram weights from the Force Displacement Transducer.

TEST POSITION

Test position for the measurement of maximal isometric strength had the subjects sitting on a wooden straight-back chair with both feet flat on the floor and elbow flexed to ninety degrees, the forearm in full pronation and the wrist at zero degrees of flexion and extension. The forearm was rigidly fixed in an Orthoplast[6] splint, similar to the method used by Tanji and Kato (1975).

[3] Grass Instrument Company, Quincy, Massachusetts 02169

[4] Blypaks, Inc. Box 942, South Lynnfield, Massachusetts 00940

[5] Hewlett-Packard Company, Page Mill Road, Palo Alto, California 94304

[6] Johnson & Johnson, New Brunswick, New Jersey 08903

A medal bar blocked the first four fingers from assisting the fifth finger and a padded block was placed over the dorsum of the hand for greater stability. Using the Liberson and Asa study (1958) as a model, isometric contractions were performed with the non-dominant fifth finger at its resting length, which is zero degrees of abduction. These investigators reasoned that a muscle generates maximal tension when it is not allowed to shorten and when it is at its resting length.

TRAINING SESSIONS

Training sessions were conducted by the same investigator on an individual basis each Monday, Wednesday, and Friday for 6 weeks. The first 3 contractions were recorded as the maximal isometric strength. The exceptions to this schedule occured on the Friday after Thanksgiving because most of the young subjects left Richmond, Virginia for the holiday; thus the measurement was delayed until the following Monday. Also in lieu of the investigator's conducting strength training sessions on the day after Thanksgiving, each subject was instructed how to perform the exercises independently at home for that day only. Additionally, 2 young subjects were trained by the investigator on the Tuesday prior to Thanksgiving instead of on Wednesday. Out of the total 340 possible training sessions, only 4 were missed, one by a young subject and one by a geriatric subject in the first and also the second weeks. No subject missed more than one session.

The exercise sessions were conducted at several locations including the Medical College of Virginia, New Bridge Baptist Church and private living quarters. The exercise regimen consisted of two sets of ten maximal isometric contractions, each lasting six seconds. A ten second rest was imposed between each contraction and a five minute rest between the two sets of ten contractions.

All subjects were instructed to maintain their daily living habits, but they were instructed not to initiate any weight-lifting, strengthening, or exercising programs for either hand. General fitness and aerobic-type activities such as jogging, swimming, cycling, and tennis were permissible.

METHOD OF DATA ANALYSIS

The pre-test and the six weekly measurements for each individaual subject were used for this analysis, for a total of 70 observations for the young sample and a total of 70 observations for the geriatric sample. First, the F test was used to compare the intra-group changes on the pre-test to post-test strength measurements. This analysis was done to determine the effectiveness of the strength training routine for each seperate group.

Second the general linear models procedure, designed for computer-use by Barr et al., (1976) for the Statistical Analysis System (SAS), was employed to develop response curves by fitting linear, quadratic, and cubic equations to the strength measurements data. Although this analysis has not been reported by other investigators of strength training, it was determined that the response curves might demonstrate the interaction between time and strength training. Each group was analysed seperately.

Finally, a double-tailed t test was used to compare the weekly strength changes in the young group with those in the geriatric group. The weekly mean strength of the two groups was compared and also the weekly mean increase for each group was compared. For example, the pre-test mean strength was 866.5 grams for the young subjects and 841.0 grams for the elderly ones. These two means were compared. After one week of training, the mean increases in strength were 54.5 grams and 21.5 grams for the young and geriatric samples, respectively. These increases were also compared.

The results of this study will be presented in the next chapter. Discussion, conclusions, and recommendations will be made in Chapter V.

CHAPTER IV

RESULTS

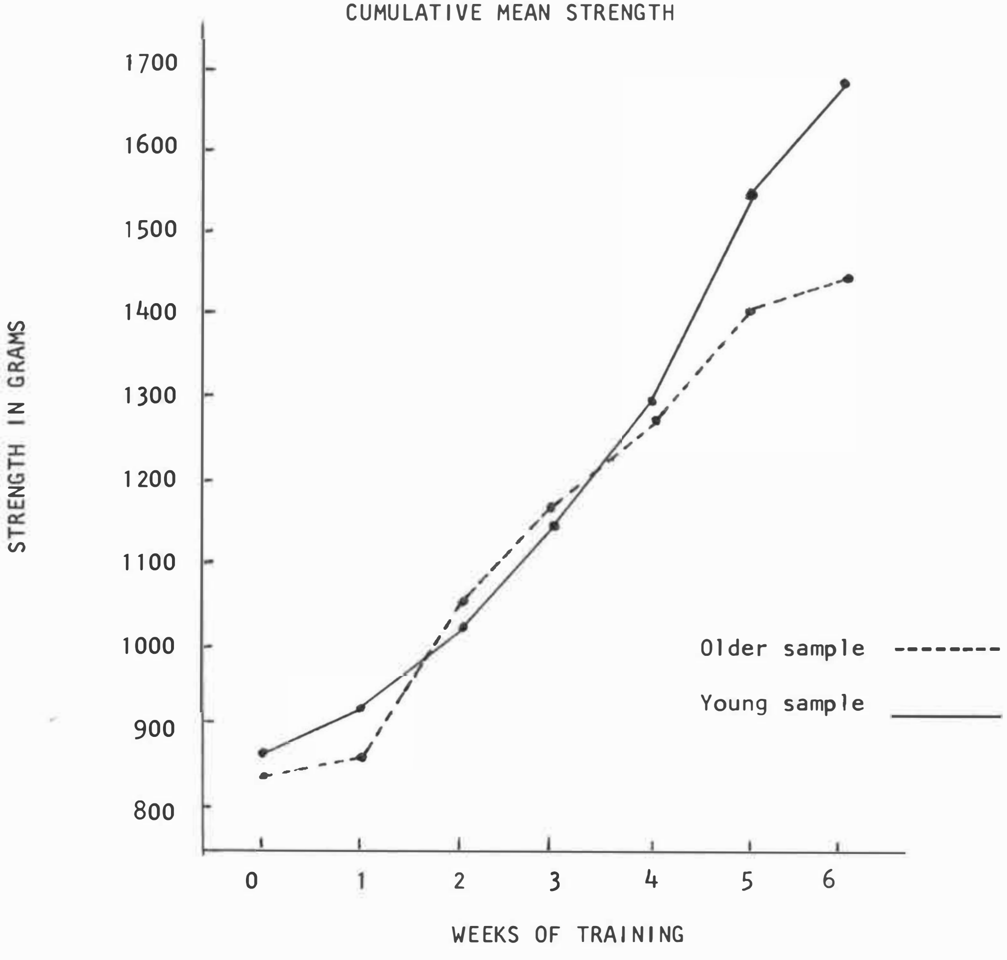
The results of this study are presented in this chapter. They are based on the data collected on a pre-test and six weekly strength measurements for all 20 subjects for a total of 140 measurements. The first section of this chapter describes plotted data curves showing the cumulative strength gains and the weekly increments of strength gains. The second section of the chapter deals with the results of the statistical analysis of the weekly strength measurements. In the next section, the pre-test to post-test measurements for each sample are compared. The fourth section presents the results of fitting linear, quadratic and cubic function to the data in order to develop regression curves for the strength training for each group.

DESCRIPTIVE DATA

The mean strength was calculated for each sample for the pre-test and each of the six weekly strength measurements. From this data, curves were plotted to show the cumulative mean strength gains (Figure 4) and the weekly mean strength increments (Figure 5). On Figure 4, a close parallel was found between the groups on the pre-test and first four weekly measurements, with the older group being slightly stronger than the younger sample after

FIGURE 4

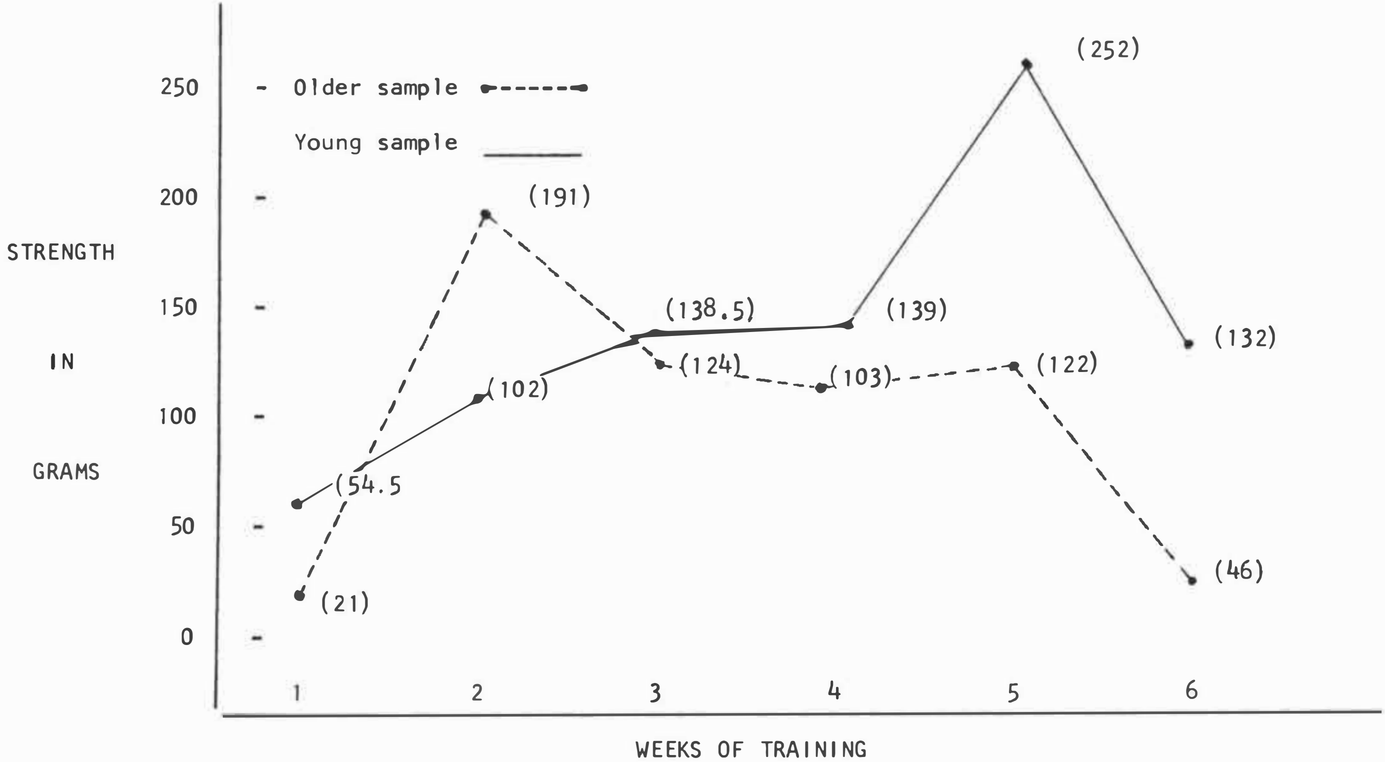
CUMULATIVE MEAN STRENGTH



The cumulative strength gains for each week are shown for each sample. The strength means are presented in the parentheses. Strength in grams is on the left.

FIGURE 5

INCREMENTS OF WEEKLY STRENGTH CHANGES



The increments of strength gains for each week are shown for each sample. The weekly mean increments in grams of strength are presented in the parentheses.

the second and third weeks. However, after the fourth week, the two curves diverged as the strength gains of the older group started to level off and the younger group continued an upward slope.

The pre-test mean strength measurements were similar for both groups with the younger subjects having a statistically insignificant advantage of only 25.5 grams or 2.7 percent. Other similarities between the two samples were noted on Figure 5. These included: increases in mean strength after each of the six weekly measurements; the smallest gains in the mean strength increments after the first week of training; and reductions of mean strength gains after the fifth week of training. One striking dissimilarity was revealed in Figure 5; that is, the largest gains in strength were found after two weeks for the older sample (191 grams) and after five weeks for the younger sample (252 grams). This will be discussed in Chapter V.

STATISTICAL ANALYSIS OF WEEKLY STRENGTH MEASUREMENTS

The t test was used to compare the strength of the two samples on the pre-test and each of the six weekly measurements. At the 0.05 level ($P > 0.05$), no statistically significant difference was found between the two samples on any of these seven mean strength measurements. The same statistically insignificant results were found when the t test was used to compare the weekly increments of strength change. These data are presented in Tables 3, 4, and 5 respectively.

Thus, the t test was used in two ways. First, the mean strength of the two samples was compared as it cumulated during the six weeks. Second, the increments of mean strength changes for the two samples were compared. For example, the pre-test mean strength was 841.0 grams and 866.5 grams for the

TABLE 3

COMPARISON OF THE TWO SAMPLES ON THE CUMULATIVE STRENGTH CHANGES BY THE t TEST

WEEK	GROUP	n	MEAN STRENGTH (g)	S.D. (g)	S.E. (g)	t STATISTIC	SIGNIFICANCE
0	older	10	841.0	227.4	71.9	-0.2816	N.S.
	young	10	866.5	174.0	55.0	-0.2816	
1	older	10	862.5	179.6	56.8	-0.7499	N.S.
	young	10	921.0	169.1	53.5	-0.7499	
2	older	10	1053.0	208.5	65.9	0.3758	N.S.
	young	10	1023.5	134.7	42.6	0.3758	
3	older	10	1177.0	242.4	76.6	0.1690	N.S.
	young	10	1162.0	141.7	44.8	0.1690	
4	older	10	1280.0	205.0	64.8	-0.2232	N.S.
	young	10	1301.0	215.6	68.2	-0.2232	

TABLE 3 - (CONTINUED)

COMPARISON OF THE TWO SAMPLES ON THE CUMULATIVE STRENGTH CHANGES BY THE t TEST

WEEK	GROUP	n	MEAN STRENGTH (g)	S.D. (g)	S.E. (g)	t STATISTIC	SIGNIFICANCE
5	older	10	1402.0	201.6	63.7	-1.6772	N.S.
	young	10	1553.5	202.4	64.0	-1.6772	
6	older	10	1448.0	214.2	67.7	-1.7312	N.S.
	young	10	1685.5	377.3	119.3	-1.7312	

TABLE 4

COMPARISON OF THE TWO SAMPLES ON INCREMENTS OF STRENGTH CHANGES BY THE t TEST

COMPARED WEEKS	GROUP	n	MEAN STRENGTH (g) ± S.D.	S.E. (g)	t STATISTIC	SIGNIFICANCE
0-1	older	10	21.5 ± 122.3	38.7	-0.6380	N.S.
	young	10	54.5 ± 108.6	34.3	-0.6380	
0-2	older	10	212.0 ± 169.5	53.6	0.8796	N.S.
	young	10	157.0 ± 101.8	32.2	0.8796	
0-3	older	10	336.0 ± 194.4	61.5	0.5253	N.S.
	young	10	295.5 ± 147.2	46.6	0.5253	
0-4	older	10	439.0 ± 167.1	52.9	0.0599	N.S.
	young	10	434.5 ± 168.5	53.3	0.0599	
0-5	older	10	561.0 ± 161.1	50.9	-1.4665	N.S.
	young	10	687.0 ± 218.8	69.2	-1.4665	

TABLE 4 (CONTINUED)

COMPARISON OF THE TWO SAMPLES ON INCREMENTS OF STRENGTH CHANGES BY THE t TEST

COMPARED WEEKS	GROUP	n	MEAN STRENGTH (g) ± S.D.	S.E. (g)	t STATISTIC	SIGNIFICANCE
0-6	older	10	607.0 ± 131.5	41.6	-1.6075	N.S.
	young	10	819.0 ± 395.8	125.1	-1.6075	

TABLE 5

COMPARISON OF THE TWO SAMPLES ON WEEKLY INCREMENTS OF STRENGTH CHANGES BY THE t TEST

COMPARED WEEKS	GROUP	n	MEAN STRENGTH (g) ± S.D.	S.E. (g)	t STATISTIC	SIGNIFICANCE
1-2	older	10	190.5 ± 128.5	40.6	1.6661	N.S.
	young	10	102.5 ± 106.7	33.7	1.6661	
2-3	older	10	124.0 ± 97.5	30.8	-0.3684	N.S.
	young	10	138.5 ± 77.3	24.4	-0.3684	
3-4	older	10	103.0 ± 164.0	51.9	-0.5689	N.S.
	young	10	139.0 ± 114.6	36.2	-0.5689	
4-5	older	10	122.0 ± 150.4	47.6	-1.8720	N.S.
	young	10	252.0 ± 161.1	51.0	-1.8720	
5-6	older	10	46.0 ± 79.8	25.2	-1.0468	N.S.
	young	10	132.0 ± 247.2	78.2	-1.0468	

older and younger groups, respectively. After one week of strength training, the mean increases of strength were 21.5 grams for the older sample and 54.5 grams for the younger sample. Therefore, the cumulative strength means were 862.5 grams for the older women and 921.0 grams for the younger women. The t test was used to compare the 841.0 to 866.5; the 21.5 to 54.5; and 862.5 to 921.0. The same analysis was performed for each of the weekly cumulative strength means and weekly increments of strength changes. Statistical summaries of these findings to include weekly mean strength, standard deviations, standard errors, and test statistics, are presented in Tables 3, 4, and 5.

STATISTICAL ANALYSIS OF PRE-TEST TO POST-TEST STRENGTH MEASUREMENTS

The mean strength of the older group increased from 841.0 $\pm$ 227.4 grams to 1448.0 $\pm$ 214.2 grams after six weeks of isometric training. The mean strength of the young group increased from 866.5 $\pm$ 174.0 grams to 1685.5 $\pm$ 377.3 grams. The F test was used to determine the statistical significance of these increases within each sample. A highly significant increase of strength was found in both groups at the 0.0001 level ($P < 0.0001$). The F test data are presented in Table 6. This level of significance indicates that the exercise routine provided a sufficient training stimulus to increase strength.

A t test was used to compare pre-test to post-test strength changes of both groups. The mean strength increases were 607.0 $\pm$ 131.5 grams in the geriatric group and 819.0 $\pm$ 395.7 grams in the young sample. There was no significant difference at the 0.05 level ($P > 0.05$). These data are presented in Table 4.

TABLE 6

SUMMARY OF THE F TEST FOR EACH SAMPLE

SAMPLE	SOURCE	DF	TYPE IV SUM OF SQUARES[1]	F VALUE	LEVEL OF SIGNIFICANCE
Older	Strength	9	2266614.64285714	24.00	0.0001
Young	Strength	9	1625087.14285714	7.67	0.0001

[1] Statistical Analysis System, P.O. Box 10066, Raleigh, North Carolina, 27605

RESPONSE CURVE

The regression equation relating time (six weeks) and strength was determined by the General Linear Models procedure (Barr et al., 1976). The large R-square values of 0.906665 and 0.848261 for the older and younger samples, respectively, indicated the important effect of training over time and the measurement of strength. The significance of this association was compared against the computed F values of 24.00 for the older women and 7.67 for the younger women, and was found to have a P value of 0.0001 ($P < 0.0001$) for both groups. These highly significant results demonstrated the effectiveness of the training programs to increase strength during the six weeks.

Tables 7 and 8 show the results of fitting a linear, quadratic, and cubic function to each group. This was done in an attempt to describe the shape of the regression curves for the strength training of these two groups. The best fit for the young sample was the quadratic term, but, this did not reach statistical significance as the P value was 0.2341. Only the cubic function for the geriatric group was found to have a statistically significant fit with a P value of .0491. However, Figure 5 easily demonstrates that the shape of the strength curve for the geriatric sample does not reflect three definite changes in direction of the slope. Thus, the predictive value of these results is limited.

TABLE 7

STATISTICAL SUMMARY OF ATTEMPT TO DEVELOP RESPONSE CURVE FOR THE OLDER GROUP DATA

SOURCE	DF	TYPE IV SUM OF SQUARES[1]	F VALUE	P VALUE
Linear Model Form $Y=Bo + B_1X$	1	7537.17882299	0.72	0.4002
Quadratic Model Form $Y=Bo + B_1X + B_2X^2$	1	34918.15476190	3.33	0.0733
Cubic Model Form $Y=B + B_1X + B_2X^2 + B_3X^3$	1	42400.41666667	4.04	0.0491

[1] Statistical Analysis System, P.O. Box 10066, Raleigh, North Carolina 27605

TABLE 8

STATISTICAL SUMMARY OF ATTEMPT TO DEVELOP RESPONSE CURVE FOR THE YOUNG GROUP DATA

SOURCE	DF	TYPE IV SUM OF SQUARES[1]	F VALUE	P VALUE
Linear Model	1	518.84679843	0.02	0.8825
Form $Y=Bo + B_1X$				
Quadratic Model	1	34063.92032968	1.45	0.2341
Form $Y=Bo + B_1X + B_2X^2$				
Cubic Model	1	13801.66666668	0.59	0.4472
Form $Y=Bo + B_1X + B_2X^2 + B_3X^3$				

[1] Statistical Analysis System, P.O. Box 10066, Raleigh, North Carolina 27605

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

REVIEW OF THE STUDY

The purpose of this study was to compare the effects of an isometric strength training routine of the non-dominant abductor digiti minimi muscles of 10 older females, mean age 69.2 years, with 10 young females, mean age 22.6 years. The training consisted of each subject performing 20 maximal isometric contractions of the left abductor digiti minimi muscles three times a week for 6 weeks. A pre-test and 6 weekly measurements of strength were made on a strain gauge and recorded on a multimeter.

The results of the study showed that the training stimulus was effective for both groups. There were no significant differences in strength between the young and the old subjects on the pre-test or on the 6 weekly measurements. The first null hypothesis stated that there is no significant difference between the change in isometric strength of the non-dominant abductor digiti minimi muscles of young adults and that of geriatric adults after isometric strength training three times weekly for six weeks. The second null hypothesis stated that there is no significant difference between young adults and geriatric adults in the change of isometric strength of the non-dominant abductor digiti minimi muscles from week to week during a six week isometric training period. These hypotheses were accepted.

CONCLUSIONS AND INTERPRETATIONS

Clearly these results do not agree with the reports of an age-dependent strength loss (Fisher and Birren 1947; Burke et al., 1953; Asmussen, Fruensgaard, and Nørgaard, 1975). On the pre-test measurement only 25.5 grams separated the mean strength of the two groups. This represents an age-related strength decline of only 2.9 percent which was statistically insignificant.

Similarly the overall improvement in strength does not agree with Hettinger's (1958) report that old persons gained less than 40 percent of what young persons gained. Hettinger (1958) did not compare the statistical significance between the strength gains in his young and old subjects. In the present study after 6 weeks of training, the older subjects gained an average of 607 grams of strength compared to an average gain of 819 grams in the young subjects. Using Hettinger's (1958) method of computing the percentage of strength gains based on the largest amount, the ten geriatric females gained 74.1 percent of the amount that the ten young females gained. Because of the large standard deviation from the mean strength gain, this difference was not statistically significant; thus, it may have occurred by chance.

Several factors may account for the difference in the results of this study compared to others. First, in this study the training stimulus of 20 maximal isometric contractions of 6 second duration was greater than the stimuli used in other studies of strength training of older subjects (Hettinger, 1958; Perkins and Kaiser, 1961). Hettinger's subjects used one maximal isometric contraction. Although he did not report the duration of each contraction in his study, elsewhere he had reported that maintaining a maximal isometric contraction for 1-2 seconds was a sufficient training stimulus (Hettinger, 1961). Also, it was not clearly stated how many weeks the training lasted. Perkins and Kaiser (1961) used 3 maximal and 3 one-half maximal isometric contractions of 6 seconds duration. Their subjects exercised 3 times weekly for 6 weeks. Liemohn (1975) did not specify how many 5 second isometric contractions were used as a training stimulus. Eight different groups of muscles were exercised during each training session which lasted 15 minutes (Liemohn 1975). Training was conducted 3 times weekly for 6 weeks.

Other investigators have reported better results of strength training when the exercise stimulus was more intense (Meyers, 1967) (Lieberson and Asa 1958). Meyers (1967) compared the effects of two isometric strength routines in college males. Both groups exercised 3 times weekly for six weeks. One group performed 3 while the other group performed 20 maximal isometric contractions of 6 seconds duration. The group that used 20 contractions showed more significant improvements in muscle strength, muscle endurance, and muscle hypertrophy. Similarly Liberson and Asa (1958) reported that subjects who performed 20 six-second maximal isometric contractions of their abductor digiti minimi muscles gained more strength, endurance, and hypertrophy than subjects who performed only 1 six-second maximal contraction.

Second, all subjects in this study were highly cooperative as evinced by the low absenteeism. Each of the 20 subjects was trained a total of 17 times for an overall total of 340 sessions. Only 4 different subjects missed one training session each. Liemohn (1975) suggested failure of some subjects to cooperate may have influenced his results which supported the concept of an age-related decline in strength and a decreased ability to gain strength in the geriatric population.

In light of the work reported by Shock and Norris (1970), the 10 older females mean age 69.2 years in the present study may not have been old enough to manifest the age-related strength decline. These researchers (Shock and Norris, 1970) measured isometric strength of the shoulders and arms of 218 subjects between the ages of 20 and 89 years. They reported that between the ages of 20 and 69 there was no decline in strength. Strength declined 13.38 percent in the 26 subjects in the 8th decade of life; and 30 percent in the 4 subjects in the 9th decade of life.

A second explanation may be invoked from the report that upper extremity strength declines more slowly with age than lower extremity strength (Asmussen and Heebøll-Nielsen, 1962). It was suggested that lower extremity strength declined more rapidly because after the age of 30 years, use of the lower extremity musculature in activities of daily living declined. In comparison, upper extremity musculature is continually used in activities of daily living (Asmussen and Heebøll-Nielsen, 1962).

This finding may have been a factor in the results obtained by Shock and Norris, (1970) and in the present study. However, most of the studies of grip strength reported a decline by the 7th decade of life (Asmussen, Fruensgaard, and Nørgaard 1975; Burke et al., 1953; Fisher and Birren 1947; and Montoye and Lamphiear, 1977).

Motivation may have influenced the measurements in the present study. Ikai and Steinhaus (1961) postulated that psychological inhibitions are a major limit to strength measurement. They based their postulations on their findings that elbow flexion strength increased 12.2 percent with shouting; 7.4 percent with firing a pistol; 22.3 percent with hypnosis; 5.6 percent after alcohol ingestion; 6.5 percent after an injection of adrenaline; and 13.5 percent after amphetamine sulfate ingestion. Possibly the 10 older female subjects in this study were more motivated and/or less inhibited than the 10 younger subjects.

In all volitional measurements of strength, the motivational factor is present; however, Botelho, Cander, and Guiti (1954) eliminated this by applying a supramaximal electrical stimulation to the ulnar nerve and measuring active tension of the adductor pollicis brevis muscle. The active tension was highest in the 6 subjects, ages 45 to 50 years (742±118 grams); next highest in the 7 subjects ages 51 to 61 years (431±88 grams), and least in the 4 subjects ages 18-24 years (215±42 grams). This work (Boletho, Cander, Guiti, 1954) may be interpreted to suggest that motivation may be a factor in the age-related strength decline.

Another concern that was considered when this study was designed was the effect of motor learning on strength measurements. Motor learning has been described as a central nervous system influence which allows an increased number of motor units to be recruited during a volitional contraction (Astrand and Rodahl, 1977). Hellenbrandt and Houtz, (1956) found large increases in strength, up to 161 percent in one subject in only ten days of strength training. They stated that this rapid large increase in strength could not have been muscle hypertrophy, but must have been due largely to central nervous system learning. In a personal communication, Nathan Shock (1977), stated that the motor learning factor must be controlled in order for a strength training program to have validity. If motor learning is controlled, large strength gains will not be found immediately. If large increases in strength are found immediately, the gains reflect the subjects' familiarization with the test instruments and learning how to perform the required muscle contraction. This means that the pre-test strength measurement was not an accurate assessment of muscle strength.

After one week of training both groups showed modest increases in mean strength, 54.5 grams for the young group and 21 grams for the old group. This could be interpreted to mean that motor learning was not a major uncontrolled factor in this study. If motor learning had been uncontrolled, the pre-test strength measurement would have been inaccurately low in which case, the first weekly measurement should have been large.

After two weeks of training the increase in mean strength of the older subjects was not only the largest weekly increase in this group; but also was greater than the gain in the younger group. The mean strength of the older group was greater than in the younger group after the second and the third weeks of training. Possibly, during these two weeks of training the younger subjects were physically or psychologically fatigued from school-related activities. Perhaps, the motor learning was manifesting in strength measurements of the 2nd and 3rd weeks in the older subjects. Also, the larger strength increments in the older group, compared to the younger group, may be reflecting improved motor unit recruitment (Mitolo, 1968). The younger subjects not having suffered the age-related changes in electromyographic (EMG) activity (Mitolo, 1968; Carlson, Alston, Feldman, 1964), would not have had the opportunity to improve EMG activity. This may account for the larger strength gains enjoyed by the older sample after the second and third weeks of training.

The mean strength gains during weeks 3, 4, and 5 were approximately the same for the older group. These may reflect the declining benefit of improved EMG patterns. After 5 weeks of training both groups had larger increments of strength gains than after the fourth week. This may be due to muscle hypertrophy. Hettinger (1961) has stated that the effects of strength training on muscle should manifest after four to six weeks.

Another plausible explanation of this large gain at week five in the young subjects is that pressure from academic activities was mitigated by the reprieve afforded by Thanksgiving vacation. Both groups gained strength on the sixth and final measurement, however the amount of increase was less than the amounts gained on each of the 3 preceding weeks. This possibly reflected a trend for the gains to level off as was reported by Perkins and Kaiser (1961). In their study, one group of subjects underwent strength training with isometric contractions and another group with isotonic contractions. In both groups, a plateau of strength increases was found after 6 weeks of training. Each of these factors may have effected the shape of the strength training curve shown in Figure 5 of Chapter IV.

Similarly, the results of fitting linear, quadratic, and cubic functions to the data, most likely were influenced by these factors of motor learning, motor unit recruitment, and muscle hypertrophy. The two peaks for the older sample in Figure 5, Chapter 4 may have resulted first from improved motor unit recruitment and later by hypertrophy of muscle. This may be why the cubic function was the only one to reach statistical significance with a P value of P = 0.491. The same reasoning may be induced to explain why the quadratic function was the closest of the three functions to reaching statistical significance (P = 0.2341) in the younger group. That is, the increments of strength gains increased until week five and then the direction of the curve turned downward (Figure 5, Chapter 4). In the literature that has been reviewed, there have been no other reports of response curves developed from the results of strength training. Therefore, there is nothing with which to compare the response curve results of this study.

The results of the present study cannot be debased by suggesting that the two samples were different from the general population. The strength of the abductor digiti minimi muscles of these ten young and ten older females compares favorably with the pre-test strength of the same muscle in 13 subjects, ages 20 to 45 years, sex not stated (Liberson and Asa 1958). Those authors reported the mean isometric strength of the hypothenar muscles in abduction to be 860 grams in one group of 6 subjects and 1020 grams in one group of 7 subjects; combined this represents a mean strength of 940 grams for the 13 subjects in the isometric group. The ranges and standard deviation were not reported. When this figure of 940 grams was accepted as representing the population mean, no significant differences ($P > 0.05$) was found between that population mean and the means of the combined geriatric and young samples in this study. The test statistic 0.1232 was determined by the formula:

$$\frac{|\bar{X} - \mu|}{X_{(n)} - X_{(1)}}$$

(Kilpatrick, 1977)

Also the 95 percent confidence limits for the geriatric sample are 1003.7 grams (upper limit) and 678.3 grams (lower limit). For the young sample the 95 percent confidence limits are 991.0 grams (upper limits) and 742 (lower limits). The accepted population mean of 940 grams (Liberson and Asa, 1958) falls within the 95 percent confidence limits of both the young and the geriatric samples.

In conclusion, no significant difference in isometric strength was found between the two samples on the pre-test/post-test measurements or on any of the weekly measurements; thus neither the first nor the second null hypothesis was rejected. The first null hypothesis stated that there is no significant difference between the change in isometric strength of the non-dominant abductor digiti minimi muscles of young adults and geriatric adults after isometric strength training three times weekly for six weeks. The second null hypothesis stated that there is no significant difference between young adults and geriatric adults in the change of isometric strength of the non-dominant abductor digiti minimi muscles from week to week during a six week isometric training period. Both null hypotheses were accepted as stated.

IMPLICATIONS AND RECOMMENDATIONS

Further research needs to be conducted in order to clarify the difference between the results of this study and others (Hettinger, 1958; Lieholm, 1975; Fisher and Birren, 1947). Different muscles must be used; however non-training activities must be acknowledged as an uncontrolled variable. If the quadraceps were trained, one contaminant of the results would be what the subjects do after the training sessions. Conceivably, young persons would return to active employment whereas older persons would return to sedentary retirement.

Another factor that needs to be considered is sex, since this study compared females only. Motivation or personality should be considered as they may influence the effort that the subjects make and/or on their outside activities.

Different training stimuli should be employed. This study used isometric strength but the effects of different types of contractions should be evaluated. Perkins and Kaiser (1961) compared isometric and isotonic strength training, but the effectiveness of isokinetic training and eccentric contractions is yet to be determined. Possibly 10 contractions or maybe 40 contractions would be more effective for increasing strength. In this study after 6 weeks of strength training, the difference between the young and old was insignificant but was approaching significance; thus a study of longer duration must be carried out.

One major implication from this study is that the effects of strength training vary from individual to individual as evinced by the standard deviations reported in Tables 3, 4, and 5. Thus, when trying to increase a patients' strength, physical therapists must consider each patient's individuality before age.

APPENDIX A

EXPLANATION OF THE PROCEDURES

The purpose of this study is to determine the effects of six weeks of isometric strength training upon maximal isometric strength. Before starting the strengthening routine, you will be completely familiarized with the measurement apparatus and how to perform maximal isometric contractions. Training will be conducted 3 afternoons each week for a total of 6 weeks. On the third (3rd) afternoon of each week your strength will be determined by the best of 3 trial tensions on a strain guage. This measurement will demonstrate the week to week effects of the training program. Each exercise training period will consist of ten (10) repetitions of a maximal isometric contraction. Upon completion of 10 repetitions, a five (5) minute rest will be enforced. Following the rest period, a second set of 10 repetitions of a maximal isometric contraction will be performed.

During each training session, you will be seated with your elbows supported and flexed to ninety (90) degrees. Your non-dominant forearm and wrist will be placed in an adjustable splint to prevent movement of these body parts. The small finger will be inserted between two blocks which are fastened to the table. This will prevent any sideward motion, in and out, of the non-dominant small finger. Despite the precautions taken by the investigator to prevent discomfort, you may experience some slight discomfort which is a temporary and common result of strength training.

APPENDIX B

DEPARTMENT OF PHYSICAL THERAPY
SCHOOL OF ALLIED HEALTH PROFESSIONS

MEDICAL COLLEGE OF VIRGINIA
VIRGINIA COMMONWEALTH UNIVERSITY

CONSENT FORM

Permission is granted to Tim Kauffman, a graduate student in the Department of Physical Therapy, Medical College of Virginia, to administer a six week isometric strength training program. The procedures have been explained to me and I understand them to my satisfaction. I may ask questions at any time. I am aware that I may experience some discomfort despite the measures taken by the investigator to minimize any discomfort. I realize that my confidentially will be maintained at all times, including the possible publication of the results of this study. I hereby reserve the right to discontinue my participation in this study at any time.

____
(Subject)

____
(Date)

____
(Witness)

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